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Migration of the Nathusius' pipistrelle *Pipistrellus nathusii* (Vespertilionidae) along the Vistula Split

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Migration of *Pipistrellus nathusii* (Keyserling and Blasius, 1839) was studied from 1995 to 1998 at the Vistula Split, northern Poland. The direction of bat movements during the night were distinguished by two ultrasound detectors facing in opposite directions and connected into a stereo system. To obtain information about fluctuations in the relative density of bats in the study area, bird nest boxes and bat boxes were checked as well. A combination of the results of these two methods allowed the identification of seasonal movements. Spring migration started at the beginning of May and continued until the end of the month. Autumn migration started in mid-July and lasted until mid-September. The peaks in spring and late summer migrations resulted from longer migration activity during nights.

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Introduction

Until the 19th century bats were one of the least studied groups of mammals. Despite this, zoologists suggested that some bat species migrate every winter to warmer areas, as only a few bat species were found in winter roosts. Ringing, which started after the World War II, did not bring expected results (Harmata 1995, Roer 1995). The new possibility of studying biology of bats (eg identification of bats in flight) increased after the invention of ultrasound detectors. The use of several connected detectors gives additional possibilities, one of which is the ability to distinguish the direction of bat movements (eg Ahlen 1990), which was applied in this study.

Despite extensive chiropterological research, *Pipistrellus nathusii* (Keyserling and Blasius, 1839) is still one of the least known European species. Long distances between winter roosts in western Europe and maternity colonies in eastern Europe, as well as studies of this species based on ringing confirmed seasonal migration of this species (Hackethal 1979, Heise 1984, Petersons 1990, Dense 1991). The longest known distance flown by a ringed *P. nathusii* was 1910 km, and the highest known mean speed of movement during migration 66 km per day (Petersons and Lapina

1990). A high abundance of this species in roosts within the Vistula Split in summer, and a lack of records in winter suggest that Vistula Split is one of the migration routes, or that bats living there form a migratory population. This study aimed to reveal the dynamics of seasonal migration of Nathusius' pipistrelle along the Vistula Split.

Material and methods

The Vistula Split is a narrow sandy peninsula, running along the south edge of the Gulf of Gdańsk between Gdańsk and Piława, western Poland. The Vistula Split is ca 1 km wide with hills up to 50 m high. The area is covered mostly by Scotish pine *Pinus sylvestis* forests (Sulma 1958).

The basic method used in this study was detector hearing. Each Nathusius' pipistrelle was identified according to the frequency and rhythm of the ultrasound signal (Ahlen 1990). Two Pettersson D100 heterodyne detectors were connected in a stereo system with headphones. The detectors were placed 10 m from each other on a road running from east to west along the seashore and faced in opposite directions. Using this method, a bat flying along the road was heard first from one detector, and then from the second. The order in which a sound signal was recorded allowed the identification of the direction of a bat pass. The number of passes in each direction during the night and during the season was compared using the Wilcoxon test (Łomnicki 1995). Differences between the measurement of passes east and west were assumed to be a result of movements.

To analyse changes in bat movements, the period between sunset and sunrise was divided into four equal parts: after sunset, before midnight, after midnight, and before sunrise (lasting from 1 h 45 min in summer to 2 h 30 min in spring and autumn). Bat movements during different periods of the night were analysed using the Kruskal-Wallis test (Statistica ver 5.0).

To check if observed movements were the result of seasonal migration, 30 bird nest boxes and 60 bat boxes were monitored. The boxes were placed along the forest roads about 2 m above the ground and checked every 5 days. The number of bats, their sex and age were noted. Changes in bat numbers in the study area were compared with the results obtained by ultrasound detectors.

Data were collected in 1996–1998 during 68 nightlong observations conducted at 5-day intervals. The study was conducted during spring (15 April – 15 June) and late summer (15 July – 15 September).

Results

In total, 4232 bat passes were recorded. The maximum observed number of bat passes per night was 220 (fourth pentad of May 1997). The maximum number of movements (difference between the number of bats going to the east and going to the west) was 88 (first pentad of August 1997)

The first Nathusius' pipistrelle was heard at the end of April. Throughout May bats passing east outnumbered those passing west. The difference was greatest in the mid-May (up to 120 passes to the east, from a total of 152 passes during the night). In contrast, in late summer (between mid-July and the beginning of August) the majority of bats travelled west (maximum difference was during first half of August: up to 60 passes to the west, from a total of 90 passes during the night). Distribution during the season of all observed movements is shown on Fig. 1 (eastward during spring and westward during summer).

