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# Some Ecological Aspects of Bats Hibernating in City of Poznań

Wiesław BOGDANOWICZ[1] & Zbigniew URBAŃCZYK[2]

Bogdanowicz W. & Urbańczyk Z., 1983: Some ecological aspects of bats hibernating in city of Poznań. Acta theriol., 28, 24: 371—385 [With 2 Tables & 6 Figs.]

During 1975—82 a total of 4,426 bats belonging to 9 species, the most numerous, *M. myotis*, *B. barbastellus*, *M. daubentoni*, *M. nattereri* and *P. auritus*, hibernated in forts, in the citadel, in single gun bunkers and in the cellars of buildings. Distinct differences were observed among the species regarding preferred temperatures and choice of types of winter shelters. *M. myotis*, the most thermophilous species, hibernated at greater heights than the other species in the most remote parts of such shelters, which ensured a relatively constant and high temperature during hibernation. Species preferring lower temperatures were more tolerant in their humidity requirements than were the more thermophilous species. In the shelters examined the distribution of bats depended on type of shelter, conditions, prevailing in it and on temperature requirements and humidity preferences characteristic of each species. Distinct differences were found in sex ratio, a statistically significant domination of females being observed in the case of *M. daubentoni*. Investigations were made to determine the rate of return of males and females of different species to the shelters they previously occupied. It was only in *M. myotis* that a significantly lower percentage of returning females was observed. This can be explained by differences in mortality among individuals of the both sexes. We suggest that there is a relation between the rate of return and the severity of local conditions, and also on the clustering strategy characteristic of each species. A negative correlation was found between the rate of return and the northern limit of range of the given species in Europe.

[Dept. Syst. Zool., A. Mickiewicz Univ., Fredry 10, 61-701 Poznań, Poland].

## 1. INTRODUCTION

Studies on the chiropterofauna of the Wielkopolska region of Poland and its chief city Poznań were initiated at the start of the current century (Schulz, 1977; Lubicz-Niezabitowski, 1933). During this period it was found, on the basis of museum material, that five species of bats, including *M. dasycneme* and *M. emarginatus* occurred within the city limits (Schulz, 1911). The finding of *M. emarginatus* must, however, be treated with reserve, as it would be the sole disjunctive locality of this species in Poland, apart from the southern part of the country (Ruprecht, 1983). Later studies also failed to confirm the presence of

Present address: [1] Mammals Res. Inst., Polish Acad. Sci., 17-230 Białowieża, Poland. [2] Os. J. III Sobieskiego 26D/142, 60-683 Poznań.

this species in the city (Bombicki, 1960; Cholewa, 1983; Bogdanowicz, 1983) or in the whole Wielkopolska region (Kozikowski & Niedzielski, 1954; Bombicki, 1960; Kowalczyk, 1962). Some information on the chiropterofauna of this region and chiefly on hibernation and distribution was provided by studies on the food of owls (Czarnecki *et al.*, 1955; Błaszczyk, 1962) and on ectoparasites of bats (Nowosad, 1974).

The longest uninterrupted period of studies on bats in Poznań lasted from 1975 to 1982. The studies were started by one of us (Z. U.) in the frame of activity of Theriological Section of the Naturalists' Scientific Circle of the A. Mickiewicz University in Poznań. During the winter seasons in 1977—79 and the autumn of 1979 these studies were carried out by Cholewa (1983), and from December 1979 to April 1982 by us. All data including those by Cholewa (1983) were pooled in this paper.

The purpose of this study is to ascertain the ecological requirements of bats hibernating in a city. We also examined the sex ratio in different species of bat and quantitative variation in the rate of return of both sexes to the same winter shelters.

## 2. MATERIAL AND METHODS

The studies were carried out from October to April over the period from 1975—1982 in forts, a citadel, single gun bunkers[1] and in several cellars in building with the city limits of Poznań (52°24'N, 16°56'E) (Fig. 1).

All bats found and handled were banded at each inspection time (or the number on the band read), noting species and sex. These results were supplemented by data on the kind of hibernating site (e.g. fort, single bunker) and shelter (e.g. fissure, crack), and by data on conditions prevailing within the hibernating site. Temperature was measured with a mercury thermometer with accuracy to ±0.1°C, and an Assmann psychrometer was used for measuring relative atmosphere humidity.

