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Seasonal and regional scale movements of horseshoe bats (*Rhinolophus*, *Chiroptera*: *Rhinolophidae*) in northern Bulgaria

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With 5 Figures

Abstract

We studied the movements of three species of horseshoe bats (*Rhinolophus ferrumequinum*, *R. euryale* and *R. mehelyi*) in northern Bulgaria in the years 2001-2009. About 1,500 horseshoe bats were marked mostly at a single cave roost used as maternity colony. Most recaptures were done at the ringing site or at a few alternative roosting sites in the close surroundings. Greater horseshoe bats (*R. ferrumequinum*) moved in autumn and winter to other caves in mean distances of 60 km and a maximum of 90 km towards the Balkan mountains. While the mean distances of hibernacula from the summer colony were significantly larger in males than in females, no significant differences were found between adult and subadult bats of each sex. In the two other horseshoe bat species several long distance movements could be detected, too. The Mediterranean horseshoe bat (*R. euryale*) changed roosts in distances of up to 60 km, while in the little studied Mehely's horseshoe bat (*R. mehelyi*) long distance movements of more than 90 km could be documented for the first time.

Zusammenfassung

Saisonale und regionale kleinräumige Bewegungen von Hufeisennasenarten (*Rhinolophus*, *Chiroptera*: *Rhinolophidae*) in Nordbulgarien

Ergebnisse einer achtjährigen Beringungsstudie in Nordbulgarien an drei Fledermausarten: Großhufeisennase (*Rhinolophus ferrumequinum*), Mittelmeer-Hufeisennase (*R. euryale*) und Mehely-Hufeisennase (*R. mehelyi*) werden vorgestellt. Dabei wurden knapp 1.500 Hufeisennasen vor allem an einer als Wochenstube genutzten Höhle markiert. Der Großteil der Wiederfänge erfolgte am Beringungsort oder an nahe gelegenen Ausweichhangplätzen. Zur Überwinterung wanderten die Großhufeisennasen im Mittel knapp 60 und maximal 90 km in Richtung Balkan-Gebirge. Während die ♂♂ signifikant größere Entfernungen zwischen Sommerhangplatz und Winterquartieren als die ♀♀ zurücklegten, gab es keine signifikanten Unterschiede zwischen Adulten und Jungtieren innerhalb eines Geschlechts. Für die beiden anderen Hufeisennasen-Fledermäuse wurden ebenfalls weite Überflüge verzeichnet. Die Mittelmeer-Hufeisennase wechselte Quartiere in Entfernungen von bis zu 60 km. Bei der bislang wenig untersuchten Mehely-Hufeisennase konnten erstmals Wanderungen von über 90 km dokumentiert werden.

Key words: *Rhinolophus ferrumequinum*, *Rhinolophus euryale*, *Rhinolophus mehelyi*, seasonal movements, recapture probability.

1 Introduction

Five species of horseshoe bats (*Rhinolophidae*) occur in Europe. Two of them, the greater (*Rhinolophus ferrumequinum* – fig. 1) and the lesser (R. *hipposideros*) horseshoe bat are or have been distributed over most parts of southern and central Europe, while the other three species (*R. mehelyi* – fig. 2, *R. euryale* – fig. 3, *R. blasii*) are confined, as far as their European distribution is concerned, to the Mediterranean and adjacent southern areas (Mitchell-Jones et al. 1999). All five species are relatively common in Bulgaria and greater and lesser horseshoe bats belong to the most abundant species of the country (Benda et al. 2003).

While greater and lesser horseshoe bats are well studied in most respects of their ecology (Gaisler 1960a, 1960b, 1963, 1965, Gaisler & Titlbach 1964, Ransome 1968, 1971, 1973, 1989, 1998, 1999, McAney & Fairley 1988a, 1988b, 1989, Ransome & Hutson 2000, Bontadina et al. 2002), the biology of the three medium-sized species is much less known. The Mediterranean horseshoe bat (*R. euryale*) has been studied mainly in Italy and the Iberian peninsula (Dinale 1963, 1967, Russo et al. 2001, 2002, Aihartza 2003, Goiti et al. 2003, 2004, 2006), while only few biological studies on *R. mehelyi* are published (Russo et al.

