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# Bats in underground shelters of Warsaw

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With 3 Figures

## Introduction

Studies on the bats of Warsaw were initiated in the 19th century (Stronczyński 1839; Loewenhard 1856; Wałecki 1866, 1881). The richest sources of information from that period are papers by Wałecki (1866, 1881), who recorded 13 bat species from the city. The study on the bats of Warsaw were resumed in the 1980s. The present paper analyses the results of observations conducted in Warsaw underground shelters, thus it almost exclusively concerns the hibernation of bats in the town. The objective of this paper is to characterize the occurrence of different bat species in underground shelters of Warsaw, their number dynamics, and sex ratio. It also compares bat communities wintering in Warsaw with those living in some other European towns.

## Study area and methods

Warsaw (52° N, 21° E) has about 1.6 million inhabitants. It is located in the temperate zone, with a mean temperature in January of about -3°C, an annual sum of precipitation of about 560 mm (Biernacki 1990).

The observations were conducted in three shelters of Warsaw.

1. Traugutt Fort - the former stronghold of tzars. Bats occurred there only in parts of the preserved underground casemates, which consist of two rooms 7 m x 4 m and ca 80-m corridor. At very low ambient temperatures, the fort got frozen (Tab. 1).

Table 1. Minimun and maximum air temperatures in winter shelters of bats in Warsaw. The ambient temperature in parentheses.

| Site | Temperature minimum | maximum |
|---|---|---|
| Traugutt Fort | - 3 °C (- 6 °C) | 12 °C (15 °C) |
| Elizeum | 3 °C (- 6 °C) | 12 °C (15 °C) |
| Fosa | 7 °C (- 7 °C) | 12 °C (14 °C) |

2. Elizeum - the remains of an underground park building from the 18th century. At present this is only a rotunda (7 m tall and 5 m in diameter) and corridors surrounding it at two levels (of the total length of ca. 70 m). During the relatively warm winter of 1989/90, Elizeum did not get frozen (Tab. 1). In the Winter of 1984/85, temperature was not measured but the walls were covered with hoar-frost on many occasions.

3. Fosa - undergrounds of unknown origin. It consists of a corridor about 70 m long and about 2,5 m wide. A 30-m section of the central part of the corridor is permanently flooded. Among the hibernation sites under study, this one is best isolated from external conditions (Tab. 1).

None of these shelters was managed. All of them were located within small green areas, and visited by people rather occasionally. Traugutt Fort and Elizeum were situated in the city, whereas Fosa in the peripheral zone, though in close vicinity to large housing estates. All the three shelters were built of brick. Most bats hibernated in interstices between bricks.

The study was carried out in 1984-1990. Most surveys were conducted twice a month in the following periods:

in Fosa from September 1987 to May 1988
and from August 1989 to May 1990,
in Elizeum from November 1984 to mid-April 1985
and from mid-August 1989 to March 1990,
in Traugutt Fort from August 1989 to May 1990.

Also the results of 57 surveys made in other periods (including 36 in Traugutt Fort) are added to the global results.

Temperature outside and inside the shelters was measured from September to April 1990.

Since only a small part of bats was ringed, it was not possible to determine whether the same or different individuals were present in shelters on successive surveys. Thus, in this paper the number of bats in each community was estimated as the sum of individuals recorded during all surveys combined for a given shelter.

From September 1989 to April 1990, some individuals of *Myotis nattereri* and *Myotis daubentoni* (20 of each species if possible) were sexed but not ringed.

Sex ratio was determined for ringed bats and not ringed *M. nattereri* and *M. daubentoni*, separately. Significance of the deviation from a 1 : 1 ratio was determined by using the binomial (Bernoulli) distribution.

Bats not identified to species (e. g. flying or hanging very high) are excluded from the present analysis. This is the case of 52 individuals, that is, 2,2% of the total number (2370) of the bats recorded.