The intensity of bat movements changed between different parts of the night. Before 15th of May (Fig. 2), the difference between passes to the east and to the

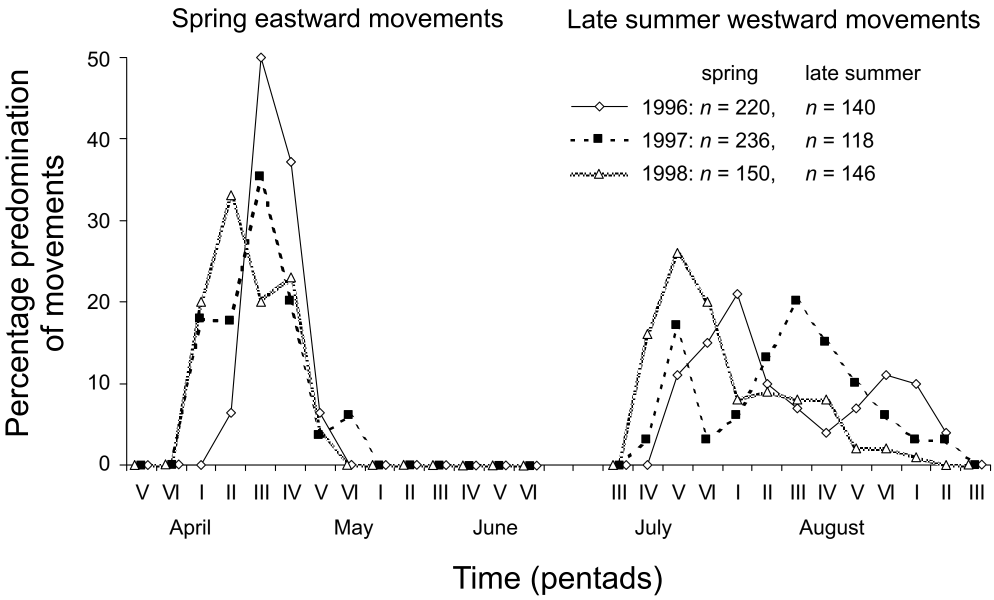

Fig. 1. Distribution of the predomination of eastward (spring) and westward (late summer) movements (ie difference between eastward and westward passes) of Nathusius' pipistrelle along the Vistula Split during 1996–1998 (n – number of passes).

west was significant in the 1st, 2nd, and 3rd parts of the night (Wilcoxon test: $Z =$ from 2.366 to 3.095, $p < 0.01$ and 0.05, $n =$ from 22 to 36). The greatest difference was noticed in the 2nd part (before midnight). Furthermore, in the 2nd and 3rd pentades of May the difference between the numbers of bat passes to the east and west during a 15-min observation (Wilcoxon test: $p < 0.05$; Fig. 2) was highest in the 2nd and 3rd parts of the night (Kruskal-Wallis test: $H = 3, p < 0.05, n = 140$; Fig. 2).

At the beginning of the late summer migration (end of July) and during the first half of August direction of bat movements was opposite to that in spring (bats passing west outnumbered those passing east; Fig. 2). The significant differences between the numbers of passes east and west per 15 min were noticed in the 2nd and the 3rd parts of the night ($Z = 1.988, p < 0.05, n = 34$ and $Z = 2.900, p < 0.01, n = 48$). During the last period of expected migration (end of August – beginning of September) some differences between the number of bats going east and west were observed in all parts of the night. However, these differences were statistically significant only in 1996.

During this study, 303 individuals of *P. nathusii* (161 males and 142 females) were captured in boxes. The maximum number of bats in boxes was found in 1995. The first males were found in boxes during the first half of May (Fig. 3). The number of males increased after the end of July. Most were observed in the second half of August. The last male left the area in the first half of September.

