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Hibernation of bats in underground shelters of central and northeastern Poland

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Abstract. Twelve species of bats were found to hibernate in underground shelters of central and northeastern Poland. The dominant species were: *Myotis nattereri* (31.0 %), *Myotis myotis* (25.7 %), *Barbastella barbastellus* (17.5 %) and *Myotis daubentoni* (17.1 %). Species composition and dominance varied in regard to shelter type. Numbers of the dominant species varied within one hibernation period. No distinct trends were recorded for the variation in numbers of the bats during the study period. The number of species and maximum numbers of individuals were positively correlated with corridor length. Many hibernacula (about 58 %) contained less than 5 individuals for each survey. Nine of all shelters surveyed (total 119) were considered as important for bat protection (the maximum numbers there exceeded 100 individuals per shelter).

Key words. Chiroptera, hibernation, Poland.

Introduction

Data on bat hibernation in central and northeastern Poland are scarce and usually concern only small isolated areas (Wałecki 1881; Krzanowski 1959, 1961; Bartosz & Markowski 1972; Ruprecht 1976; Kowalski & Lesiński 1988; Kasprzyk & Fuszara 1992). The forts at the Modlin fortress are the best known hibernation sites. Here species composition and dynamics of numbers within a hibernation period were studied (Lesiński 1980, 1986, 1991). Studies on species composition and changes in bat numbers over many years have also taken place at the Szachownica cave on the Wieluń Upland (Lesiński 1983; Kowalski & Lesiński 1991). The purpose of this study was to determine:

- species composition and dominance of hibernating bats in different underground shelters
- regional differences in the characteristics mentioned above
- changes in numbers of some species within a hibernation period
- population trends of individual species based on long-term change in the number of hibernating individuals in underground shelters
- sites important for bat protection.

Study area

The study area covered about 100.000 km² (Fig. 1). It was mainly comprised of a lowland and lake district to the north and a belt of uplands to the south. Height above sea level varied between 100 and 300 m. The average January temperature in the study area ranged from —2.5° C to —5° C.

The sites under study (119 shelters) were unevenly distributed and frequently formed groups with up to 19 shelters (Fig. 1). For purposes of this study the winter shelters were classified