Some of the observations on flights of bats were also made during the summer season (chiefly in 1980 and 1981), at which time a large number of lofts, belfries and attics of several building were inspected.

## 3. RESULTS

### 3.1. Ecological Requirements

From 1975—82 a total of 4,426 bats belonging to 9 species *Myotis myotis* (Borkhausen, 1797), *Myotis natterreri* (Kuhl, 1818), *Myotis mystacinus* (Kuhl, 1819), *Myotis daubentoni* (Kuhl, 1819), *Vespertilio murinus* (Linnaeus, 1758), *Eptesicus serotinus* (Schreber, 1774), *Plecotus auritus* (Linnaeus, 1758), *Plecotus austriacus* (Fischer, 1829), and *Barbastella*

[1] Military fortification of the city, build in XIX century.

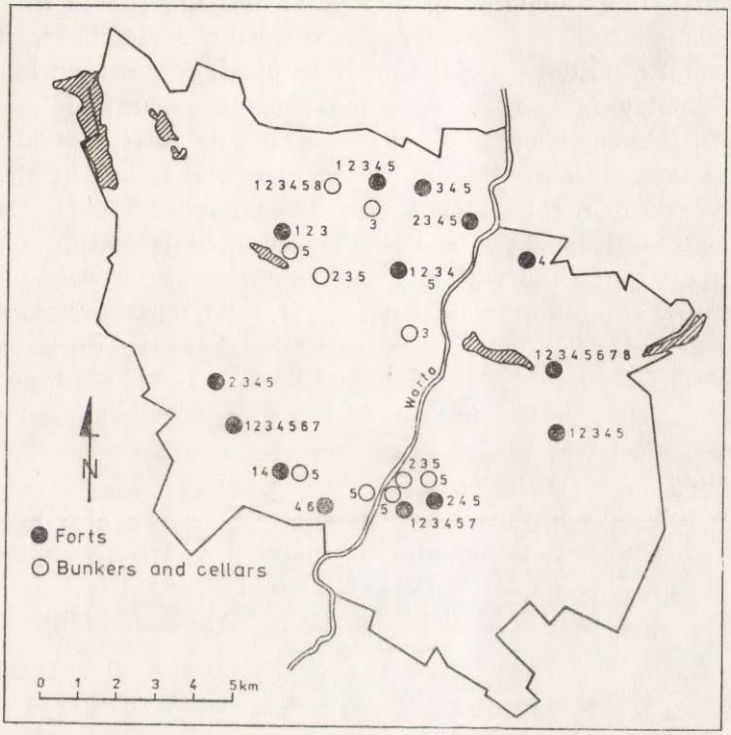


Fig. 1. Position of forts (together with citadel), gun bunkers and cellars within the city limits of Poznań, occupied by bats during the 1975—82 winter seasons. 1=*M. myotis*, 2=*M. daubentoni*, 3=*M. nattereri*, 4=*B. barbastellus*, 5=*P. auritus*, 6=*P. austriacus*, 7=*E. serotinus*, 8=*M. mystacinus*. The hibernation site of *V. murinus* is not known — Cais, pers. comm.

*barbastellus* (Schreber, 1774) were found hibernating in city of Poznań (Fig. 1).

Ecological requirement of the five most numerously hibernating species in the town were examined, *i.e. M. myotis* (2,272), *B. barbastellus* (799), *M. daubentoni* (590), *M. nattereri* (472) and *P. auritus* (264).

### 3.1.1. Ambient Temperature and Relative Humidity

The mean temperature in the vicinity of the hibernating bats was usually relatively high at the start of hibernation, dropped abruptly in December and January, and reached the level characteristic of late autumn and early winter in March. Distinct differences were, however, found between the species in respect of the range of temperatures most often preferred. *B. barbastellus* and *P. auritus* hibernated in the greatest numbers in the ventilated chambers in forts — usually near the venti-

lation shafts. Individuals of these species also hibernated in small and draughty single bunkers in which there were considerable variations in hygrothermal conditions. On the other hand *M. daubentoni, M. nattereri* and particularly *M. myotis* were most often encountered in quarters isolated to a greater or lesser degree from the effect of atmospheric conditions. Mass hibernation of *M. myotis* was found in the disused ventilation chimneys in fort I (see Bogdanowicz, 1983). Differences between different species in their choice of hibernating places and shelters were connected with the differences in preferences for characteristic hibernation temperatures (Fig. 2). The most thermophilous of these species — *M. myotis* — most often hibernated in places where the temperature varied from 3.5—10.0°C, whereas *M. nattereri, M. daubentoni, P. auritus* and *B. barbastellus* respectively, exhibited particular preferences for lower temperature ranges: 2.5—6.0°C, 2.0—6.0°C, 1.0—4.0°C and 0.0—3.0°C (Fig. 2).