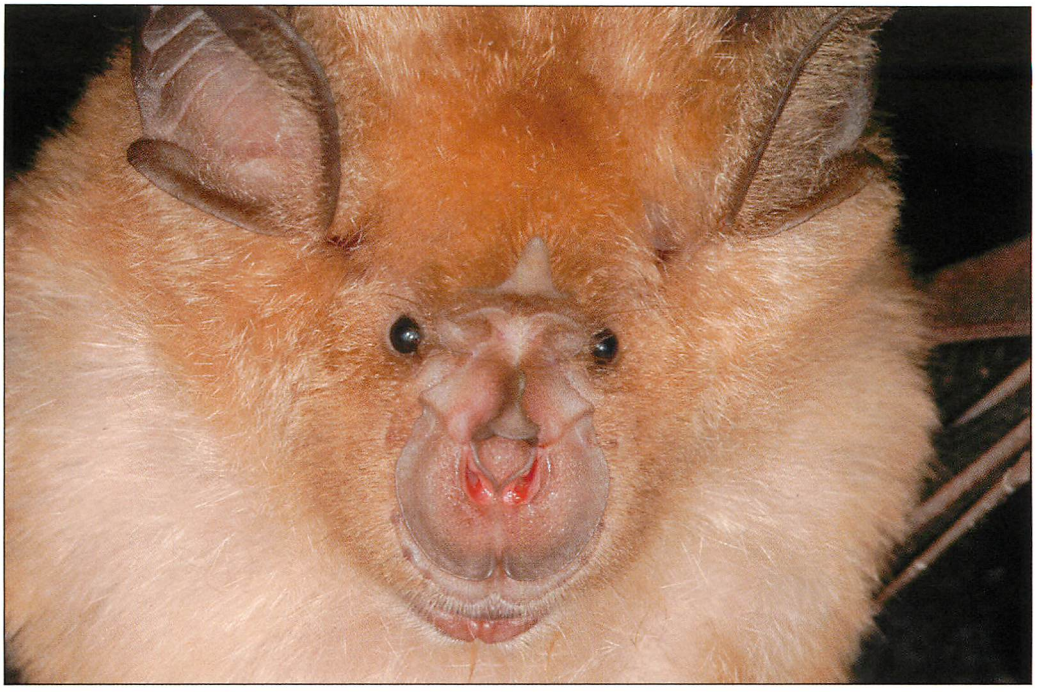

Fig. 1. Portrait of a several years old Greater Horseshoe Bat (*Rhinolophus ferrumequinum*). - Porträt einer mehrjährigen Großhufeisennase (*Rhinolophus ferrumequinum*). Alle Aufn.: Dr. C. Dietz

Fig. 2. Portrait of a Mehely's Horseshoe Bat (*Rhinolophus mehelyi*). - Porträt einer Mehely-Hufeisennase (*Rhinolophus mehelyi*).