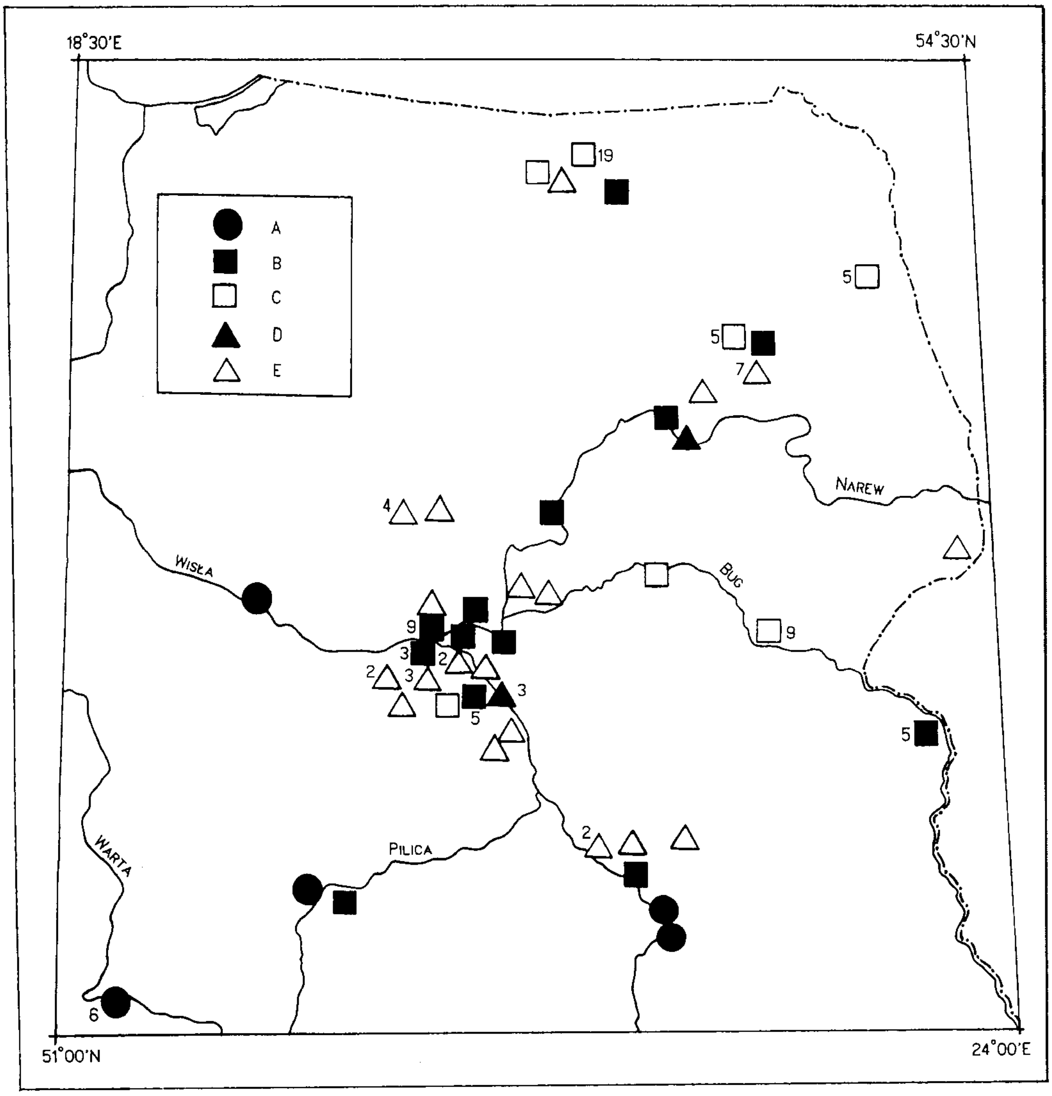

Fig. 1: Distribution of winter shelters studied within central and northeastern Poland. A — caves, B — forts, C — bunkers, D — large cellars, E — small cellars. Some shelters were grouped and their numbers are given.

into 5 categories taking into account their size, presence of corridors, and origin of shelter (numbers of shelters studied are presented in brackets):

1. Caves (10). Natural caves occurred only within the southern part of the study area. Six limestone caves were studied — five of them were 26—100 m in length (Szelerewicz & Górny 1986) and one was much longer (length of corridors over 1000 m according to Głazek et al. 1978). The last one comprised natural corridors as well as large spaces formed in the process of stone exploitation. The remaining four caves were artificial and originated from an exploitation of lime or sandstone.

2. Bunkers (41). The bunkers were small, concrete, one or two floor military structures without corridors.

3. Forts (31). The forts consisted of corridors and rooms of different sizes, located mainly above the ground level and covered by a layer of soil. They had many entrances causing a strong air circulation within the corridors. Similar to bunkers, forts were constructed from

concrete or brick. Those situated in cities were built exclusively of brick what made them similar to large cellars.

4. Small cellars (33). Cellars classified within this category were located close to buildings and were composed of one or several rooms situated under or outside buildings.

5. Large cellars (4). These cellars had a complicated system of corridors. Their origin varied but they were characterized by considerably long corridors (over 50 m) and location below ground level. Their walls were usually built of brick.

The southern part of the study area differs from the rest in respect of the occurrence of particular shelter types. There are almost all caves (with the exception of one small cave), but bunkers and large cellars are absent.