The humidity requirements of these species were also investigated. The relative atmospheric humidity in hibernating sites occupied by bats during the season characteristically fluctuated. At the beginning and towards the end of the bats' hibernation relative humidity was lower

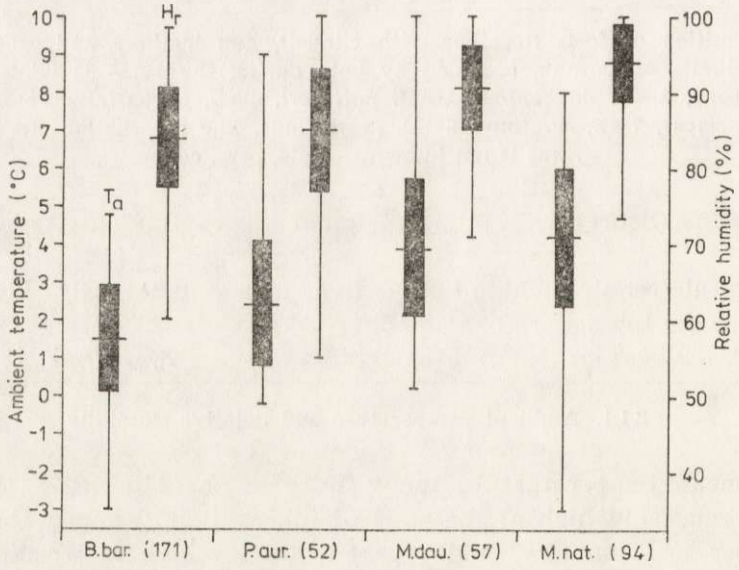


Fig. 2. Ambient temperature ($T_a$) and relative humidity ($H_r$) near the shelters occupied by *B. barbastellus, P. auritus, M. daubentoni* and *M. nattereri* in hibernation sites within the city. Numbers in brackets indicate sample size. Observed ranges and $\bar{X}\pm SD$ (blocks) are shown.

than in the middle of winter, when it attained maximum values. Significant differences in humidity conditions were also observed in different parts of hibernation sites. A higher percentage of relative humidity (up to 100%) was usually found in the more distant parts of such sites, which were frequently flooded. Near the entrance relative humidity was subject to considerable fluctuations, varying over a range from 63 to 97%. A species particularly tolerant to such fluctuations proved to be *P. auritus*, which as frequently hibernated at 75 as at 95% relative humidity (Fig. 2). Similar humidity conditions were preferred by *B. barbastellus* (75—90%). The remaining species occupied shelters with greater humidity (*M. natterreri* — 90—100%, *M. daubentoni* — 85—90%, *M. myotis* — 85—95%) (Fig. 2).

### 3.1.2. Shelter Preferences

Bats hibernating in different parts of shelters (entrance zone, transitional zone and rear sections) and occupying varying kinds of shelter (*e.g.* narrow crevices and gaps) are exposed to the effect of climatic factors to different degrees. Usually in the entrance zones of hibernating sites characterized by considerable fluctuations in temperature and relative humidity, considerably more bats occupied shelters (fissures, crevices and cracks in walls and roofs) guaranteeing them complete protection from variations in hibernationg conditions. A similar situation was observed in the rear sections of some forts and in the majority of single bunkers, where presence of small damaged chambers and large entrances dit not provide complete isolation from the relative drastic effect of external conditions. Only in shelters with more stable hibernation conditions (*e.g.* in fort VIa and in the bunker near fort I — see Bogdanowicz, 1983) did bats occupy niches, depressions and wide grooves (shelter partly protected) to a greater degree than elsewhere, or hang free on walls and from the roof (shelter not protected).