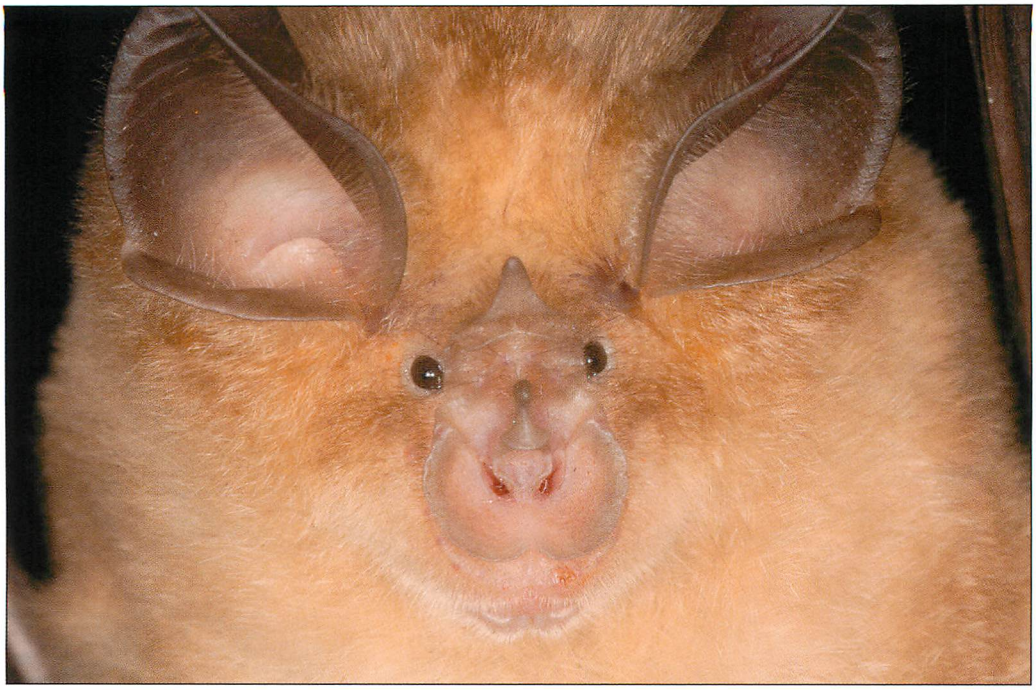

Fig. 3. Portrait of a Mediterranean Horseshoe Bat (*Rhinolophus euryale*). -Porträt einer Mittelmeer-Hufeisennase (*Rhinolophus euryale*).

2005). Numerous observations on seasonal movements of *R. ferrumequinum*, *R. hipposideros* and *R. euryale* were collected by the pioneers of bat banding (Mislin 1945, Issel 1951, Bels 1952, Hooper & Hooper 1956, Issel & Issel 1960, Kepka 1960, Beaucournu 1963, Dinale 1963) and many scientists have contributed to improve the knowledge since. All three species are regarded as mostly sedentary (Gaisler & Hanák 1969a, 1969b, Roer 1965). However, very few observations deal with Mehely's (*R. mehelyi*) and Blasius' (*R. blasii*) horseshoe bats (e. g. Paunović 1997a, 1997b). There are hardly any data available on movements of horseshoe bats from the Balkans, the only part of Europe where all five species occur in sympatry (Dulić 1957, Paunović 1997a, 1997b, 1998).

The aim of our study was to obtain data on regional and seasonal movements of one of the most abundant Bulgarian bat species, *R. ferrumequinum* and two of its congeners *R. euryale* and *R. mehelyi*. Bats were marked and recaptured mostly within the course of studies on reproductive biology (Dietz et al. 2007a), morphology (Dietz et al. 2006a), echolocation behaviour (Siemers et al. 2005) and foraging ecology and feeding behaviour (I. Dietz, unpublished).

2 Material and Methods

Our study site was the hilly karst-area between the lowlands of the Danube and the Balkan mountains in Northern Bulgaria (fig. 4, 5). Bats were marked in the years 2001-2004 at sites around the village Muselievo in the Osăm valley (near the town Nikopol, District Pleven, 43°37'N, 24°51'E), about 10 km south of the river Danube. Most of the bats were captured at a single cave (Nanin Kamăk) inhabited by a colony of up to 1,000 bats (*R. ferrumequinum*, *R. mehelyi*, *R. euryale*, *Myotis capaccinii*, *M. emarginatus* and *Miniopterus schreibersii*). Some more bats were marked in the surroundings of Muselievo in alternative roosting sites of the colony in several small caves or in night roosts and foraging sites.

At the main study site (cave Nanin Kamăk) and in its close surroundings bats were captured during 132 capture nights by mist nets, harp traps (PALMEIRIM & RODRIGUES 1993) and by so called "doll-hair nets" at the roost entrances and at a few occasions by hand-nets inside the roosts. Caves, buildings and night roost in a 15 km radius around the study site were checked regularly for the presence of bats and if possible marked bats were captured. In the years 2001-2009, caves in a distance of up to 100 km were visited during the summer season and checked for marked bats in a total of 57 excursions. In addition all known colony sites of horseshoe bats have been inspected during transition time end of September/beginning of October in a 100 km radius around the study site. The Bulgarian Bat Research and Protection Group carried out winter censuses and a survey for marked bats in all hibernacula known to be used by high numbers of horseshoe bats.

Captured bats were identified by characters of the nose-leaf and the lower lip (DIETZ & VON HELVERSEN 2004, DIETZ et al. 2007b). To mark the bats individually, we used 2,9, 3,5 and 4,2 mm flanged metal bat rings (manufactured by Lambournes Ltd., Leominster, Herefordshire, UK; rings used in 2001; and by Porzana Ltd., Wetland-Trust, UK; rings used in 2002-2004). Effects of the banding method on the bats (ring injuries) were discussed in a separate publication (DIETZ et al. 2006b).