Methods

The study was conducted during bat hibernation periods (October—April) between 1979—1993. Species and number of individuals inhabiting the particular shelter were determined mostly without removing the bats from shelter walls. Changes in numbers within a hibernation period were determined for four species (*Myotis myotis*, *Myotis nattereri*, *Myotis daubentoni*, *Barbastella barbastellus*) in winter shelters inhabited by them in the highest numbers:

— cave Bochotnica (1987—1993) for *Myotis* species,
— large cellars and fort in Warsaw (1987—1993) for *M. nattereri* and *M. daubentoni*,
— forts near Modlin (1979—1982 and 1989—1990) for *M. myotis*, *M. daubentoni* and *B. barbastellus*.

These observations were made from September to April twice a month.

Long-term changes in numbers were determined for five species: *M. myotis*, *M. nattereri*, *M. daubentoni*, *Plecotus auritus* and *B. barbastellus*. For this purpose ten shelters (2 caves, 1 large cellar and 7 forts) were inspected over two periods: 25 Nov.—10 Dec. and 29 Jan.—15 Feb. in 1987—1993. Species diversity of bats in particular shelter types was determined using the Shannon-Weaver species diversity index (H')

$$H' = -\sum (n_i/N) \ln(n_i/N)$$

where n_i is the number of a given species and N is the number of all species.

Results

During the 14-year study of bat hibernation in underground shelters of central and northeastern Poland 12 species were noted: large mouse-eared bat (*Myotis myotis*), Bechstein's bat (*Moytis bechsteini*), Natterer's bat (*Myotis nattereri*), whiskered bat (*Myotis mystacinus*), Brandt's bat (*Myotis brandti*), pond bat (*Myotis dasycneme*), Daubenton's bat (*Myotis daubentoni*), northern bat (*Eptesicus nilssoni*), serotine bat (*Eptesicus serotinus*), brown long-eared bat (*Plecotus auritus*), grey long-eared bat (*Plecotus austriacus*) and barbastelle bat (*Barbastella barbastellus*) (Table 1). The dominant species in the study area were *M. nattereri* and *M. myotis*, while *B. barbastellus* and *M. daubentoni* occurred frequently. *P. auritus* inhabited the highest number of shelters (74 shelters).

The dominant species in caves were *M. myotis* and *M. nattereri*, in forts and bunkers — *B. barbastellus*, in small cellars — *P. auritus*, in large cellars — *M. nattereri* (Table 1). The highest species richness and species diversity were noted in caves (Table 1).

About 60 % of the total number of bats were observed in caves. All *M. bechsteini* and *M. mystacinus* and almost all *M. brandti* and *M. myotis* occurred there. The majority (over 50 %) of *M. dasycneme*, *M. nattereri* and *P. auritus* were recorded in caves.

Table 1: Dominance structure (%) of bat communities within different shelter types. N — total number of encounters, H' — Shannon-Weaver index of species diversity.

Species	All shelters N=28 753	Caves N=17 483	Bunkers N=141	Forts N=8608	Small cellars N=231	Large cellars N=2290
M. myotis	25.70	40.26	0	3.43	0	2.31
M. bechsteini	0.18	0.31	0	0	0	0
M. nattereri	31.03	39.13	3.55	5.76	2.60	68.78
M. mystacinus or *M. brandti*	1.86	3.04	0	0.05*	0.43*	0
M. dasycneme	0.18	0.23	0	0.10	0.43	0
M. daubentoni	17.10	7.61	2.84	34.55	26.00	23.93
E. serotinus	0.77	0.59	0.71	1.34	0	0
E. nilssoni	0.08	0.01	11.35	0.07	0	0
P. auritus	5.46	5.58	29.08	3.67	60.61	4.28
P. austriacus	0.15	0.02	0	0.27	7.36	0
B. barbastellus	17.49	3.22	52.48	50.77	2.60	0.70
H'	1.63	1.37	1.20	1.20	1.08	0.86