Distinct interspecific differences were, however, found in shelter preferences. More than 70% of *M. nattereri, B. barbastellus, P. auritus* and *M. daubentoni* individuals (with variations of ± 10% for each species in different seasons) were found in places providing complete shelter (Fig. 3). Contrastingly only 1.7% of *M. myotis* occupied "highly protected positions" (sense of Bezem *et al.*, 1964). Preferences for shelters exhibited by *M. myotis* are simultaneously connected with hibernation at far greater heights within the chamber than the other species (Fig. 4), in the further parts of the underground, which consequently guaranteed them relatively high and constant hibernation temperature. Species for

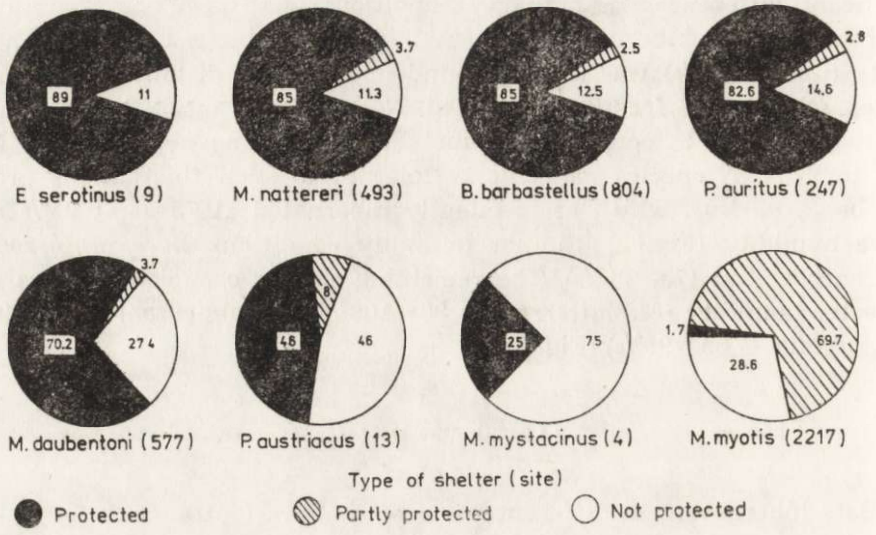


Fig. 3. Occupation frequency of different shelters by bats hibernating in Poznań. Sample size in brackets.

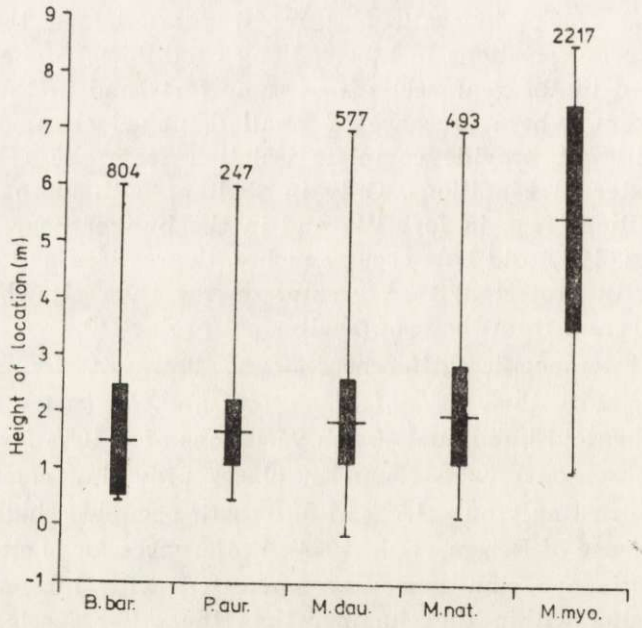


Fig. 4. Variation in height of location among hibernating bats. Figures indicate sample size. Observed ranges and $\bar{X}\pm SD$ (blocks) are shown: 0 m — floor level.

which numbers were exceedingly small (n<30) were not included in this analysis.

The results obtained confirm that there are significant differences between different species of bats in their preferences for various types of winter shelters. Thus species preferring shelters ensuring complete protection, *i.e. M. nattereri, B. barbastellus, P. auritus* and *M. daubentoni*, were considered as "fissure bats", and *M. myotis*, a species usually hibernating in shelters guaranteeing at least partial protection, was allocated to the group of "space bats" (cf. Gaisler, 1966).