## Results

Five bat species were recorded from underground shelters of Warsaw (Tab. 2): *Myotis myotis* (Borkhausen, 1797), *M. nattereri* (Kuhl, 1818), *M. daubentoni* (Kuhl, 1819), *Plecotus auritus* (Linnaeus, 1758) and *Barbastella barbastellus* (Schreber, 1774). *M. nattereri* was the dominant species. It accounted for almost 75% of the individuals in Fosa and more than half in Elizeum. Only in Traugutt Fort *M. daubentoni* was more abundant (Tab. 2).

Table 2. Dominance structure (%) of bat communities in winter shelters in Warsaw over 1984-1990.

| Site | *Myotis myotis* | *Myotis nattereri* | *Myotis daubentoni* | *Plecotus auritus* | *Barbastella barbastellus* | N = 100% |
|---|---|---|---|---|---|---|
| Traugutt Fort | 0 | 38.3 | 59.1 | 2.6 | 0 | 116 |
| Elizeum | 3.9 | 56.4 | 31.4 | 5.4 | 2.9 | 408 |
| Fosa | 2.4 | 74.2 | 20 | 3.2 | 0.2 | 1794 |
| Total | 2.6 | 69.3 | 23.9 | 3.5 | 0.7 | 2318 |

Bats were most abundant in Fosa (a maximum of 161 individuals per survey), than in Elizeum (max. 29 individuals), and least abundant in Traugutt Fort (max. 15 individuals). In Fosa, numbers of bats fluctuated about a high level throughout the winter. A similar situation was observed in Elizeum, except for an extremely cold winter of 1984/85, when numbers of bats

