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Hibernation ecology of the Barbastelle (*Barbastella barbastellus*) colony in the Szachownica cave (Central Poland)

Ökologie der überwinternden Mopsfledermauskolonie (*Barbastella barbastellus*) in der Szachownica-Höhle (Zentral-Polen)

Écologie de la colonie de Barbastelles (*Barbastella barbastellus*) hivernant dans la grotte de Szachownica (Pologne centrale)

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Summary

The Szachownica cave is one of the most important winter bat roost in Poland. The total length of its corridors is over 1000 metres and about 1000 individuals of 10 bat species winter there every year. One of the dominant species is the Barbastelle which colony increased in number during the last sixteen years and now counts about 200-275 individuals.

The authors visited the cave 81 times during four winter seasons (since the autumn of 1993). This work concerns the results of visual censuses, study of bats distribution, social interactions and measurements of chosen abiotic factors (temperature inside and outside the cave, relative humidity).

The Barbastelle stayed in the cave from the beginning of October till the end of March and preferred the coldest (overfreezing!) part of the cave located near the entrance. However, after severe frosts when the temperature measured near the colony dropped to -12.1° C many individuals changed the place of hibernation, probably invading deeper crevices. This species usually forms unispecific groups. The biggest noticed groups counted about 80 individuals. Interspecific associations were found in 301 cases (22.8% of the groups), mostly with *Plecotus auritus* (166 cases) because of the similar thermopreferendum, but also with *Myotis nattereri* (53), *Myotis daubentonii* (42), *Myotis myotis* (36) and *Myotis brandtii/mystacinus* (4).

Zusammenfassung

Die Szachownica-Höhle ist eines der bedeutendsten Fledermauswinterquartiere Polens. Die Gesamtlänge ihrer Gänge beträgt mehr als 1000 Meter, und ca. 1000 Individuen von 10 Fledermausarten überwintern dort jährlich. Eine der dominierenden Arten ist die Mopsfledermaus, deren Koloniestärke in den letzten Jahren anstieg und sich mittlerweile auf ca. 200-275 beläuft.

Die Autoren suchten die Höhle im Laufe von vier Wintern (seit Herbst 1993) 81mal auf. Diese Arbeit beinhaltet die Ergebnisse visueller Zählungen, Studien zur Ausbreitung der Fledermäuse und sozialer Interaktionen sowie die Größen ausgewählter abiotischer Faktoren (Innen- und Außentemperatur der Höhle, relative Luftfeuchtigkeit).

Die Mopsfledermäuse verweilten von Anfang Oktober bis Ende März in der Höhle; sie bevorzugten den kältesten (überfrierenden!) Teil der Höhle, welcher sich in Eingangsnähe befand. Nach einigen strengen Frösten jedoch, als die in Kolonienähe gemessene Temperatur auf -12,1° C absank, wechselten viele Individuen ihre Hangplätze, wahrscheinlich drangen sie in tiefere Spalten ein. Diese Art bildet in der Regel unispezifische Gruppen. Die größten festgestellten Gruppen zählten ca. 80 Individuen. Interspezifische Verbindungen, die meist mit *Plecotus auritus* (166 Fälle) aufgrund des ähnlichen Thermopräferendums, aber auch mit *Myotis nattereri* (53), *Myotis daubentonii* (42), *Myotis myotis* (36) and *Myotis brandtii/mystacinus* (4), eingegangen wurden, kamen in 301 Fällen (22,8% der Gruppen) vor.

Résumé

La grotte de Szachownica est un des plus importants sites d'hivernage pour les chauves-souris en Pologne. La longueur totale de ses galeries est de plus de 1000 mètres et environ 1000 individus de 10 espèces de chauves-souris y hivernent chaque année. Une des espèces dominantes est la Barbastelle dont l'effectif a augmenté pendant les 16 dernières années et compte maintenant entre 200 et 275 individus.