### 3.2. Report on Bat-banding

During studies carried out by the Theriological Section of the Naturalists' Scientific Circle of the Adam Mickiewicz University (1975—77), by Cholewa (1977—79) and the authors' own studies (1979—82) during the winter seasons from 1975—1982, 1,689 individuals of eight bat species were banded: *M. myotis, M. nattereri, M. mystacinus, M. daubentoni, E. serotinus, P. auritus, P. austriacus* and *B. barbastellus* (see Table 1).

Table 1

Sex ratio among newly banded and recaptured bats in winter shelters in Poznań (1975—1982).

| Species | Newly banded n | Newly banded %F | Recaptured n | Recaptured %F |
|---|---|---|---|---|
| *M. myotis* | 375 | 41.3[1] | 86 | 27.9[1] |
| *M. nattereri* | 349 | 45.6 | 52 | 34.6 |
| *M. mystacinus* | 4 | — | — | — |
| *M. daubentoni* | 320 | 56.6[1] | 62 | 51.6 |
| *E. serotinus* | 5 | — | 1 | — |
| *P. auritus* | 165 | 37.6[1] | 31 | 29.0[1] |
| *P. austriacus* | 11 | 45.5 | 3 | — |
| *B. barbastellus* | 440 | 38.4[1] | 115 | 34.8[1] |

[1] Significant deviation of proportions from ratio 1 : 1 ($P \leqslant 0.05$).

#### 3.2.1. Sex Ratio and Returns to the Same Shelters

When estimating sex ratio newly-banded individuals were separated from recaptured individuals, those bats being excluded from the second group, which had been found in the same season in which banding took place. This was essential for a correct estimate of rate of return of males and females of different bat species to the same shelters.

Among bats found for the first time (and banded) statistically significant predominance of males — assuming that sex ratio is 1 : 1 — was observed in *B. barbastellus*, *M. myotis* and *P. auritus* (Table 1). Numerical preponderance of males was also found in *M. nattereri*, but the differences were not statistically significant. Significant predominance of females was observed only in the case of *M. daubentoni*.

In the group of bats for which confirmation of return was obtained, the greatest differences in sex ratio were observed in *M. myotis*, *B. barbastellus* and *P. auritus* (Table 1). In the remaining species domination of neither sex was significant.

When comparing the two groups of bats in only one case — *M. myotis* — were significant differences found in rate of return of males and females to the same shelters. In the newly-banded group of bats of this species females formed 41.3%, whereas only 27.9% of the recaptured bats were females.

On the basis of the percentage formed by recaptured individuals in the total number of newly-banded individuals, a general estimate *i.e.* without division into sex classes, was made of the degree of rate of return of the various species to the same winter quarters (Table 2). In order to arrive at the correct degree of rate of return the final study season in reports of newly-banded bats was not taken into consideration.

The results revealed certain differences in the rate of return of various species to winter shelters previously occupied. The greatest percentage of recaptured individuals — over 30% — was found for *B. barbastellus* and *M. myotis*, that is, species frequently hibernating in clusters. In turn, in the case of species with lesser tendency to cluster *i.e. M. nattereri*, *M. daubentoni* and *P. auritus*, the degree of rate of

Table 2

Numbers of newly banded individuals, number of returns and rate of return to the same shelters for 8 species of bats (Poznań, 1975—1982).

| Species | Bats newly banded (without season 1981/82) | Bats recaptured | |
|---|---|---|---|
| | | Number of returns | Rate of return (%) |
| *M. myotis* | 283 | 86 | 30.4 |
| *M. nattereri* | 248 | 52 | 20.1 |
| *M. mystacinus* | 4 | — | — |
| *M. daubentoni* | 224 | 62 | 27.7 |
| *E. serotinus* | 5 | 1 | — |
| *P. auritus* | 128 | 31 | 24.2 |
| *P. austriacus* | 10 | 3 | — |
| *B. barbastellus* | 366 | 115 | 34.2 |
| Total | 1,268 | 350 | 27.6 |

return was also lower (Table 2). This indicates that species more often forming clusters are distinguished by a greated rate of return than species more often hibernating singly.