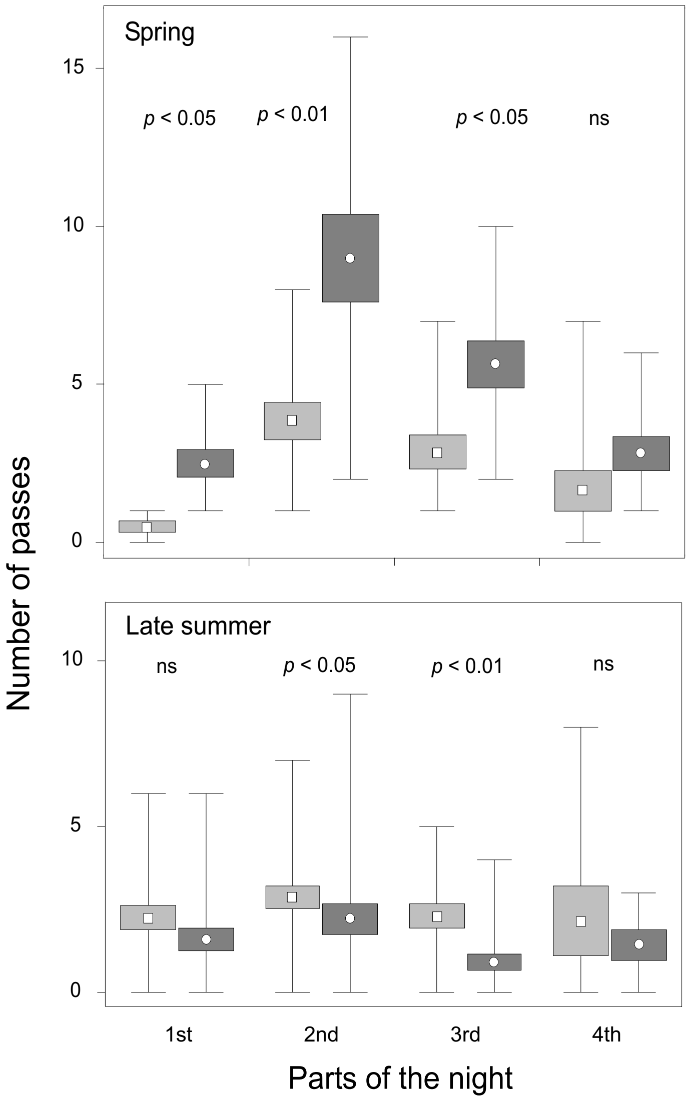

Fig. 2. Comparison of mean numbers of bat passes per 15 minutes during peak of spring (II and III pentad of May, n = 36) and late summer (V pentad of July – III pentad of August, n = 48) movements during different parts of night. Mean ± SD (blocks), maximum and minimum (whiskers) as well as results of pairwaise comparisons by Wilcoxon test are shown. Parts of the night: 1st – after sunset, 2nd – before midnight, 3rd – after midnight, 4th – before sunrise. ☐ – westward, ○ – eastward passes.

Females also started to occupy boxes during May. They appeared again in the study area in mid-July. They were most numerous between the end of July and mid-August to the beginning of September (Fig. 3). The largest change in the number of bats was observed in 1995, the smallest in 1996. There was a positive

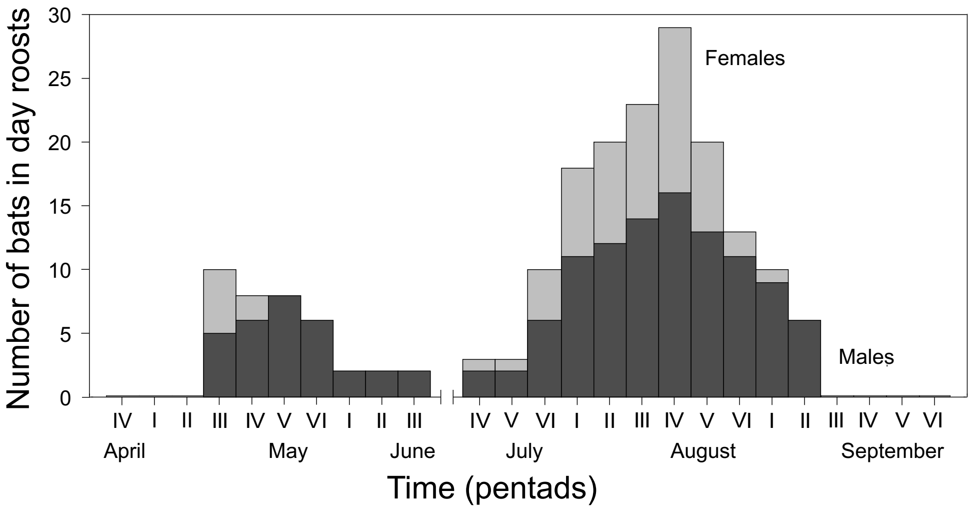

Fig. 3. Mean distribution of number of bats captured in day roosts during the seasons 1995–1998.

correlation between the number of bat passes heard and the number of females (Spearman correlation: $r_S = 0.72$, $p < 0.1$, $n = 75$) and males ($r_S = 0.49$, $p < 0.1$, $n = 75$) in boxes.