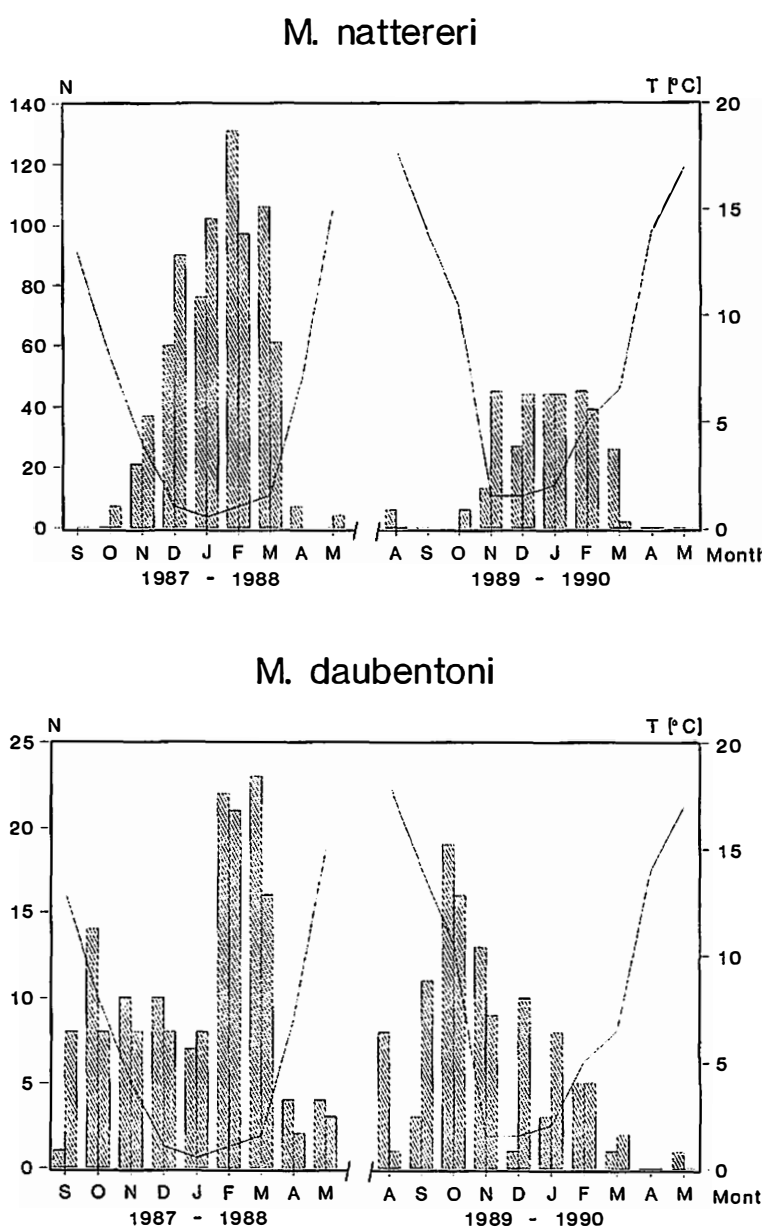


Fig. 1. Changes in numbers of *M. nattereri* and *M. daubentoni* in Fosa over two hibernation seasons, and mean monthly temperatures in Warsaw at that period (data from the Agrometeorological Bulletin of IMGW).

▨ - numbers of bats in the first and second half of the month

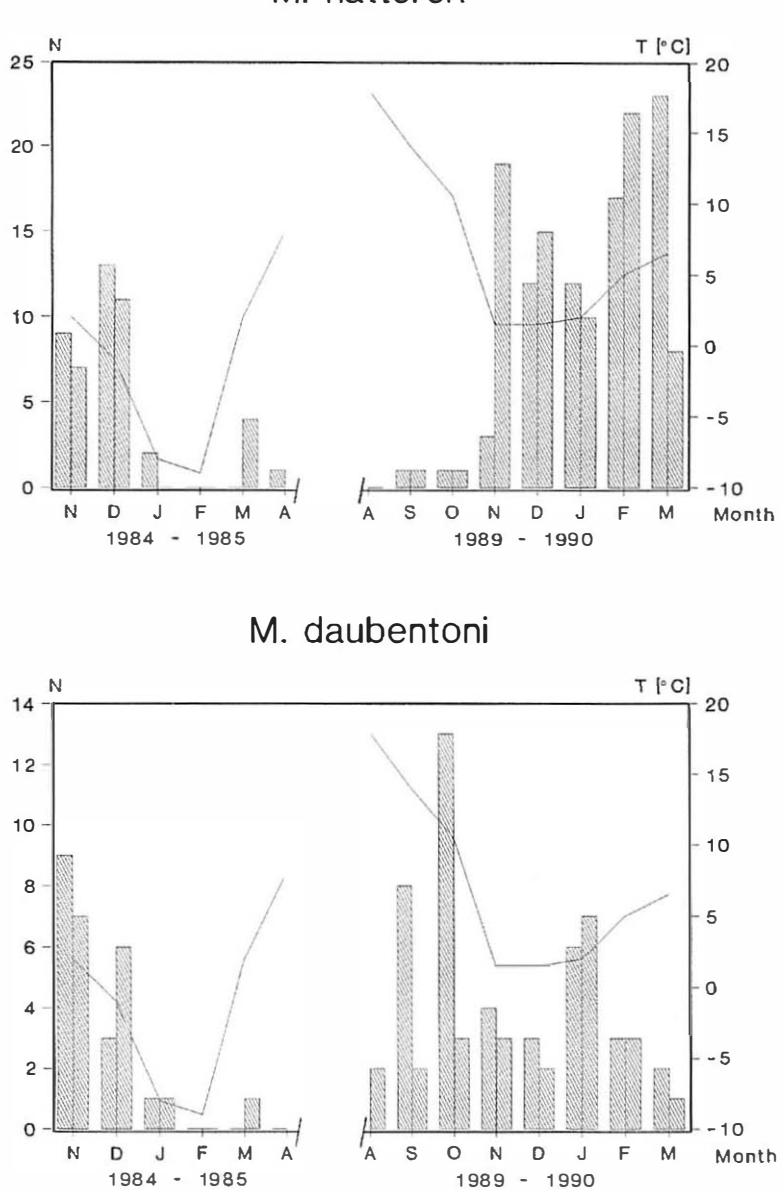


Fig. 2. Changes in numbers of *M. nattereri* and *M. daubentoni* in Elizeum over two hibernation seasons, and mean monthly temperatures in Warsaw at that period (data from the Agrometeorological Bulletin of IMGW).