### 3.2.2. Flights between Shelters

During the period 1975—1982 several limited displacements of bats of up to 1 km were found during the same winter season between different shelters within a given fort. It was only in one case during the season in which banding took place that *M. daubentoni* was found 6 km from the banding site. Displacements between seasonal shelters were found three times: (1) from summer to winter quarters — flight of *M. nattereri* from a distance of 15 km from the north-east direction; (2) from winter to summer quarters — flight of *B. barbastellus* for a distance of 22 km southward; and (3) of *M. myotis* over a distance of 11 km southeastward (Fig. 5). The remaining displacements were observed in different winter seasons and most probably indicated only a change of hibernation place

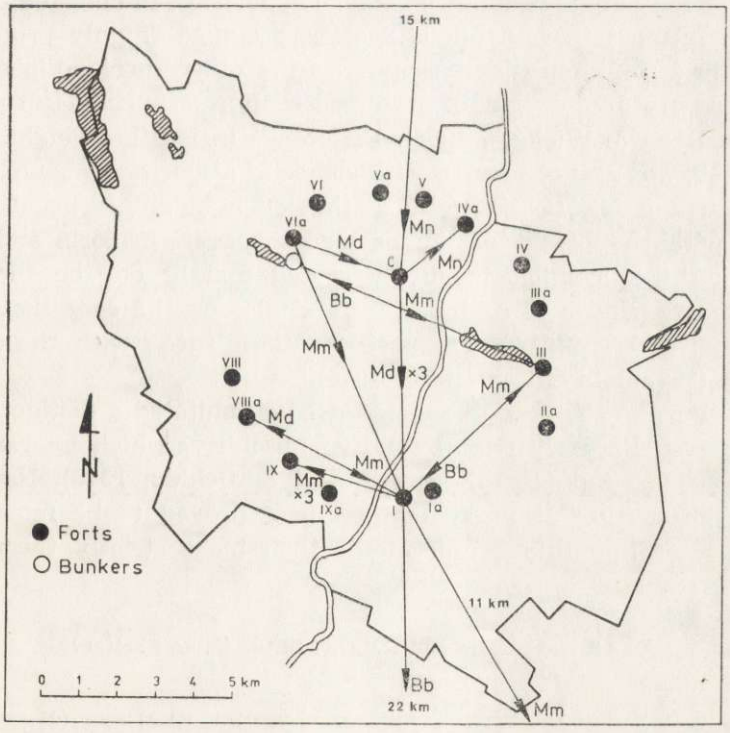


Fig. 5. Map of flights of bats in Poznań to distances over 1 km (1975—1982) Mm=*M. myotis*, Mn=*M. nattereri*, Md=*M. daubentoni*, Bb=*B. barbastellus*.

up to a distance of 8 km from the last known hibernaculum. The majority of *M. myotis* displacements took place to fort I or fort IX, where this species hibernates in large numbers in unused ventilated chimneys (see Bogdanowicz, 1983). It is clear from the foregoing that in *M. myotis* a change of winter shelter was connected with the search for more favourable hibernation conditions. No such distinct relation was observed in the other species.

## 4. DISCUSSION

### 4.1. Ecological Requirements

Biotic factors chiefly determine numbers and life cycle of bats in the tropics. In cooler regions a similar role is played by climatic factors (Krzanowski, 1966; cf. also Vaughan, 1976). In the temperate climate zone bats are dependent primarily on temperature (Gaisler, 1979), and consequently in studies on the ecological requirements of bats the essential point is to define their thermopreference. Distinct differences were found between species in the range of preferred temperatures, and this to a greater or lesser extent determined shelter choices. In our studies *M. myotis*, as the most thermophilous species, occupied "highly protected positions" to a minimum degree, whereas the other species hibernating at lower temperatures decidedly preferred shelters affording full protection (see also Daan & Wichers, 1968). Difference in location height of hibernating bats was also connected with choice of a specific range of temperature. Bezem *et al.* (1964) consider that such height is negatively correlated with the height of the passage in caves. In forts and bunkers in Poznań the location height depended mainly on the temperature requirements proper to each species and also on the conditions prevailing in the given shelter. These observations agree with the results of Harmata (1973) and Gilson (1974—1976).

In the Poznań shelters all species of bats exhibited a distinct tendency to occupy shelters with high relative humidity, which guaranteed minimum evaporation (see also Funakoshi & Uchida, 1978). Nevertheless species hibernating at lower temperatures proved to be more tolerant in respect of humidity requirements than more strictly thermophilous species.