* — only *M. brandti*

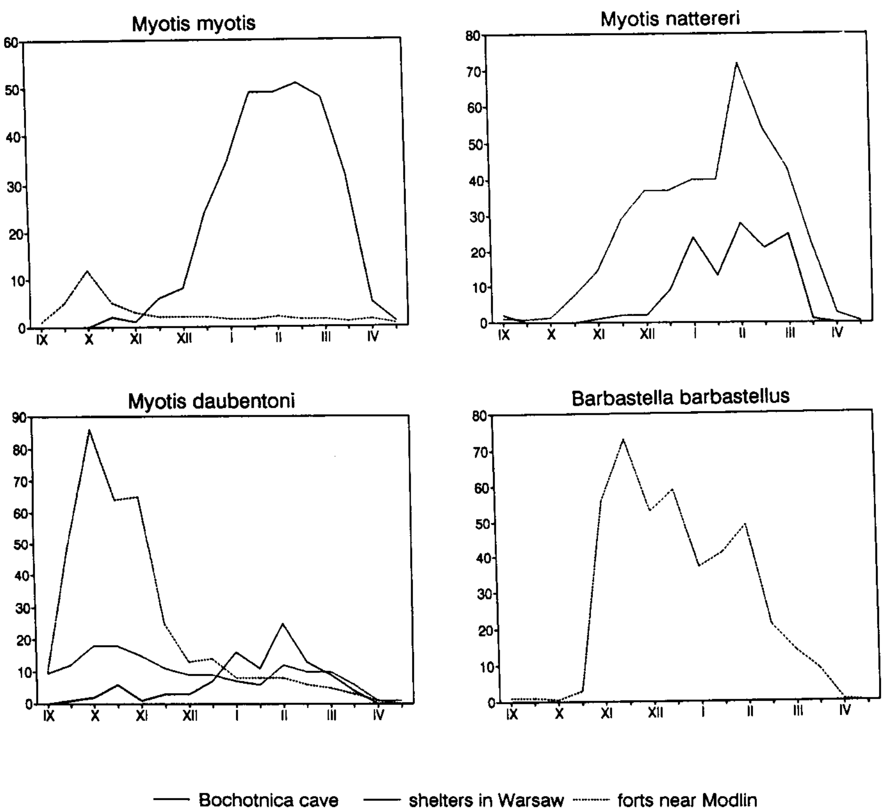

Fig. 2: Changes in numbers of four bat species within a hibernation period at different hibernation sites.

The distribution of some species was limited only to a part of the study area. *M. bechsteini* and *M. mystacinus* occurred exclusively, and *M. brandti* was considerably more numerous in the southern part of the study area. The absence of *M. myotis* and *P. austriacus* was noted in the north. *E. nilssoni* avoided the central part.

Bat species dominance in the southern part of the study area strongly depended on the dominance noted in caves, because they contained the majority of bats occurring in this part. *M. myotis* and *M. nattereri* formed about 78 % of the individuals there. The shelters of the remaining area were inhabited mostly by *B. barbastellus* (38.9 %), *M. daubentoni* (32.3 %) and *M. nattereri* (18.9 %).

Data on numbers of bats within one hibernation period showed differences in dynamics between species. In case of two species various dynamics in different types of hibernation sites were noted. *M. myotis* and *M. daubentoni* attained their peak numbers early (during October) in forts and late (during February) in the Bochotnica cave. *M. nattereri* was the most numerous found in February in the Bochotnica cave, as well as in the large cellar in Warsaw. *B. barbastellus* occurred in the highest numbers in November (data for the Modlin forts only) (Fig. 2). Changes in numbers between 1987—1993 for five bat species showed many fluctuations. Distinct trends were not found but it is possible that *B. barbastellus* slightly increased and *P. auritus* decreased in numbers (Fig. 3).

The studied shelters differed distinctively in regard to numbers of hibernating bats. 58 % of the shelters (mainly bunkers and small cellars) had no more than 5 individuals per observation. However, in 9 shelters the maximum numbers exceeded 100 individuals in each (Table 2). A significant positive statistical relationship between the number of species and corridor length was established ($r = 0.71$, $n = 36$, $p < 0.05$), as well as between the maximum number of hibernating bats and corridor length ($r = 0.75$, $n = 36$, $p < 0.05$).