Les auteurs ont visité la grotte 81 fois pendant quatre hivers depuis l'automne 1993. Ce travail concerne les résultats de recensements visuels, de la distribution des chauves-souris, des interactions sociales et des mesures de quelques facteurs abiotiques choisis (température à l'intérieur et à l'extérieur de la grotte, humidité relative).

Les Barbastelles fréquentent la grotte depuis le début octobre jusqu'à la fin mars et préfèrent les parties les plus froides (au - dessous de 0° C!) situées à l'entrée de la grotte. Cependant, après des gels très rigoureux, quand la température mesurée près de la colonie descendaient jusqu'à -12,1°C, de nombreux individus changeaient de place, probablement pour s'enfoncer plus profondément dans les fissures. Cette espèce forme généralement des groupes monospécifiques. Le plus grand essaim repéré comptait environ 80 individus. Des associations interspécifiques ont été trouvées dans 301 cas (22.8% des groupes), principalement avec *Plecotus auritus* (166 cas) à cause du préférendum thermique similaire, mais aussi avec *Myotis nattereri* (53), *Myotis daubentonii* (42), *Myotis myotis* (36) et *Myotis brandtii/mystacinus* (4).

Abstract

The studies were conducted during winter seasons of 1993-1997 in the „Szachownica" cave – one of the biggest known bat hibernaculum in Poland (WOŁOSZYN 1989). The detailed dynamics of hibernation is shown in the aspect of weather conditions (night temperature). Also microclimate gradient in the cave influences the spatial distribution of bats. The Barbastelle is found the most cold resistant one among 10 bat species occurring in the cave. The species prefers the places with very unsteady microclimate. For the winter roost the Barbastelle hibernates mostly in unispecific groups or even solitary (Fig. 9, 10 F). Most of joint clusters occur with *Plecotus auritus* but also with *Myotis nattereri, Myotis daubentonii, Myotis myotis* and *Myotis brandtii/mystacinus.*

1. Study area and methods

The „Szachownica" cave is located in Central Poland (Fig. 1) at 51°04'N and 18°50'E, 215 m above sea-level in a limestone hill covered by mixed forest. System of corridors has semi-natural character caused by the chalk exploitation which ended in 1962. The total length of corridors and rooms is over 1000 m (GAZEK et al. 1978).

Regular observations were started in the autumn of 1993 making controls in 10-14 days intervals till the beginning of May. During 81 visits in four winter seasons the visible bats were determined (without disturbing the animals) and counted. The ground level temperature was measured by mercury (and in season 1996/97) electronic thermometer with accuracy to 0.1° C. The relative air humidity was measured at the level of 0.5 m by an Assmann psychrometer during the first two seasons. Climatic data were taken from the meteorological reports.

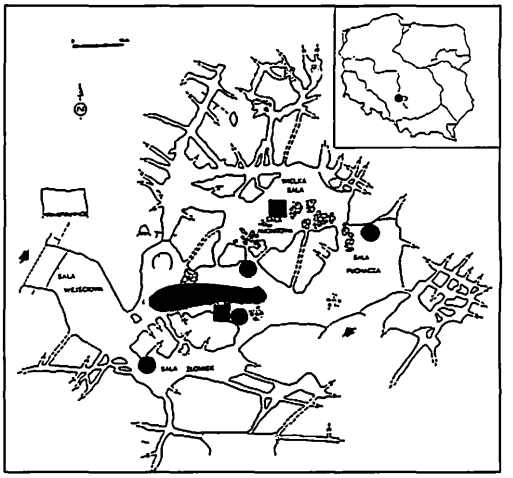


Fig. 1. The map of the „Szachownica" cave with marked positions of the Barbastelle colonies (black area and circles) and places where the temperature and humidity were measured (black squares)

Abb. 1. Karte der „Szachownica"-Höhle mit eingezeichneten Positionen der Mopsfledermauskolonien (schwarze Flächen und Kreise) sowie der Stellen, an denen Temperatur und Luftfeuchtigkeit gemessen wurden (schwarze Quadrate)

Graph. 1. Carte de la grotte de „Szachownica" avec les localisations des essaims de Barbastelles (zones noires et cercles) et les endroits où la température et l'humidité ont été mesurées (carrés noires)

The proportion of the Barbastelle abundance to other bats in the cave was estimated by the Index of dominance D = (Ni/N) x 100% (Ni - number of the Barbastelle, N - total number of bats). Temperature and air humidity mean values and standard deviations were calculated. The differences between standard deviations were checked using F test.