### 4.2. Sex Ratio and Returns to the Same Shelters

Males usually outnumber females in winter quarters (cf. *e.g.* Tinkle & Milstead, 1960, Davis & Hitchcock, 1964; Gaisler, 1975). A similar situation was also observed in hibernating places in Poznań. An except-

ion to this was *M. daubentoni*, for which a statistically significant domination of females was found (see Table 1). Remarkably, other authors also have frequently observed numerical predominance of females in this species (*e.g.* Bels, 1952; Bezem *et al.*, 1960; Haitlinger, 1976). In our opinion this exerts a decisive effect on reproduction potential which, in the case of *M. daubentoni*, would appear greater than in other European species of bats which, together with a high survival rate (Bezem *et al.*, 1960) and climatic changes favourable to this mesophilous species (Roer, 1977, 1979) more than compensate for mortality. These might explain why a constant increase in numbers of *M. daubentoni* is observed in many European countries (*e.g.* Daan, 1980; Fairon, 1980—1981; Gaisler *et al.*, 1980—1981).

In the majority of the species examined a tendency to return would appear uniform for individuals of the two sexes. It was only in *M. myotis* that a far smaller percentage of returning females was found, probably due to differential mortality of males and females. This hypothesis is confirmed by Eisentraut's observations (1947, 1950), which indicated statistically significantly greater mortality among females in this species. Rate of return of bats, however, depends to a great extent on local conditions. For instance ,in Czechoslovakia the rate of return of individuals of the two sexes for different species seems the same (Gaisler, 1975). In Poznań a far smaller percentage of returning females was found for *M. myotis*, as in the Leningrad district for *M. dasycneme* and *M. mystacinus* from among six species of bats hibernating there (Strelkov, 1974).

According to Gaisler (1975), rate of return is negatively correlated with variations in numbers. The numbers of species with a lower degree of fidelity to winter shelters places increased during those studies, whereas the numbers of species with a higher degree of fidelity decreased. Similar results were obtained by Bagrowska-Urbańczyk & Urbańczyk (1983).

Rate of return was compared with the northern limit of the range of the given species in Europe (Fig. 6). There was a negative correlation for the pooled data ($P \leqslant 0.05$). More southerly species are thus distinguished by a higher rate of return than are species ranging further north. This is certainly connected with hibernation conditions in these latitudes, since the relation between the thermopreferendum of different species of bats and their geographical distribution in Europe is well known (Daan & Wichers, 1968; Hharmata, 1969; cf. also Funakoshi & Uchida, 1978). The further north, the greater the difficulties which will be encountered by thermophilous species in finding suitable winter quarters (consequently they will more often return to those previously occupied)

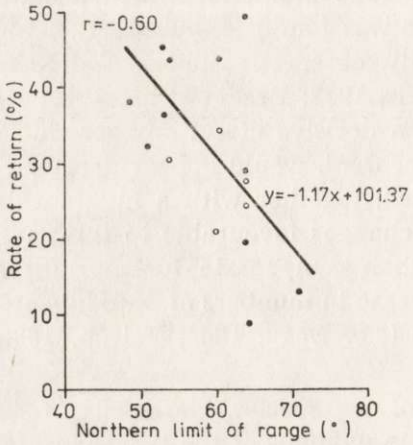


Fig. 6. Relation between the northern limit of range (according to Stebbings, 1982) and rate of return of different species of bats to the same shelters. Use has been made of the authors' own data (light dots) and those from Gaisler's paper (1975) — (black dots) (for $n \geqslant 30$).

compared with species preferring lower temperatures and which are more often able to find suitable shelters.

