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Characteristics of the northernmost population of *Rhinolophus ferrumequinum* in the Carpathian Basin

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Roost utilisation by *Rhinolophus ferrumequinum* (Schreber, 1774) was investigated between 1984 and 1998 in north-eastern Hungary. Exploration of summer and winter roosts, monitoring and bat-banding were implemented to find movements between the colonies. Data on roost utilisation by this species in south-eastern Slovakia, collected in a similar way, were included for comparison. Twenty-two marked bats were recaptured. The studied bats created nursery colonies in Hungarian churches and moved to Slovakian mines and caves to hibernate in winter. The population used two main hibernacula, two large nursery roosts and one temporary roost but several other roosts were also visited. The area occupied by the population was 5180 km^2. *R. ferrumequinum* living in SE Slovakia and NE Hungary formed probably a separate population on the northern edge of the species range. This population is a part of the metapopulation of the species.

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Introduction

Bats migrate between winter and summer roosts (Racey and Stebbings 1972, Ransome 1990). Some species interrupt their migration spending some time at temporary roosts. The selection of roosts is influenced by environmental factors which differ seasonally. Such factors include temperature and humidity (Fenton and Rautenbach 1986, Churchill 1991, Entwistle *et al.* 1997) and the surrounding landscape of the roost (Wunder and Carey 1996). A warmer roost decreases the energetic costs of bats in the summer (Entwistle *et al.* 1997) and it can improve the survival (Ransome 1989). A warm roost, however, is unsuitable for winter hibernation.

The greater horseshoe bat *Rhinolophus ferrumequinum* (Schreber, 1774) migrates only short distances or not at all (Schober and Grimmberger 1987). In Hungary summer and winter roosts are located within 20–30 km from each other (Szatyor 1995a). This species usually roosts in attics in the summer and in caves or abandoned mines in the winter (Pandurska 1995, Szatyor 1995b). Greater horseshoe bats are sensitive to conditions in the winter roosts: they prefer reasonably warm (7–10°C) locations (Pandurska 1993).

In this paper the term 'colony' is used to imply animals living at the same roost at the same time. The population is the totality of these colonies, which associate and breed mainly with each other. The size of population may change in time and space. Some, more or less separate populations collectively form a metapopulation (Levins 1970). These populations are connected to each other by occasional migration.

How large is the area within which the colonies can be seen as a population? The size can depend on the species and characteristics of the region. The population of a sedentary species is likely to occupy a much smaller area because its home range is smaller. Bats are forced to gather around resources (mainly roosts) that are near and more easily available. The population of a migratory species may use a very large area, which includes several countries (Brosset 1990, Masing *et al.* 1999). It can be accepted as one population because there is an intensive gene-exchange even between individuals from the furthest points of the species range.

Earlier findings (Gombkötö 1995, Molnár 1997, Závoczky 1997, Dobrosi 1998) suggest that five, more or less separated populations of *R. ferrumequinum* exist in the Carpathian Basin (Fig. 1). The aim of this study was to give new data to this prediction by monitoring the roost utilization and migrations of bats from the northernmost population of this species.

Study area

Examinations were carried out in the north-eastern part of the Carpathian Basin. The southern part of the study area was located in Hungary: the region of Zemplén Mts, among the Rivers Hernád, Bodrog and the Slovakian-Hungarian border. The northern part of the study area was in the connected south-eastern Slovakian regions: the Slanské vrchy Mts and Zemplínske vrchy Mts, between the rivers Topl'a and Torysa (Fig. 2). The region was situated 200–900 m above sea level. It was covered by forests, pastures, river valleys and streams, providing excellent foraging habitats for bats. It seems that all environmental resources, except the winter roosts, were abundant here. The territory lay in volcanic mountains with no natural caves. Therefore, only abandoned mines provided winter roosts for bats. The lofts of several churches and historic buildings might supply summer roosts. Neighbouring regions (in a 50-km circle around the study area) were also investigated to find roosts and possible connections between the colonies.