▒ - numbers of bats in the first and second half of the month

declined almost to zero. In Traugutt Fort, the coldest of the study sites, numbers of bats largely fluctuated and dropped to zero in January or February almost each winter.

*M. nattereri* appeared in larger numbers in Fosa and Elizeum in November. Then, its high numbers were maintained until March or April. Low numbers of this species (less than 10 individuals per shelter) were observed already in March of the season 1989/90 and only in April of the season 1987/88 (Fig. 1 and 2). In both these seasons, this coincided with an increase in the mean temperature above 5°C, this taking place in March of 1990 and in April of 1988 (Fig. 1). *M. nattereri* showed a different behaviour when shelters got frozen. In Elizeum, numbers of this species dropped to zero when mean monthly temperatures were below -5°C (Fig. 2).

In Traugutt Fort, *M. nattereri* was scarce (max. 6 individuals in one survey). In the warmer season of 1989/90, 1-2 individuals were observed in the period from August to May, whereas in the season of 1987/88, this species was present only in three surveys.

In Fosa and Elizeum *M. daubentoni* was the second most abundant species (Tab. 2). It appeared already in August and reached high numbers early in October (Fig. 1 and 2). At that time, it reached the highest numbers in the season of 1989/90, but in the season of 1987/88, highest numbers of this species were observed at the second peak at the end of winter in February and March (Fig. 1 and 2). In the coldest period of the season of 1984/85 (in February), *M. daubentoni* was absent from Elizeum. In Traugutt Fort, *M. daubentoni* was relatively abundant from September to November (max. 9 individuals in one survey). On other dates only single individuals were occasionally encountered.

The other species were rare in the study sites (Tab. 2). *P. auritus* was encountered throughout the year, most abundantly from August to March. *M. myotis* occurred in shelters from Septemberto April. Both *P. auritus* and *M. myotis* were most abundant in Fosa. *B. barbastellus* was encountered only in winter, in January, February, and March, most frequently in Elizeum.

In Traugutt Fort and Elizeum, the number of females was higher than the number of males of *M. daubentoni* (Tab. 3).

Table 3. Sex ratio of not ringed *M. nattereri* and *M. daubentoni* in winter shelters in Warsaw over 1984-1990

| Site | Traugutt Fort | | | Elizeum | | | Fosa | | |
|---|---|---|---|---|---|---|---|---|---|
| Sex | ♂ | ♀ | ♂ : ♀ | ♂ | ♀ | ♂ : ♀ | ♂ | ♀ | ♂ : ♀ |
| *Myotis nattereri* | 13 | 18 | 0.72 | 42 | 41 | 1.02 | 105 | 92 | 1.14* |
| *Myotis daubentoni* | 6 | 39 | 0.15* | 12 | 30 | 0.40* | 58 | 43 | 1.35* |

* - statistically significant deviation ($p<0.05$) from a 1 : 1 ratio of males to females in different shelters

In Fosa, however, where 83% of all records of *M. daubentoni* was noted, males prevailed (Tab. 3). Also male *M. nattereri* prevailed over females at this hibernation site (Tab. 3). Males also prevailed among ringed *P. auritus* (Tab. 4), most of which were ringed in Fosa.