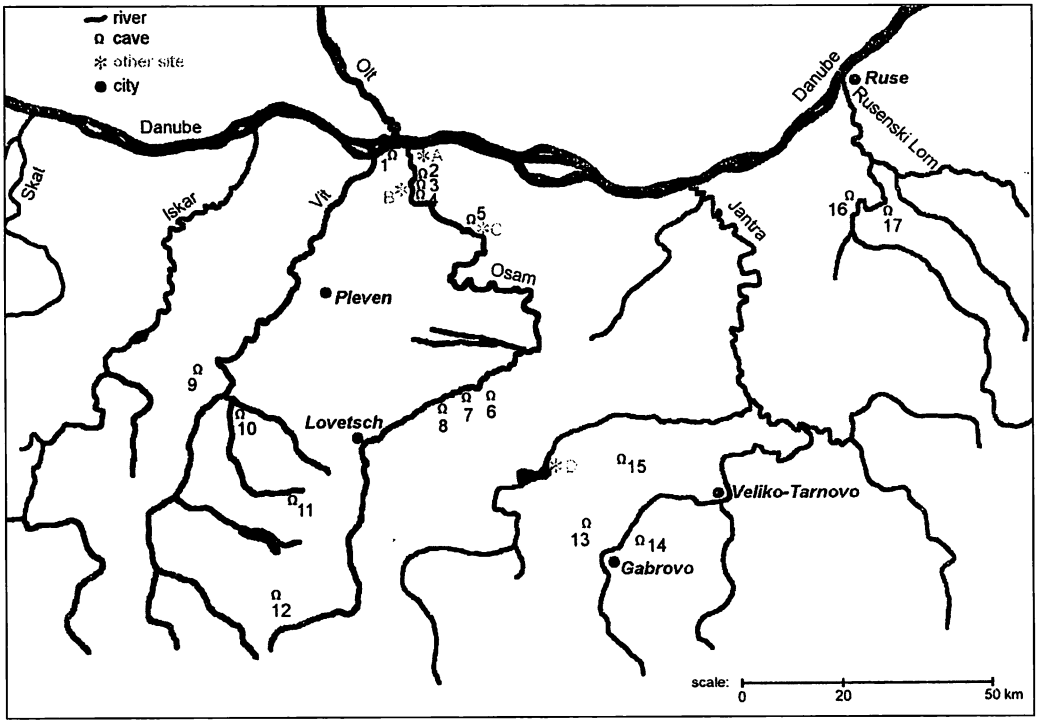

Fig. 4. Map of the study site in northern Bulgaria showing the main river systems and the recapture sites of three species of horseshoe bats. Numbers refer to caves, letters to other recapture sites (bridges, buildings and dams). – Karte des Untersuchungsgebietes in Nordbulgarien mit den größeren Flüssen und den Wiederfangorten von drei Hufeisennasen-Fledermausarten. Nummern bezeichnen Höhlen, Buchstaben andere Wiederfangorte (Brücken, Gebäude, Staudämme).

1 – underground gallery near Somovit, 2 – cave Morenitza, 3 cave Nanin Kamăk, 4 – cave (twin cave) near Muselievo, 5 – small mine near Sanadinovo, 6 – Uruška Maara cave, 7 – Mandrata cave, 8 – Devetaškata Peštera cave, 9 – Sedlarkata cave, 10 – Parnitcite cave, 11 – Mikrenska Peštera cave, 12 – Mecha dupka cave, 13 Machanov trap, 14 – Anduka Peštera cave, 15 – Emenskata Peštera cave, 16 – Orlova Čuka cave, 17 – Zorovica Peštera cave, A – bridge near Nikopol, B – farm building near Muselievo, C – building in Sanadinovo, D – dam of Alexander Stamboliiski reservoir.

Fig. 5. Typical aspect in the North of Bulgaria: the prebalkan hills form a karstic landscape. The land use of plain and the plateau is dominated by an intensive agriculture, while the slopes were used for grazing sheep and goates until recently. - Typische Landschaft im bulgarischen Donauhügelland mit aus Kreidekalken aufgebauter Karstlandschaft. Die Ebenen und Hochflächen werden intensiv landwirtschaftlich genutzt, die mageren Hangbereich dienten bis vor wenigen Jahren als Weideflächen.