2. Results

2.1. Dominance structure

Ten bat species hibernating in the cave were found every season. The bat community consi-

sted of 3 dominants: *Myotis nattereri, Myotis myotis* and *Barbastella barbastellus*, 4 accessory species: *Plecotus auritus, Myotis daubentonii, Myotis brandtii/mystacinus*, and 3 were rare: *Myotis bechsteinii, Myotis dasycneme, Eptesicus serotinus.*

The increase of the Barbastelle population in this cave since 1982 is significant (KOWALSKI & LESINSKI 1991; LESINSKI now).

The Barbastelle usually appeared in the cave after first frost and its number increased fast to maximum level which was usually completed in the second half of December (Fig. 2). Each season the Barbastelle dominated in November and first half of December reaching Dmax. equal to 30.5% (16.11.1993), 52.4% (10.12. 1994), 45.3% (29.11.1995) and 47.3% (12.12. 1996) as the other dominant species used to appear later. In the early spring the Barbastelles left the winter roost after several warmer nights with temperatures above 0°C (in March/ April). Cooler periods were decreasing the departure rate but didn't make the bats to come back as it was noticed with *Myotis myotis* and *Myotis nattereri* (HEJDUK & RADZICKI 1996).

2.2. Distribution inside the cave in connection with microclimate conditions

The Barbastelle occupied the coldest and most exposed parts of the cave. The biggest groups hibernated in narrow roof rift near the entrance (Fig.1) which is normally exposed to daylight and air current. The severe winter frosts also influence the bats positions there. On the 25.01.1996 there was noticed -12.1°C under the colony and -4.5°C between the bats. Even during such low temperatures only some bats escape from the most exposed places probably entering deeper crevices or changing the winter roost. In such situations there is expanded temperature gradient in the cave causing the positions of different species. The example of this is shown in Fig. 3 for the control from the 06.01.1995.

The characteristics of the unsteady temperature and humidity conditions by the Barbastelle colony are compared with more stable inner parts of the cave (Table 1, Table 2). The differences in standard deviations of temperature and air humidity are in some cases statistically significant but the significance level changes a lot from season to season.