Table 4. Bats ringed and bats recaptured in winter shelters in Warsaw over 1984-1990.

| Species | Ringed bats | | | Bats recaptured in the same season | | Bats recaptured in successive seasons | |
|---|---|---|---|---|---|---|---|
| | ♂ | ♀ | ♂:♀ | ♂ | ♀ | ♂ | ♀ |
| *Myotis myotis* | 1 | 1 | - | 0 | 0 | 0 | 0 |
| *Myotis nattereri* | 39 | 32 | 1.22 | 7 | 1 | 7 | 6 |
| *Myotis daubentoni* | 23 | 54 | 0.43* | 1 | 4 | 5 | 3 |
| *Plecotus auritus* | 15 | 4 | 3.75* | 2 | 0 | 2 | 0 |
| *Barbastella barbastellus* | 1 | 5 | 0.20 | 0 | 4 | 0 | 0 |

* - statistically significant deviation ($p<0.05$) from a 1 : 1 ratio of males to females

Sex ratio of *M. nattereri* and *M. daubentoni* showed large changes over the year. The proportion of male *M. nattereri* varied from 71% in January to 29% in March (Fig. 3). Male *M. daubentoni* accounted for as many as 80% of the captured individuals in August but not much more than 30% two months later (Fig. 3).

A part of the ringed bats was recaptured in the same hibernation season. *B. barbastellus* remained in the highest proportion (4 out of 6 individuals) in the place of ringing (Tab. 4). *M. nattereri* returned in highest proportions to hibernation sites in Warsaw one or more years after ringing (over 18% of the ringed individuals).

## Discussion

Species richness of the bats hibernating in Warsaw is low when compared with that in other towns of Europe such as Berlin (HAENSEL 1967, 1972, 1982; KLAWITTER 1975, 1986), Brno (GAISLER 1979; GAISLER & BAUEROVÁ 1985-1986), Pilzno (HŮRKA acc. to BOGDANOWICZ 1983), Poznań (BOGDANOWICZ & URBAŃCZYK 1983; CHOLEWA 1987), London (MICKLEBURGH 1987) and Vienna (SPITZENBERGER 1990).

One of the reasons is the location of Warsaw to the north-east or east of these towns. Because of that, Warsaw is beyond the geographical range of such species as *Rhinolophus hipposideros* (Bechstein, 1800) hibernating in Vienna, *R. ferrumequinum* (Schreber, 1774) recorded from London, or *Myotis bechsteini* (Kuhl, 1818) recorded from Berlin.

Some species occurring in Warsaw in summer but leaving Poland before winter (*Pipistrellus* sp., *Nyctalus* sp.). The shelters they use for hibernation are poorly isolated from the outside environment (GAISLER et. al. 1979; GEBHARD 1983; SPITZENBERGER 1990), which under climatic conditions of Poland would not provide a sufficient isolation from low temperatures. Absence of these species makes the major difference between bat communities hibernating in Warsaw and those hibernating in towns further south or west. *N. noctula* (SCHREBER, 1774) is the most abundant species hibernating in Vienna, and *P. pipistrellus* (SCHREBER, 1774) predominates the bats hibernating in Brno and Pilzno. *P. pipistrellus* and *N. noctula* also hibernate in Berlin. Especially *P. pipistrellus* is frequently recorded in winter.

Of the species hibernating in other towns, we have not so far recorded from Warsaw *Myotis mystacinus* (Kuhl, 1819), *Myotis brandti* (Eversmann, 1845), *Vespertilio murinus* Linnaeus, 1758, or *Eptesicus nilssoni* (Keyserling & Blasius, 1839), which are rare in Poland.

Also *Plecotus austriacus* (Fischer, 1829) was not recorded from Warsaw. Presumably, because Warsaw may be situated at the verge of the contiguous range of this species (RUPRECHT 1983b), although several sites of *P. austriacus* are located on the north-west of the town (LESIŃSKI 1986, KOWALSKI & LESIŃSKI 1988). Absence of this strictly synanthropic species makes difference between Warsaw and such towns as Brno, Pilzno, or Vienna, where *P. austriacus* belongs to most frequently recorded species and is more abundant than *P. auritus*.