Field work was carried out under licence of the responsible Bulgarian authorities (15-RD-08/15.01.2001, 48-00-56/16.01.2001, 8/02.07.2004 RIOSV Pleven, RIOSV Ruse).

3 Results

3.1 Influences on recapture rate

The horseshoe bats learnt quickly how to avoid nets and traps. While it has been very easy to capture large numbers at the roost entrances with two-framed harp-traps or normal mist nets within the first two months of the study period, it got more and more complicated to capture any bats toward the end of the study. To prevent horseshoe bats from simply crushing through the harp-trap we had to use six frames in the end and it was impossible to catch bats with mist nets anymore. The use of the eastern-German "doll-hair nets" improved capture success for several instances, but the horseshoe bats quickly learned to avoid them, too. While in the beginning 85-90 % of the horseshoe bats leaving the entrance were trapped, in the end only 1-5 % of the approaching bats became entangled in nets or the trap, paralleled by a steady increase of bat activity in front of the nets. The horseshoe bats hovered in front of the capture devices and escaped through holes in the nets and through broken wires of the harp trap (the capture success in *Myotis* spp. and *Miniopterus* was also reduced, but to a much lesser degree). In 2003 and 2004 after having marked approximately 1,500 bats, about 70-80 % of the adult horseshoe bats in the colony at cave Nanin Kamăk carried rings (counted from photographs in the colony); however, the proportion of marked bats in captures at the two entrances of the cave never exceeded 44,2 % and averaged at 32 %. So the capture probability was very much biased towards individuals never captured before, while "experienced" bats were captured in lower numbers. In 2006, after not having been there for 22 months, the proporti-

on of marked bats among the captures rose to 51,3 %, indicating that at least some of the marked bats lost their mistrust within the meantime.

Recapture success was also low in sites other than the ringing place: Only about 50 % of the observed bats with rings could be captured in night-roosts and alternative day roosts. At other colony- and breeding sites ringed bats could be observed in many instances by binoculars, but usually we could not read the ring numbers and we were unable to catch the bats either because of the height of the roosting site (up to 30 m above the ground) or because they were roosting within huge mixed clusters of several thousand bats (especially *R. euryale* and *R. mehelyi*). This applies especially for reproducing females: a total of 14 marked bats was observed together with attached young in caves of the Osăm-valley (caves Devetaškata Peštera, Mandrata and Uruška Maara) 40-45 km south of the ringing place without having a possibility to capture them, in only four bats the first part of the ring number could be read on photographs. In early spring, autumn and winter recapture success in torpid *R. ferrumequinum* was quite high; more than 90 % of the observed bats could be captured. But in autumn and sometimes also in Winter the medium-sized horseshoe bats formed very densely packed clusters of torpid bats, a so called "wall-carpet" or "tapestry". It was impossible (without irresponsible disturbance) to search such dense clusters of many hundred to several thousand medium-sized horseshoe bats for rings, because most of the forearms and even most of the wrists were not visible.

Despite the attempt to visit all known large colony sites in a hundred kilometre radius around the ringing site there was a heavy bias in the probability to recapture bats: no sites in Romania have been checked for ringed bats (no colonies are known within the radius of focus), the Bulgarian sites have been checked quite irregularly, many colony sites (especially smaller ones) might be unknown and no systematic search could be done outside the 100 km radius at all. The strong bias of surveyed possible recapture sites, the observed interactions between many colony sites (see recaptures) an the low recapture rate in *R. euryale* and *R. mehelyi* do not allow to draw conclusions on population size. Favoured direction, mean distance of movements, survival and return probability can not be derived from our data as recapture sites were not evenly distributed but predefined by known roost sites, furthermore individual recapture probability has been biased. Especially the bias in low individual recapture probability due to high agility and quick learning of how to avoid getting trapped seems to be specific for horseshoe bats, at least comparable problems have not been found neither in published nor in our own studies on vespertilionid bats.

3.2 Recaptures

The number of marked and recaptured bats is given in table 1. Recapture rates vary strongly between the species, as well as between sexes and age classes. Of 1,255 marked greater horseshoe bats 541 have been recaptured between on to eight times, in total 857 times: 596 recaptures at the banding site, 172 within a 15 km radius and 89 long distance recaptures (tab. 1). Mediterranean (n = 111) and Mehely's (n = 112) horseshoe bats have been marked in much lower number and we got only a few recaptures at other sites than the ringing place (tab. 1).