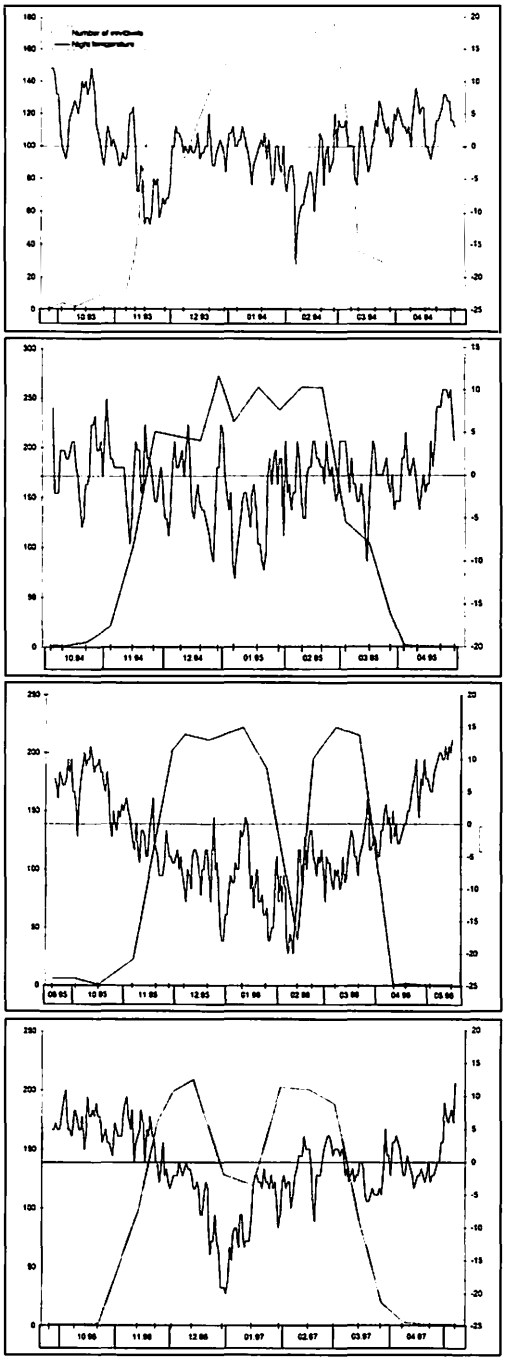


Fig. 2. Seasonal dynamics of the Barbastelle hibernation in four seasons with marked night temperature

Abb. 2. Saisonbedingte Dynamik der Mopsfledermausüberwinterung von vier Saisons mit gekennzeichneter Nachttemperatur

Graph. 2. Dynamique saisonnière de l'hibernation de la Barbastelle pendant quatre saisons avec les températures nocturnes

Table 1. Comparison between temperature conditions in inner chamber and the Barbastelle colony during four seasons

Tab. 1. Vergleich der Temperaturbedingungen im Inneren und bei der Mopsfledermauskolonie während der vier Saisons

Tableau 1. Comparaison entre les températures dans la salle d'hivernage et près de l'essaim de Barbastelles pendant quatre saisons

Season 1993/1994	Min.temp. (°C)	Mean temp. (°C)	SD	Test F
Inner chamber „Sala Wielka"	2,2	5,164	2,2496	F'=2,7299
By the Barbastelle colony	-0,8	4,004	3,7169	α=0,1
Season 1994/1995	**Min. temp. (°C)**	**Mean temp. (°C)**	**SD**	**Test F**
Inner chamber „Sala Wielka"	2,3	4,79	1,5958	F'=4,5138
By the Barbastelle colony	-3,2	5,024	3,3904	α=0,01
Season 1995/1996	**Min. temp. (°C)**	**Mean temp. (°C)**	**SD**	**Test F**
Inner chamber „Sala Wielka"	-0,5	3,628	3,0657	F'=3,5422
By the Barbastelle colony	-12,1	1,939	5,7699	α=0,1
Season 1996/1997	**Min. temp. (°C)**	**Mean temp. (°C)**	**SD**	**Test F**
Inner chamber „Sala Wielka"	-1,0	3,612	3,0717	F'=2,5636
By the Barbastelle colony	-9,3	2,971	4,9182	α=0,5

Table 2. Comparison between humidity conditions in inner chamber and the Barbastelle colony during two seasons

Tab. 2. Vergleich der Luftfeuchtigkeit im Inneren und bei der Mopsfledermauskolonie während zwei Saisons

Tableau 2. Comaparaison entre l'humidité dans la salle d'hivernage et près de l'essaim de Barbastelles pendant quatre saisons

Season 1993/1994	Min/Max humidity (%)	Mean hum. (%)	SD	Test F
Inner chamber „Sala Wielka"	87/98	93,376	3,2645	F'=6,2748
By Barbastelle colony	71/97	86,02	8,1774	α=0,01
Season 1994/1995	**Min/Max humidity (%)**	**Mean hum.(%)**	**SD**	**Test F**
Inner chamber „Sala Wielka"	84/99	95,0555	3,8293	F'=1,1617
By barbastelle colony	84/99	93,2	4,1274	α=0,5

2.3. Social interactions

In the cave the Barbastelles form usually unispecific clusters of different size.