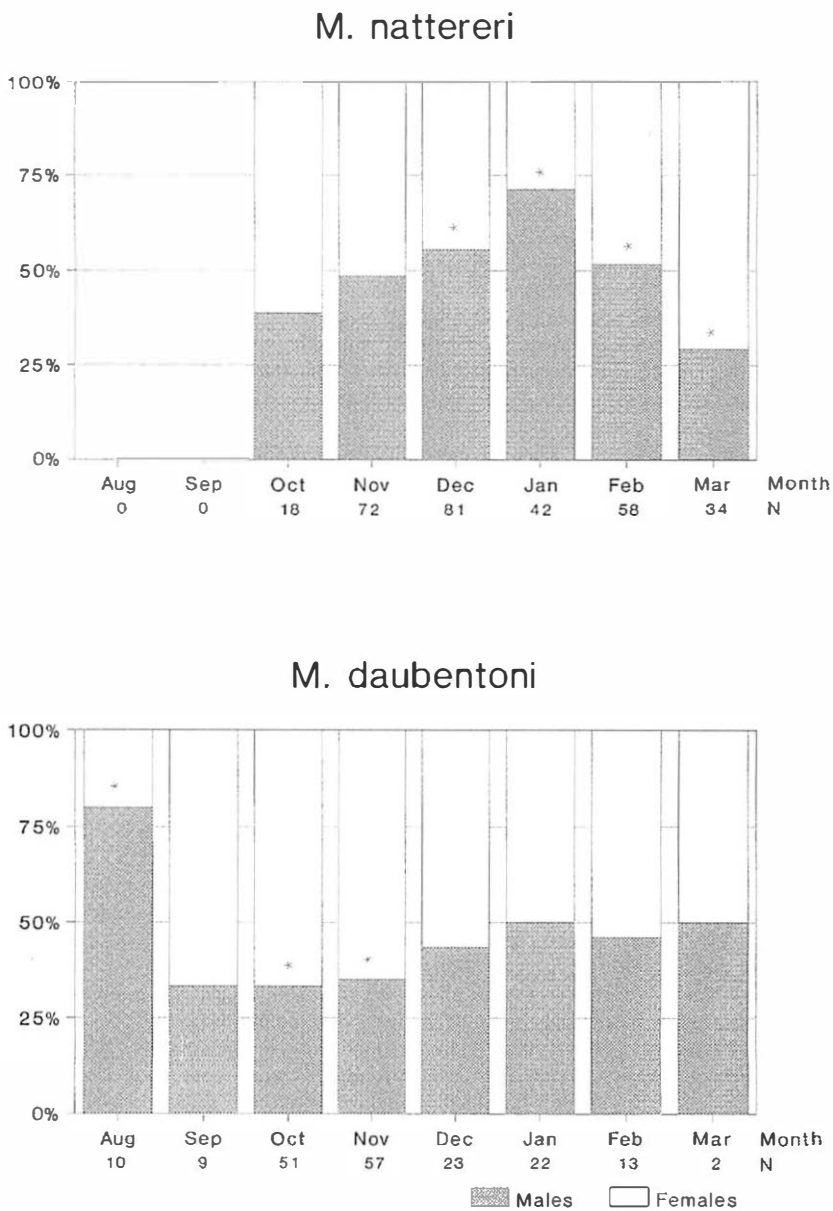


Fig. 3. Changes in male to female proportions of *M. nattereri* and *M. daubentoni* in winter shelters of Warsaw from August to March (data from 1984-1990 combined). Sample size for each month (N) is given under the graphs.