Material and methods

In the present study, population number 4 (Fig. 1) was investigated. This population is the northernmost one in central and eastern Europe, and is at the edge of the species range. The first step of the examination was to discover summer and winter roosts of bats living in this region. Repeated observations were performed in nearly 200 churches, other buildings, mines and cellars in Hungary. Winter roosts were examined in December–January and summer roosts in June–August during the period of 1984–1998. Bomboly mine and churches in Bodrogkeresztúr and Tolcsva (Fig. 2) were chosen for medium and long-term monitoring. In summer the mine was checked every month and the churches 4 times per summer in order to count the number of bats present. In order to map the migratory movements, bats were ringed at the churches of Bodrogkeresztúr and Tolcsva, and Bomboly mine. Animals were captured by mist-net around the churches and at the foreground of caves, and were marked by aluminium rings on their forearm. During six ringing sessions 53 bats were marked.

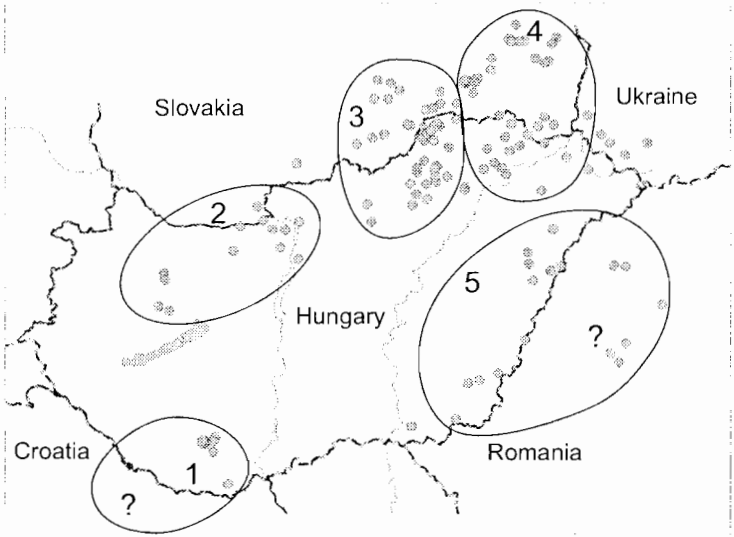

Fig. 1. The supposed five *Rhinolophus ferrumequinum* populations in the Carpathian Basin, on the basis of several Hungarian and Slovakian studies (references in the text).

Data from Slovakia

Data collected by Danko and Mihók (1988), Fulín (1995), Uhrin *et al.* (1996), and Danko (1997) on bat roosts in mines, cellars and caves in SE Slovakia were used for comparison. The data were collected in a similar way as in the present study. The Jasov cave and four Dubnik mines (Fig. 2) were chosen for medium and long-term monitoring. Several ringing sessions were performed at Jasov cave and the Dubnik mine-system and 17 bats were marked.

Results

Summer roosts. In summer, nine bat species were found in churches (*Rhinolophus ferrumequinum*, *R. hipposideros*, *Myotis myotis*, *M. blythii*, *M. daubentonii*, *M. emarginatus*, *Eptesicus serotinus*, *Plecotus austriacus*, *Pipistrellus pipistrellus*). Greater horseshoe bats were found in 14 attics in Hungary and in 8 attics in Slovakia (Fig. 2). Only two of these colonies (in Tolcsva and Bodrogkeresztúr churches) were large (≥ 100 individuals). The maximum size of these two colonies varied from 100 to 300 bats during 1984–1998. The Bomboly mine in Mád village was the only important summer roost under the ground (the number of individuals varied from 70 to 90). This nursery colony, however, was not present there every year.