Table 2: The maximum number of bats noted in the most important bat hibernation sites of central and northeastern Poland.

Site	Max. N	Date
Szachownica (cave)	1477	7. 3. 1987
Osowiec (fort)	344	20. 3. 1993
Konewka (fort)	297	10. 12. 1993
Strubiny (fort)	200	13. 2. 1991
Fosa (cellar)	166	30. 12. 1992
Drozdowo (cellar)	157	2. 12. 1992
Bochotnica (cave)	132	9. 2. 1991
Goławice I (fort)	128	12. 12. 1992
Błogosławie (fort)	109	5. 12. 1993

Discussion

The absence of *M. myotis*, *M. bechsteini* and *P. austriacus* in the northern part of the study area is a result of their limited geographical range (Ruprecht 1983). *M. mystacinus* and *M. brandti* were recorded more frequently in the southern part of the study area which reflects their higher densities in southern Poland (Ruprecht 1983).

E. nilssoni is a boreal species occurring mainly in northern and eastern Poland, but also in southern uplands and mountains. Therefore, its range covers the edges of the study area.

The majority of bats were registered in the largest and most easily found shelters. Small underground shelters surveyed represented only a small portion of possible sites of this type inhabited by bats. Taking this into account, one can expect that the frequency of the species inhabiting this type of shelter (*P. auritus*, *M. daubentoni* and *P. austriacus*) is considerably higher than was found in this study. Therefore the most common species in the study area probably are: *M. nattereri*, *M. myotis*, *M. daubentoni*, *B. barbastellus* and *P. auritus*.

Dominance of *M. myotis* and *M. nattereri* in cave communities reported in the study area is not a common phenomenon. It is true that *M. myotis* dominated in some cave communities in Germany (Gauckler & Kraus 1963; Feldmann 1973) and Czechoslovakia (Baiuerová & Zima 1988), but *M. nattereri* represented only a small percentage of those communities. Sometimes the dominant species were *M. daubentoni* (Masing 1983; Józa & Kareš 1986; Degn 1987) or *B. barbastellus* (Gaisler et al. 1981; Danko & Mihók 1988). Apart from single exceptions in underground shelters of Germany (Schröder 1984; Heise 1989) and Denmark (Jensen & Baagøe 1984), the proportion of *M. nattereri* in bat communities inhabiting other large European hibernation sites was considerably lower than in our study area.

Frequent occurrence of bats of the genus *Plecotus* in small cellars recorded in the study area were observed in other regions of Poland. *P. auritus* inhabited cellars in the east (Ruprecht 1976) and *P. austriacus* in the south (Haitlinger 1976), the latter similar to Czechoslovakia (Gaisler et al. 1981). However, another characteristic of the small cellars studied is also the relatively frequent occurrence of *M. daubentoni* and *M. nattereri*.

The dominance of *B. barbastellus* in military sites (forts, bunkers) described in this paper is commonly noted in central Europe. This has been observed in Bohemian forts (Rybář 1975; Sklenář 1981; Řehák 1992), the region of Kalliningrad and in Lithuania (Masing & Buša 1983). Relatively low air temperatures in winter characteristic of the studied forts and bunkers favour the hibernation of this species (Rybář 1975; Bogdanowicz & Urbańczyk 1983; Lesiński 1986). On the other hand in forts of western Poland, there was a different bat species composition with dominating *M. daubentoni* and *M. myotis* (Bogdanowicz 1983; Cholewa 1987; Urbańczyk 1989; Bernard et al. 1991).

Nyctalus, *Vespertilio* and *Pipistrellus* bats were absent in studied winter shelters — they migrate to areas far west and south of the study area (Strelkov 1969) and they do not hibernate in underground shelters of central and northeastern Poland. *P. pipistrellus* does hibernate in Poland but in low numbers. This was noted within a hibernation period in underground shelters of western Poland (Bagrowska-Urbańczyk & Urbańczyk 1983; Urbańczyk 1989; Gólski 1992).