* - statistically significant deviation ($p<0.05$) from a 1 : 1 ratio of males to females

*Eptesicus serotinus* (Schreber, 1774), another strictly obligatory synanthropic species, has not been recorded from Warsaw in winter. It occurs in winter in Berlin and Vienna, and was also noted in Brno, Pilzno, and Poznań. *E. serotinus* is the most common bat that can be observed in Warsaw in summer. It has also been noted every year in winter shelters near Warsaw (unpublished data of the authors and G. LESIŃSKI). The absence of *E. serotinus* from the shelters under study could have been a result of lack of deep, narrow crevices preferred by these bats. The preference of *E. serotinus* for such shelters was observed in forts near Warsaw (LESIŃSKI 1986) and in the cave Bochotnica in central Poland (unpublished authors' data). It is also possible that in Warsaw *E. serotinus* hibernates in shelters of a different kind, for example, in lofts. In the 19th century, this species abundantly hibernated in both underground shelters and lofts in Warsaw (WAŁECKI 1881).

Bats communities hibernating in Warsaw are most similar to those hibernating in London and in western part of Berlin (Spandauer Zitadelle, Fichtenbergbunker). In Berlin *M. daubentoni* is dominant and *M. nattereri* is on the second position in winter. In London, *M. nattereri* and *M. daubentoni* are on the second position (after *P. auritus)* with respect to the number of shelters they occupy.

The dominant species in winter shelters in Poland most often are *B. barbastellus, M. myotis,* and *M. daubentoni*. Proportions of each of them depend on two factors. The first is geographical location. In Poland there is the north-eastern boundary of the range of *M. myotis* (RUPRECHT 1983a). The second factor is the microclimate of shelters. *B. barbastellus* shows preference for cooler and more humid shelters than *Myotis* sp. (BOGDANOWICZ & URBAŃCZYK 1983; LESIŃSKI 1986). The dominance of *M. nattereri* hibernating in Warsaw is puzzling, as typically this is not an abundant species and it accounts for 10-15% of bat communities. In the literature concerning central Europe there is information about only five underground shelters where the proportions of this species was high and similar to that in Warsaw. These are: in Poland cave Szachownica (KOWALSKI & LESIŃSKI 1991 - 43% *M. nattereri)* and an artificial cave in Puławy (KRZANOWSKI 1959 - 56%), in Denmark dungeons and the flagstation at Kronborg castle (JENSEN & BAAGØE 1984 - 69%), in Germany a cementary chapel in Schönermark (HEISE 1989) and cellars of the castle Torgelow (SCHRÖDER 1984). It is worth noting that this species was abundant in underground shelters of Warsaw also at the end of the 19th century (WAŁECKI 1866, 1881).

The high frequency of *M. nattereri* in the shelters under study in Warsaw can be explained by its preference for relatively warm shelters during hibernation (2-10°C - HARMATA 1969; BOGDANOWICZ & URBAŃCZYK 1983). So, it is not surprizing that it was most abundant in Fosa, the warmest hibernation site, and least abundant in Traugutt Fort, the coldest site. This also explains a clear response of this species to changes in temperature, and the fact that they abandon shelters getting frozen. A decrease in *M. nattereri* due to low temperatures was also observed in a cave in Puławy Poland (KRZANOWSKI 1959). Changes in numbers not disturbed by freezing temperatures and similar to changes observed in Fosa in 1987/88 were found in an artificial cave in Bochotnica (unpublished authors' data). Rather small variation in numbers of *M. nattereri* in 1989/90, probably due to an extremely mild winter, was also noted in other winter shelters of this species in Poland (unpublished authors' data).

*M. daubentoni* typically appeared in shelters already in late summer (LESINSKI 1989). In some winter shelters, peak numbers of this species were observed in October or November (KLAWITTER 1980; CHOLEWA 1987; LESIŃSKI 1989; BERNARD et al. 1990). Also frequently observed pattern was an increase by October, followed by fluctuations at a high level, and peak numbers in January-March (JENSEN et al. 1985; JÓŹA & KAREŚ 1986; DEGN 1987).

In Warsaw, both patterns were observed. Neither of them seems to depend on the type of shelter (both patterns were observed in Fosa) or directly on the season (both occurred in the same season, though in different winter shelters).