Winter roosts. Examining mines and caves in winter, greater horseshoe bats were found continuously in high numbers only in Bomboly mine and in Jasov cave,

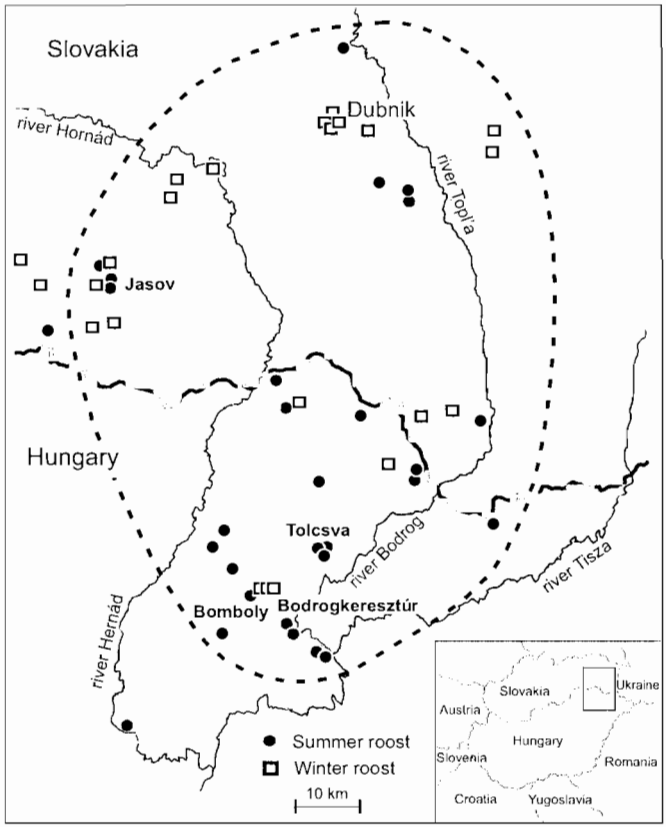

Fig. 2. The summer and winter roosts of *Rhinolophus ferrumequinum* with the estimated border of the local population.

while occasionally there were groups of 1 to 50 individuals in 23 other Hungarian and Slovakian underground roosts (Fig. 2).

Colony size fluctuations. The bat monitoring in Bomboly mine shows that the greater horseshoe bats arrive and leave at a similar time every year (Fig. 3). It was a transitory roost, where the number of bats increased considerably every spring and autumn like in a 'distributive centre'. Since some small groups of bats left soon after a few days stay, Fig. 3 does not reflect the exact number of bats which turn up in the mine in certain seasons.

The hibernating bats left the mines, caves and cellars situated in Slovakia in the early spring, and most of them moved to Bomboly mine in April (Fig. 4, Table 1). Under favourable weather the bats hunted in the surrounding area, but in the case of cool, rainy weather they fell asleep for days. About 200 bats arrived at the mine every year, and then left after a one-month stay. In the middle or end of April,

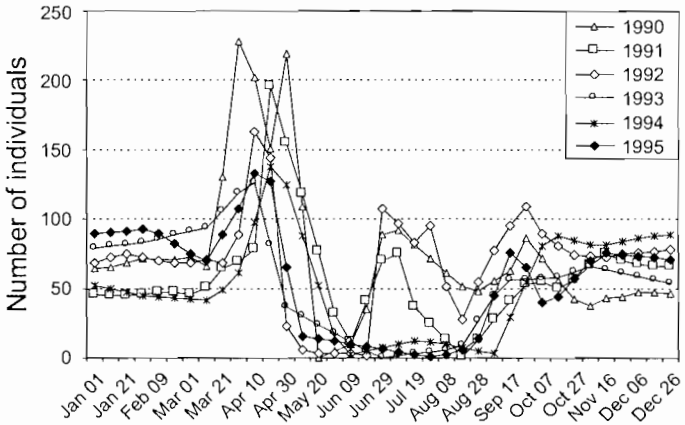

Fig. 3. Seasonal changes in the number of greater horseshoe bats in Bomboly mine between 1990–1995.

depending on the weather, these animals appeared at the churches of Tolcsva and Bodrogkeresztúr (Fig. 4, Table 1), where they established maternity colonies.

The bats left the maternity roosts in August. The Bomboly mine became populous again from the beginning of September. Numbers of bats observed in the mine were lower in autumn ($\bar{x}_{\text{Sep 27}} = 60$, range: 51–109) than in spring ($\bar{x}_{\text{Apr 20}} = 133$, range: 81–195) between 1990–1995. Some of them left the mine in October, and they appeared later at the Slovakian winter roosts. These animals wintered there.