By the beginning and the end of each season the Barbastelle occurred in small number of individuals roosting solitary or in small clusters while in the time of maximum abundance they often formed big groups. The total count of all observations (n=7526 ind.) is shown in Fig. 4 and presents majority of small clusters. Similar classification was prepared only for maximum abundance from four seasons (Fig. 4) (n=871 ind.) and presents different, bimodal pattern of distribution - showing the dominance of small (6-10) and big (> 40) clusters. The biggest noticed groups were about 80 individuals.

Interspecific associations (Fig. 5) were found in 301 cases (22.8% observed groups), including *Plecotus auritus* (166 cases) and also *Myotis nattereri* (53), *Myotis daubentonii* (42), *Myotis myotis* (36) and *Myotis brandtii/mystacinus* (4). This co-occurrence depends mostly on similar ecological requirements, such as thermopreferendum. It was noticeable especially during colder winter periods when the temperature gradient inside the cave was expanded (Fig. 3).

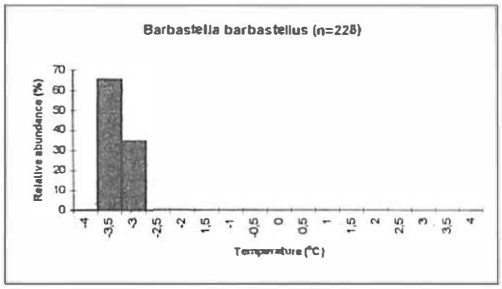
2.4. Cases of mortality

The authors noticed a very low percentage of dead Barbastelle bats during the hibernation period ranging from 1 to 3% yearly. The most harmful for bats were temperature changes appearing usually by the end of the winter. Short periods of warm weather and strong frost at nights make the water soaking from ceiling freeze on the bats. In some cases the reason of death is simply unknown.

We also noticed some cases of predation. The pellets of Tawny owl *Strix aluco*, faeces of fox *Vulpes vulpes* and marten *Martes* sp. were found but only one individual of the Barbastelle was recorded in marten faeces. Very interesting was the observation of the Great *Parus major* and Blue Tits *P. caeruleus* feeding on the freshly dead Barbastelle still hanging on the wall. It happened in January 1996 during the long period of frost in connection with snow cover depth about 15-20 cm. The birds had eaten the brain and the tissues located on the back of the bat. We also found two other bats: *Plecotus auritus* and *Myotis nattereri* remaining alive with deep wounds on the back. It suggests that tits can also be dangerous for poorly hidden bats hibernating in the entrance part of the cave.

3. Discussion

Among the works devoted to ecology of the Barbastelle only few have exact data about arrival and departure time, hibernation duration



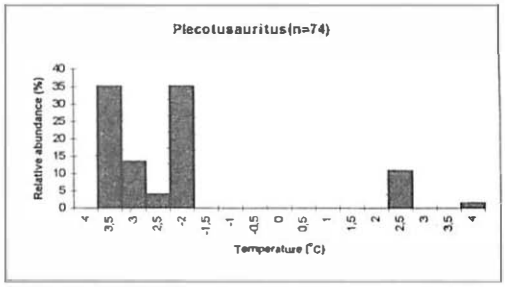
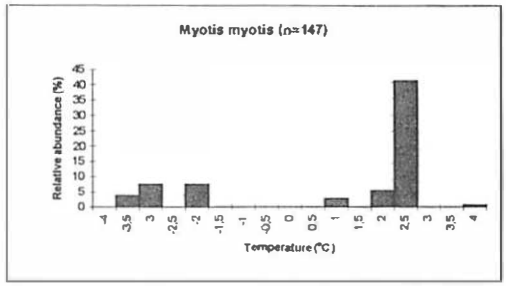


Fig. 3. Diagrams with temperature preferred by different bat species observed on 06.01.95 (by the outside temperature about -5°C)