Differences in the sex ratio in communities of hibernating bats were frequently observed (Strelkov 1971; Sklenář 1981). The dominance of male *P. auritus* over females in underground shelters of Warsaw was very high as compared with that in other shelters in Poland (Bogdanowicz & Urbańczyk 1983; Lesiński 1986). But the male to female ratio in hibernating *M. nattereri* communities in Warsaw was typically similar to that in other towns of Poland, and it varied between 1.2 and 1.4 (low, but in most cases statistically significant, predominance of males) (Krzanowski 1959; Lesiński 1983, 1986).

In different winter shelters of *M. daubentoni* either males predominated (e.g. Gilson 1985) or females (e.g. Jóźa & Kareš 1986). In Poland, most often females were more abundant than males (Haitlinger 1976; Bogdanowicz & Urbańczyk 1983), but nowhere their dominance was so high as in Traugutt Fort or Elizeum.

Interpretation of differences in sex ratio requires much caution. Brosset & Poillet (1985) have found that in the French Jura, male *Rhinolophus ferrumequinum* hibernate in large mine galleries, whereas females prefer small, rocky shelters. As typically the observations were conducted in large shelters with many bats, a biased sex ratio was obtained for the population of this species. Thus, the results obtained in several places cannot be extrapolated to the whole population living in a given area. Depending on the method applied, either males or females can be found to be dominant in a given area.

Having this in mind, we are inclined to explain the observed predominance of one sex over the other in some species by the specific character of the urban habitat. The predominance of male *M. daubentoni* and *M. nattereri* in Fosa may imply that warmer shelters are more readily occupied by males than by females. Similarly, predominance of male *P. auritus* observed in Warsaw seems to indicate that also in this cold-resistant species (Bogdanowicz & Urbańczyk 1983) males more readily than females hibernate in shelters with rather stable and relatively high temperature.

The observed seasonal changes in sex ratios can be a source of bias in the estimate of the sex ratio of a bat community. Seasonal fluctuations can even be larger than found in this study. For example, in an artificial cave in Puławy, the male to female ratio of *M. nattereri* ranged from 8 : 1 in autumn to 1 : 2 in spring (Krzanowski 1959).

The site-fidelity observed for ringed *B. barbastellus* in this study was earlier observed in other winter shelters (Lesiński 1986). Also about 20% of the ringed *M. nattereri* hibernated in the same shelters from season to season not only in the present study area but also in other shelters (Bogdanowicz & Urbańczyk 1983).

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## Summary

In 1984-1990, the occurrence of bats was studied in three underground shelters of Warsaw. The hibernation of five species was recorded: *Myotis myotis*, *M. nattereri*, *M. daubentoni*, *Plecotus auritus*, and *Barbastella barbastellus*. The dominant species was *M. nattereri* (69%), followed by *M. daubentoni* (24%). In the coldest winter, *M. nattereri* and *M. daubentoni* abandoned frozen shelters. Comparison of sex ratios in different shelters seems to indicate that male *M. nattereri* and *M. daubentoni* prefer warmer shelters than females. The sex ratio of *M. nattereri* and *M. daubentoni* showed large variations over the year.

## Zusammenfassung

Von 1984 - 1990 wurde das Vorkommen von Fledermäusen in drei Untertagequartieren von Warschau untersucht. Das Überwintern von 5 Arten wurde festgestellt: *Myotis myotis*, *M. nattereri*, *M. daubentoni*, *Plecotus auritus* und *Barbastella*

*barbastellus*. Die dominierende Art war *M. nattereri* (69%), gefolgt von *M. daubentoni* (24%). Im kältesten Winter verließen *M. nattereri* und *M. daubentoni* ausgefrorene Quartiere. Ein Vergleich der Geschlechterverhältnisse in verschiedenen Quartieren scheint anzudeuten, daß die ♂♂ von *M. nattereri* und *M. daubentoni* wärmere Quartiere bevorzugen als die ♀♀. Das Geschlechterverhältnis von *M. nattereri* und *M. daubentoni* unterliegt über das ganze Jahr hinweg einer großen Variabilität.

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