In winter, about 260 animals could be found in the Jasov cave (Slovakia), and they left it at the end of April (Fulín 1998). Fewer (2–23) individuals spent the winter in Libanka mine (Danko 1997). The numbers of bats were similar to this

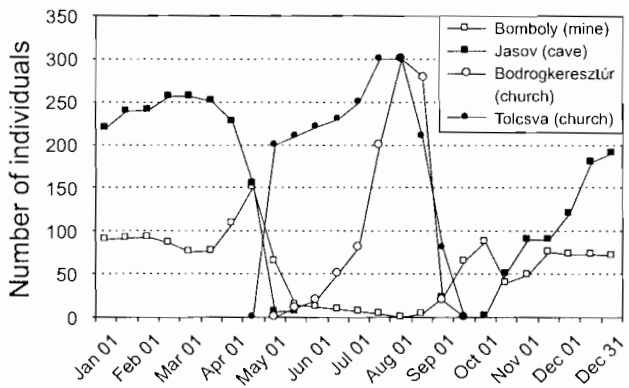

Fig. 4. The presence of greater horseshoe bats in their four main roosts in 1995. Data concerning the Jasov cave were published by Fulín (1995)

Table 1. Examples of ringed *Rhinolophus ferrumequinum* movement between winter, temporary and summer roosts in the north-eastern part of the Carpathian Basin.

Ring number	Time and place of:	
	marking	recapture
Praha 37040	06 February 1973 Jasov cave	20 April 1986 Bomboly mine
Praha 90500	16 September 1980 Kasov cellar	12 March 1988 Dubník mine
Praha Z634548	17 January 1984 Kasov cellar	20 February 1988 Brehov, cellar
		29 January 1991 Kasov cellar
Praha Z659280	17 January 1987 Kasov cellar	03 April 1988 Bomboly mine
Praha Z6592??	?	02 April 1989 Bomboly mine
Praha Z659378	31 January 1987 Dubník mine	09 April 1988 Bomboly mine
		17 December 1994 Dubník mine
Budapest 50113	02 August 1989 Bodrogkeresztúr church	31 April 1990 Bomboly mine
		02 July 1992 Bodrogkeresztúr church
Budapest 50119	02 August 1989 Bodrogkeresztúr church	31 April 1990 Bomboly mine
Budapest 50104	03 August 1989 Bodrogkeresztúr church	15 April 1990 Bomboly mine
Budapest 53013	02 July 1992 Bodrogkeresztúr church	10 April 1993 Bomboly mine
Budapest 53021	03 July 1992 Bodrogkeresztúr church	09 April 1995 Jasov cave
Budapest 54087	23 July 1992 Tolcsva church	30 January 1993 Bomboly mine
		13 March 1993 Bomboly mine
Budapest 54088	24 July 1992 Bodrogkeresztúr church	25 February 1993 Drienovec cave
Budapest 56044	18 August 1993 Bodrogkeresztúr church	16 October 1993 Bomboly mine
Budapest 56049	18 August 1993 Bodrogkeresztúr church	12 November 1996 Jasov cave
Budapest 56041	18 August 1993 Bodrogkeresztúr church	16 October 1994 Bomboly mine
		10 November 1994 Bomboly mine
Praha 1435?	09 September 1997 Jasov cave	07 October 1997 hit by a car
		(5 km from Bodrogkersztúr)
Budapest 56042	18 August 1993 Bodrogkeresztúr church	18 January 2000 Drienovec cave

figure in Drienovec cave with its 4–57 individuals (Uhrin *et al.* 1996), and in Kasov cellar where 4–15 bats spend the winter. The number of greater horseshoe bats decreased from March 15 until April 15 in the Jasov cave (Fulín 1998), exactly at the same time when it increased in the Bomboly mine (Fig. 4).

Migration. Altogether, 22 banded bats were recaptured. They usually moved in a north-south direction (Fig. 5). The longest distance (80 km) was recorded between the Bomboly mine and the Dubnik mine.