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Wiesław BOGDANOWICZ i Zbigniew URBAŃCZYK

## NIEKTÓRE ASPEKTY EKOLOGII NIETOPERZY ZIMUJĄCYCH W POZNANIU

Streszczenie

W latach 1975—82 w fortach, na cytadeli, w pojedynczo stojących bunkrach oraz w piwnicach kilku budynków stwierdzono zimowanie 4426 nietoperzy należących do 9 gatunków, z których najliczniejszymi okazały się *M. myotis, B. barbastellus, M. daubentoni, M. nattereri* i *P. auritus*. Pomiędzy poszczególnymi gatunkami zaobserwowano wyraźne różnice w zakresie preferowanych temperatur (Fig. 2), jak też i wybiórczości schronień (Fig. 3). *M. myotis* jako gatunek najbardziej termofilny zimował na większych niż pozostałe gatunki wysokościach (Fig. 4) w głębszych partiach kryjówek, co gwarantowało względnie stałą i wysoką temperaturę hibernacji. Gatunki preferujące niższe temperatury (*B. barbastellus* i *P. auritus*) okazały się bardziej plastyczne pod względem wymagań wilgotnościowych niż gatunki bardziej termofilne (*M. myotis, M. nattereri, M. daubentoni*) (Fig. 2). W badanych kryjówkach rozmieszczenie nietoperzy zależało od typu kryjówki, warunków jakie w niej panują oraz od właściwych dla każdego gatunku wymagań temperaturowych, w mniejszym stopniu również od preferencji wilgotnościowych.

Stwierdzono wyraźne różnice w stosunku płci przy czym u *M. daubentoni* zaobserwowano istotną statystycznie dominację samic (Tabela 1). Dyskutuje się wpływ stosunku płci na potencjał rozrodczy. Zbadano stopień powracalności samców i samic różnych gatunków nietoperzy do tych samych kryjówek. Jedynie u *M. myotis* zaobserwowano istotnie mniejszy procent powracających samic. Fakt ten tłumaczy się różnicami w śmiertelności osobników obu płci. Sugeruje się zależność stopnia powracalności od surowości warunków lokalnych, jak też i od charakterystycznej dla każdego gatunku strategii skupiania się. Stwierdzono ujemną korelację pomiędzy stopniem powracalności a północną granicą zasięgu danego gatunku w Europie (Fig. 6).

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## BOOK RECEIVED

**Flury, B., Riedwyl, H., 1983. Angewandte multivariate Statistik. Computergestützte Analyse mehrdimensionaler Daten.** Gustav Fisher Verlag, 187 s.

Metody statystyki matematycznej, opisujące zjawiska charakteryzowane przy pomocy wielu zmiennych, znalazły szerokie zastosowanie w różnych dziedzinach, jak na przykład w biologii, geografii, ekonomii, medycynie, psychologii, socjologii, antropometrii, w technice i kontroli jakości. Obejmują one szereg procedur statystycznych, pozwalających analizować zespół cech, opisujących pewien zbiór obiektów, przy czym cechy te są traktowane wspólnie, jednocześnie, w powiązaniach jako tworzące systemy. Dzięki tym metodom napotykane przez nas zjawiska mogą być bardziej realistycznie i precyzyjnie opisane. Teoreteyczne podstawy statystyki wielu zmiennych stworzone zostały już w latach 30-tych przez R. A. Fishera w Anglii, P. C. Mahalanobisa w Indiach i H. Hotellinga w Ameryce. Ich praktyczne zastosowanie stało się jednak możliwe dopiero później wraz z rozwojem maszyn cyfrowych.

W trzynastu rozdziałach omawianej książki opisano ważniejsze metody analizy statystycznej wielu zmiennych oraz przedstawiono ich zastosowanie. Od czytelnika korzystającego z niniejszej pozycji wymagana jest znajomość podstawowych pojęć matematycznych jak i ważniejszych metod statystycznych stosowanych przy opisie zagadnień z jedną zmienną. Dlatego też pierwsze rozdziały dotyczą krótkiego przypomnienia wybranych elementów statystyki opisowej z jednoczesną ilustracją ich na przykładach konkretnych danych eksperymentalnych. Dane te w następnych rozdziałach również stanowią przedmiot analizy statystycznej.

Dobór przykładów dla cech ilościowych i jakościowych (niemierzalnych) pozwala na przedstawienie zakresu możliwości jakimi dysponuje się przy analizie wielu zmiennych. Podstawą bardziej zaawansowanych rozważań statystycznych jest wielokrotna regresja liniowa i statystyczna analiza modeli liniowych w przypadku dwóch i wielu zmiennych. W modelach liniowych kombinacja liniowa wielu zmiennych wyjściowych tworzy nową, jedną zmienną, którą poddajemy dalszej analizie metodami stosowanymi do interpretacji zjawisk z jedną zmienną.