In *R. ferrumequinum* 383 juveniles were marked in 2001-2003. While the proportion of marked juvenile males and females and of the recaptures in the same year did not differ significantly from an equal distribution, recapture rate of females was highly significantly bigger in the following years [180 marked juvenile males and 203 juvenile females (108:2003): $Chi^2 = 1.3812$, $p = 0.2399$, same year recaptures (30:38): $Chi^2 = 0.9412$, $p = 0.3320$, following years recaptures (7:61): $Chi^2 = 42.8824$, $p < 0.0001$, comparison of marked bats and same year recaptures: Chi^2 with Haber-correction = 0.1566, $p = 0.6923$, comparison of marked bats and following years recaptures: Chi^2 with Haber-correction = 31.4641, $p < 0.0001$]. While the recapture rate

Table 1. Marked and recaptured horseshoe bats (*Rhinolophidae – Rhinolophus*) in northern Bulgaria. - Markierte und wiedergefangene Hufeisennasen (*Rhinolophidae – Rhinolophus*) in Nordbulgarien

	n banded (♂♂, ♀♀)	n individuals recaptured (♂♂, ♀♀)	n total recaptures	max individual recaptures	n recaptures at banding site	n short distance recaptures (< 15 km)	n long distance recaptures (> 15 km)
Rfer	1255 (213, 1042)	541 (51, 490)	857	8	596	172 (128 ind.)	89 (69 ind.)
Reur	111 (26, 85)	39 (8, 31)	57	4	36	12 (8 ind.)	9 (8 ind.)
Rmeh	112 850, 62)	62 (26, 36)	88	4	66	17 (11 ind.)	5 (5 ind.)

Rfer – Rhinolophus ferrumequinum; *Reur – R. euryale*; *Rmeh – R. mehelyi*

of juveniles and adults in the same year did not differ significantly, recapture rate of juveniles in the following years was much lower than of adults [Chi^2 with Haber-correction = 18.6459, $p < 0.0001$]. In *R. euryale* (30 juveniles marked, 8 recaptures in the same and 4 in the following years) and *R. mehelyi* (7 juveniles marked, 2 recaptures in the same and 1 in the following years) sample size were too small for statistical analysis.

3.3 Movements

Most of the bats were recaptured at the initial ringing site or in its close surroundings within a 15 km radius (tab. 1). Telemetry studies on all three species have shown that the bats use alternative roosts and foraging sites within this radius; home-ranges and core foraging areas extended usually up to 10-15 km around the roosts (own unpublished data). Of the short distance recaptures, a high proportion concern movements between two alternative roost sites: *R. ferrumequinum* and *R. euryale* alternatively roosted in a small cave system ("twin cave") 1,8 km to the south and *R. mehelyi* in a different one (cave Morenitza) 0,6 km to the north of cave Nanin Kamăk. Accordingly, 150 movements could be documented between these alternative roosts in *R. ferrumequinum*, 5 in *R. euryale* and 16 in *R. mehelyi*. The other short distance movements were between night roosts, foraging habitats and day roosts during transition time in spring and autumn. The use of the two alternative roosts in horseshoe bats was paralleled by partial movements of other bat species inhabiting the same cave roost. The *M. emarginatus*-colony likewise moved between the same two caves used by *R. ferrumequinum* and *R. euryale* (own observations of several marked *M. emarginatus* and recapture of the female A 03262). The roost changes in *R. mehelyi* were followed by the partial movements of the *M. capaccinii*-colony (20 movements recorded by recaptures, own data). In the years 2001 and 2004, a small nursery colony of R. ferrumequinum was established in the basement of a school-building in the village of Sanadinovo, 15 km south of the cave Nanin Kamăk. It was used by a maximum of 13 breeding females in 2001, yet no bats were present in 2002 and 2003. In 2004, two out of the three breeding adult females carried rings and had been banded in the previous years at cave Nanin Kamăk, so the small colony could be regarded as a temporary satellite roost of the main colony.