Abb. 3. Diagramme von verschiedenen Fledermausarten, beobachtet am 06.01.1995, im Zusammenhang mit den bevorzugten Temperaturen (bei einer Außentemperatur von ca. -5° C)

Graph. 3. Diagrammes des températures préférées par différentes espèces de chauves-souris observées le 6.1.1995 (à une température extérieure d'environ -5°C)



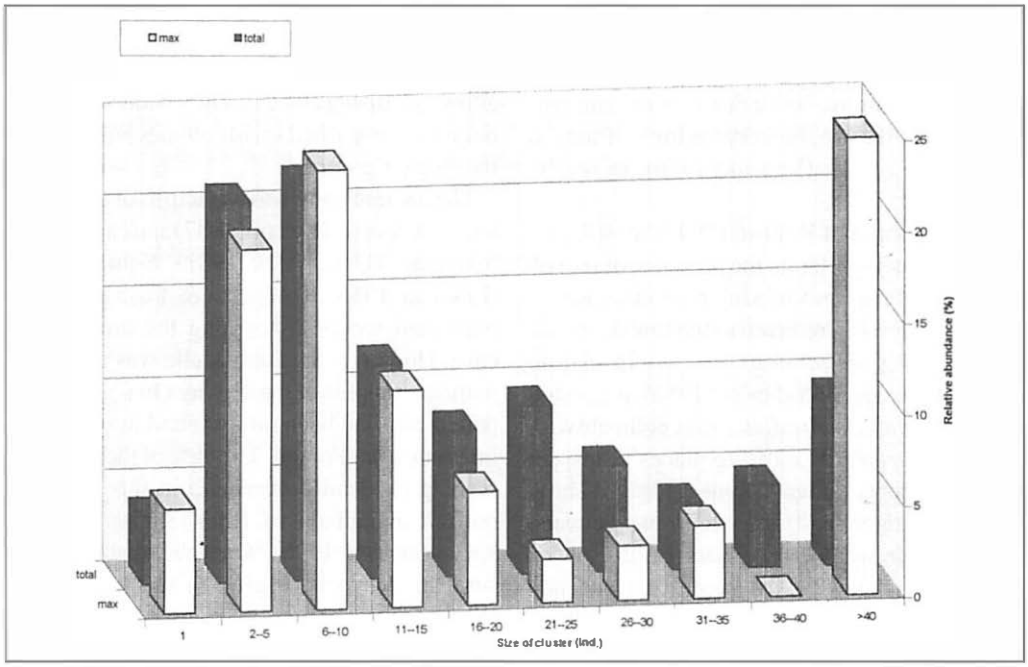


Fig. 4. Cluster size of the Barbastelle hibernating in „Szachownica" cave in the years 1993-1996 including:
- total number of observed individuals (n=7526)
- only for maximum numbers (n= 871)

Abb. 4. Clustergröße der in der „Szachownica"-Höhle überwinternden Mopsfledermäuse der Jahre 1993-1996 einschließlich:
- Gesamtzahl der beobachteten Individuen (n=7526)
- nur für maximale Anzahl (n=871)

Graph. 4. Taille des essaims de Barbastelles hivernant dans la grotte de „Szachownica" pendant les années 1993-1996 comprenant:
- le nombre total d'individus observés (n=7526)
- seulement pour les nombres maximaux (n=871).

(Rybar 1975; Bagrowska et al. 1983; Joa & Kare 1983; Lesinski 1986; Urbanczyk 1991), and social interactions (Bogdanowicz 1983). The duration of hibernation observed in this cave agrees with the results of Lesinski 1986 and Rehak 1992. Data given by Urbanczyk (1991) and Joa & Kare (1983) from areas with milder climate show two weeks later arrivals of first individuals(beginning of November). Daan (1968) described the latest arrival of the Barbastelle starting in the half of December (Koepelgroevecave, the Netherlands). Surprisingly early arrivals of small groups of bats were noticed by us even at the beginning of September during periods of colder weather. It occurs also in other roosting places in Central Poland such as forts near Modlin (Fuszara et al. 1996).