It is likely that bat movement also occurred between the Bomboly mine or Bodrogkeresztúr church, and the Pácin church (60 individuals) and Tokaj cellar (10 individuals). This supposition lies on the facts that (1) two ringed bats were seen there (but they could not be captured) and (2) there were no other ringings in this region.

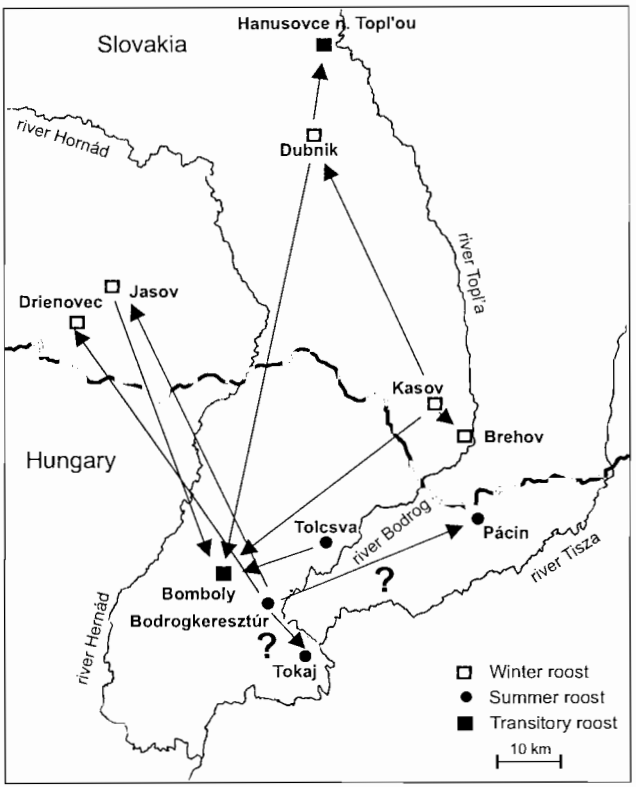

Fig. 5. Movements of *Rhinolophus ferrumequinum* in the north-eastern part of the Carpathian Basin.

Discussion

The obtained results suggest that, in all probability, a separate and nearly closed population of *Rhinolophus ferrumequinum* exists in the investigated area. As a consequence of the seasonal movements, strong permanent contact exist between the roosts in the Zemplén Mts (Hungary) and in south-eastern Slovakia. No data was found if bats moved between them and other distant colonies. The main roosts in the Bomboly mine, the Jasov cave and the two Hungarian churches form the basis of the population.

There are no other greater horseshoe bat colonies east and south from the study area: the nearest colonies are west from this population (Boldogh and Gombkötö 1996). Bat banding, however, indicated the existence of another population in the Bükk Mts, Aggteleki–karszt and Slovensky kras (Boldogh and Gombkötö 1996). The borders of these populations are in contact, but this study found no evidence that animals moved between them. Further, more distant summer colonies

situated 80 km south from the population no. 5 (Fig. 1), have significant contacts with the caves in Romania (Dobrosi 1998).

The results suggested that the greater horseshoe bats form a metapopulation in the study area. The study population inhabited a well determinable region. It is a characteristic of the metapopulation that the geographical situation of the component populations changes from time to time. The study population now living in an area of 5180 km^2, consists of 350 individuals, but it increases up to 500 after the juveniles are able to fly. This indicates a bat density of 0.05 specimens per 1 km^2. Stebbings and Arnold (1989) estimated 0.06 individuals of this species per square km in southern Great Britain. These low densities are explained by the very few underground roost possibilities. This region is suboptimal from the point of view of winter roost availability. The fact that bats migrate from here to longer distances away (60–80 km) than in other regions (20–30 km) also indicate the suboptimality.

This leads to the conclusion that greater horseshoe bats living in the investigated region (population no. 4) should be treated as a homogeneous unit. Therefore, the efficient protection of the bats can be achieved only by the protection of all known roosts.

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