E. serotinus is one of the most common bat species in summer communities of the study area (Ruprecht 1983). There is no information about its longer seasonal migrations. The low proportion of this species observed in winter communities most likely results from the fact that it hibernates mainly in different types of shelters (i. e. building lofts), similar to *E. fuscus* in North America (Whitaker & Gummer 1992).

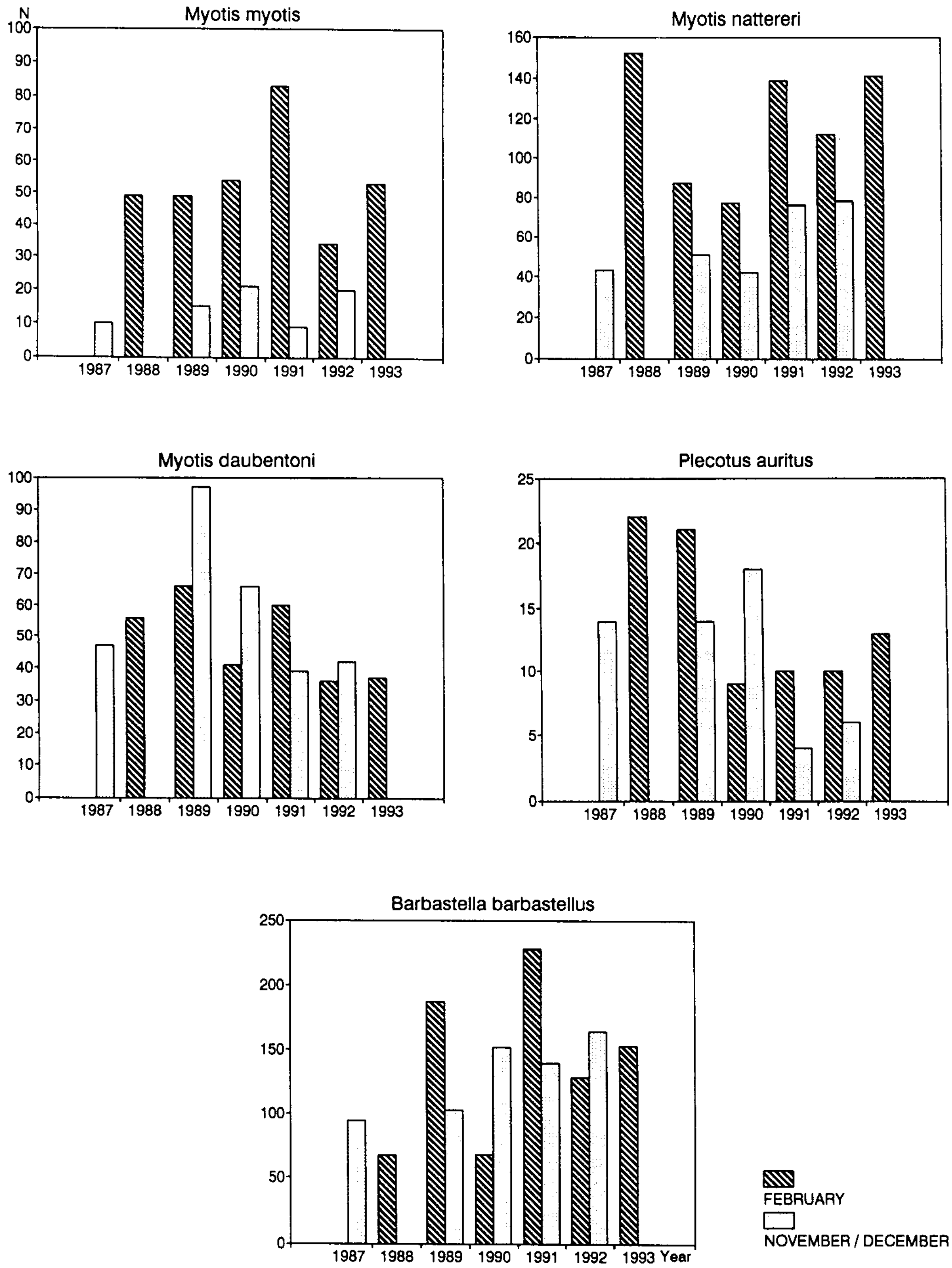

Fig. 3: The long-term changes in numbers of five hibernating bat species observed yearly at ten hibernation sites.

Early peak numbers of *M. daubentoni* in the Modlin forts (Oct.—Nov.) were noted as well as in some military shelters in western Poland (Cholewa 1987; Bernard et al. 1991). The late peak numbers of this species attained in Bochotnica cave were also observed in old mines of northern Bohemia (Józa & Kareš 1986) and in a cave in Denmark (Degn 1987).

Autumn peak numbers of *M. myotis* noted in the Modlin forts were not observed in other hibernation sites. Generally, the maximum numbers of this species are noted in winter (Gauckler & Kraus 1963; Cholewa 1987; Bernard et al. 1991), corresponding with observations in the Bochotnica cave.

High numbers of *M. nattereri* were observed in other winter shelters in the same term (Schröder 1984; Bernard et al. 1991) or slightly later — in April (Krzanowski 1959) as in the area discussed.

The rather early autumn peak numbers of *B. barbastellus* from the Modlin forts (November) was a non-typical phenomenon. The earliest peak in numbers observed in other shelters was in December (Rybář 1975). Usually it occurs in February (Krzanowski 1959; Józa & Kareš 1986) or March (Cholewa 1987).