This species is known to be very resistant to cold during hibernation and even in places with wide temperature gradient the Barbastelle prefers temperatures about 0°C (Daan & Wichers 1968, Joa & Kare 1983, Bogdanowicz 1983). Some publications confirm cases of temperatures below 0°C in the very vicinity of bats in range from -2.5°C (Lesinski 1986), to -4.2°C (Urbanczyk 1991).

In the opinion of Ryberg (1947) most European bat species tolerate the presence of individuals of other species in winter colonies. Krzanowski (1955) has referred to the low degree of tolerance only of *Eptesicus serotinus* in relation to other species. Tatarinov (1956) suggested that *Barbastella barbastellus* may compete with *Plecotus auritus* for roosting places in respect of their numbers. Our results (Fig. 5) show also the stronger trend to co-occurrence between these two species than the others. Bogdanowicz (1983) proved statistically a significant tendency to form mixed clusters between *Barbastella barbastellus* and *Plecotus auritus* in forts of Poznan. According to this author and Brosset (1974) the co-occurrence of *Barbastella barbastella, Plecotus auritus, Myotis nattereri, Myotis daubentonii, Myotis myotis* and *Myotis brandtii/mystacinus* in winter clusters depends on similar ecological requirements such as thermopreferendum, preferences for shelters or clustering strategy.

In some forts controlled by us the Barbastelle forms big clusters (up to 100 ind.) hanging directly on the wall or ceiling of corridors. Colonies noticed in „Szachownica" are usually hidden in narrow rifts and crevices which rather do not allow to form big clusters. Only while maximum numbers are reached small colonies join together into bigger groups.

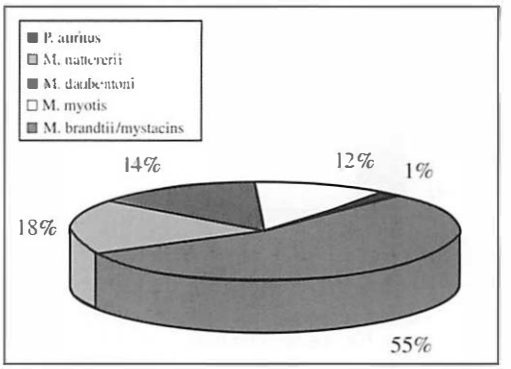


Fig. 5. Percentage of mixed clusters with the Barbastelle

Abb. 5. Prozentuale Verteilung der gemischten Cluster mit Mopsfledermäusen

Graph. 5. Pourcentage de sessaims mixtes avec des Barbastelles

The bats are known to be victims of owls (Nowosad & Saata-Piaciska 1987) and carnivorous mammals (Urbanczyk 1981). Some authors (Lesinski 1983, Kowalski & Lesinski 1990) published works concerning the area of this cave. However, the Barbastelle was not found in those samples of the Tawny Owl *Strix aluco* pellets and had been rarely found in other publications from Poland. The case of the Great Tit feeding on dead *Barbastella* in this area was noticed in January of 1993 (Sachanowicz & Krasnodobski 1996). Our observations confirm this way of foraging of two tits species (*P. major, P. caeruleus*) during long lasting, severe frosts connected with snow cover. Observations of few still living bats with characteristic wounds similar to those eaten by birds suggest that tits can also attack and cause death of poorly hidden hibernating bats.

Martens *Martes* sp. can specialise in taking bats in roosting places (Lesinski & Romanowski 1988). In the underground of the „Nietoperek" reserve they preyed almost exclusively on bats (Urbanczyk 1981). The analysis of martens faeces in Szachownica cave confirmed the high

percentage of bats remains as well – also including one case of the Barbastelle. This bat species roosting there in deeper rifts is hardly available for mammal predators.

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