Discussion

Because of its geographical features, Vistula Split may play a role of natural "corridor" during migration. In fact, from the beginning of May the majority of bats moved to the east on this area. In contrast, during late summer (after the second half of July) more bats moved to the west. This is consistent with the expected direction of bat migration (Massing 1988, Oldenburg and Hackethal 1989, Brosset 1990, Neiderfringer *et al.* 1991).

If this was a result of seasonal migration, then changes in bat numbers in boxes should have occurred at this time. Groups of females were found in the study area in the 2nd decade of May (when most bats were flying to the east). In late summer, females were found in boxes after the end of July, when most bats were flying west (Fig. 3). On the areas located south of the Vistula Split (eg in Bohemia), *P. nathusii* occupied day roosts at the same time as in northern Poland – between the beginning of May and the end of September. However, the maximum number of bats in day roosts was observed later in those areas (Hanák and Gaisler 1976). An increase in numbers of Nathusius' pipistrelle in September was also observed in Germany (Schmidt 1985, Bastian 1988). During summer, only solitary males were found in Bohemia and the southeastern part of Germany (Bastian 1988). However, there is no evidence that the Nathusius' pipistrelle breeds in this area (Hanák and Gaisler 1976). Until 1993, there was no breeding colonies found in western Europe

(P. H. C. Lina, unpubl.). However, the latest study confirmed the presence of mating groups and breeding colonies of *P. nathusii* in late autumn in England and Ireland (Barlow and Jones 1996, Russ *et al.* 1998).

In the Netherlands, males of this species were numerous during summer but there were no females. In contrast, females were abundant in autumn, when mating groups were found. The majority of *P. nathusii* found in autumn probably also wintered in the Netherlands (P. H. C. Lina, unpubl.). Movements of bats during migration (eg from Vistula Split) seems to be the most reasonable explanation of a September increase in the number of Nathusius' pipistrelle in Germany and Bohemia. The fact that there are no winter records of Nathusius' pipistrelle in this part of Europe also suggests migration of this species along the Vistula Split.

Late summer–autumn migration was documented in Lithuania and Latvia (Massing 1988). Migration in Germany and Sweden was also shown on the basis of ringing (Heise 1982, Schmidt 1984). Most of the Nathusius' bats were ringed in Latvia (Petersons 1990, Petersons and Lapina 1990). During the 4 years of that study, the authors received 13 return messages from ringed bats, which were found in the Netherlands (4 ind.), France (4 ind.), Germany (2 ind.), Poland (1 ind.) (Petersons and Lapina 1990), and Italy (2 ind. – Niederfriniger *et al.* 1991). However, the highest intensity of migration in Latvia was noted at the beginning of September – much later than expected regarding movements on Vistula Split. Even if mean speed of movements during migration were 70 km per day (Petersons and Lapina 1990), migration in Latvia started too late to cause an increase in bat numbers in Bohemia during September (Hanák and Gaisler 1976), or Vistula Split in August. More likely is that the increased number of bats caught in nets in Latvia was a result of movements of bats from areas located to the east or north of this area. Additionally, different populations likely migrate to different areas of eastern and southern Europe (Heise 1982, Oldenburg and Hackethal 1989, Brosset 1990).

Differences in the intensity of bat movement between spring and autumn could have resulted from the biology of this species. During late summer migration, females stopped in day roosts on their migration route, and mated with males. Autumn migration may also be slower because of intensive feeding before hibernation (Ewing *at al.* 1970, O'Shea 1976). The increase in bat passes along with the season was caused by the lengthening of the period of migration during the night rather than by an increase in intensity. This was suggested during autumn migration, when the total number of bat passes per 15 minutes was lower.

During the 3 years of study, spring and autumn migration was observed generally at the same time of the year. However, there were some differences within particular seasons (eg in 1998, both spring and autumn movements were observed earlier in the season and lasted shorter than movements in 1997). Because of the short period of observation it was impossible to determine why this occurred. Changes in weather condition were the most likely explaination: heavy rain or fog could have influenced bat movements (Venables 1943, Church 1957, Stebbings 1968). For example, during 1997 cool and wet weather likely made migration between the 10th and 25th of August less intensive. In contrast, observation on Kuronian Split showed almost no influence of weather condition on migration (D. Pauza, unpubl.)

Conclusions

On the basis of information concerning migration of Nathusius' pipistrelle in Europe, phonology of this species on Vistula Split, and observations of movements on this area, I conclude: (1) spring migration of *P. nathusii* on the Vistula Split lasts from the 2nd until the 5th pentad of May; (2) late summer and autumn migration lasts from the 4th pentad of July until the 6th pentad of September; (3) the peak of spring and autumn migrations are caused by a longer migration activity during the night rather than increased movement intensity.

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