The lack of distinct trends in bat numbers in underground shelters of central and northeastern Poland indicates that the process of recovery of bat populations, after the intensive use of pesticides in Europe in the fifties and sixties, has been stopped. Only fluctuations can be observed. An increase in numbers of *M. daubentoni* (Daan 1980; Masing & Poots 1984; Urbańczyk 1989) or *M. myotis* (Daan 1980; Gaisler et al. 1981; Bauerová & Zima 1988; Urbańczyk 1989; Červený & Bürger 1990) noted in many European hibernation sites was not marked in the study area.

Sites in the study area where over 100 individuals were observed, constitute about half of the number of the similar large winter shelters known in Poland (Wołoszyn 1989, 1991, 1992). They are very important for bats in central and northeastern Poland, because there is a lack of hibernation sites comparable to the underground shelters of "Nietoperek" in western Poland, where 20—30 thousand bats hibernated in recent years (Urbańczyk 1989; personal comm.).

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Zusammenfassung

In den Jahren 1979—1993 wurden 10 Höhlen, 72 Bunker und Forts und 37 Keller in Zentral- und Nordostpolen auf überwinternde Fledermäuse kontrolliert. Dabei wurden 12 Fledermausarten nachgewiesen: *Myotis myotis*, *Myotis bechsteini*, *Myotis nattereri*, *Myotis mystacinus*, *Myotis brandti*, *Myotis dasycneme*, *Myotis daubentoni*, *Eptesicus nilssoni*, *Eptesicus serotinus*, *Plecotus auritus*, *Plecotus austriacus* und *Barbastella barbastellus*. Die dominierenden Arten waren: *M. myotis* und *M. nattereri* in den Höhlen, *B. barbastellus* in den Bunkern und Forts, *P. auritus* in den kleinen Kellern und *M. nattereri* in den großen Kellern. Es wurden Bestandsschwankungen von vier Arten (*M. myotis*, *M. daubentoni*, *M. nattereri*, *B. barbastellus*) in jeder Hibernationsperiode gefunden. Die Arten- und Tieranzahl korrelierte mit der Korridorlänge. In 9 von 119 Winterquartieren lag die beobachtete Maximalzahl der Tiere über 100.

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