A relatively small number of individuals was recaptured in distances of more than 15 km and up to 100 km; all records are given in table 2. In addition, two bats marked by other people have been captured; unfortunately it was not possible to get any information about the initial ringing sites and dates. In figure 1 the sites of the long-distance recaptures are given. They spread over a considerable part of the north-Bulgarian lowland towards the Balkan mountains. The longest movements recorded are 89.6 km in *R. ferrumequinum*, 58.8 km in *R. euryale* and 94.1 km in *R. mehelyi*.

Table 2. Recapture localities in more than 15 km distance from the ringing site (cave Nanin Kamăk) and recapture statistics. – Angaben zu weiter als 15 km vom Beringungsort (Höhle Nanin Kamăk) entfernt liegenden Wiederfangorten und statistische Daten zu den Wiederfängen

Locality	N	E	distance from main ringing site (km)	direction from main ringing site (°)	*Rfer*	*Reur*	*Rmeh*
small mine near Sanadinovo	43°33'	25°00'	15.1	142	10 ♀♀ ad	1 ♀ ad	-
Uruška Maara cave, Krušuna	43°15'	25°02'	44.9	160	5 ♀♀ ad 5 ♀♀ sad	6 ♀♀ ad	-
Mandrata cave, Aleksandrovo	43°14'	24°58'	43.8	169	1 ♀ ad	1 ♀ ad	-
Devetaškata Peštera cave, Devetaki	43°14'	24°53'	41.9	182	6 ♀♀ ad 4 unident.	-	-
Sedlarkata cave, Rakita	43°17'	24°18'	60.3	230	1 ♂ sad	-	-
Parnitcite cave, Bežanovo	43°12'	24°26'	58.8	218	1 ♂ ad 1 ♂ sad 6 ♀♀ ad 8 ♀♀ sad	1 ♀ sad	-
Mikrenska Peštera cave, Mikre	43°04'	24°31'	67.9	205	1 ♂ sad 7 ♀♀ ad 3 ♀♀ sad 1 unident.	-	-
Mecha dupka, Shipkovo	42°52'	24°28'	88.4	200	1 ♀ ad	-	-
dam of Alexander Stamboliiski reservoir	43°07'	25°10'	61.4	155	2 ♂♂ ad 2 ♀♀ ad	-	-
Machanov trap near Zdravkovets	42°58'	25°15'	80.8	156	1 ♀ ad	-	-
Anduka Peštera cave	42°56'	25°25'	88,7	148	1 ♂ ad	-	-
Emenskata Peštera cave, Emen	43°08'	25°22'	68.8	144	1 ♀ sad	-	-
Orlova Čuka cave, Pepelina	43°35'	25°58'	89.6	92	1 ♂ sad	-	2 ♂♂ ad 1 ♀ ad
Zorovica Peštera cave, Červen	43°36'	26°01'	94.1	93	-	-	1 ♀ ad 1 unident.

unident. - unidentified

3.4 Individual movements

The shortest observed duration for a long distance translocation were recorded in a non-reproducing nulliparous *R. euryale* (E 411102) between the caves Nanin Kamăk and Mandrata within 6 days (43,8 km in straight line, but more than 80 km according to telemetry data) and in a pregnant female *R. mehelyi* (E 411318) caught on 07.05.2003 at cave Nanin Kamăk and 19 days later, still pregnant, 94.1 km to the west at cave Zorovica Peštera. This bat had also been tagged by a radio-transmitter and left the cave Nanin Kamăk shortly after the in-

itial marking. Since it did not come back within the following two weeks, it might have changed the roost quite fast to the cave Zorovica Peštera, inhabited by a colony of more than 5,000 *R. mehelyi*. Both bats reproduced in the same or in the following years within other colonies than the one were they have been marked. In addition, the female *R. euryale* (E 411102) mentioned above, changed from the cave Mandrata to the cave Uruška Maara 5 km away 2002: while the cave Mandrata was inhabited by a colony of 50-200 *R. euryale* from 1999 to 2001 (BENDA et al. 2004, own data), the colony disappeared in 2002 due to the start of mushroom growing by villagers inside the cave paralleled by an increase in the number of *R. euryale* in the cave Uruška Maara to a maximum of about 1,000 individuals. Judging from the recapture of the banded *R. euryale* (E 411102) and the similar movement of a marked female *M. emarginatus* (A 03144), the disturbance by mushroom growing made at least parts of the Mandrata colony move to cave Uruška Maara.

Our recapture data of marked bats give only a very rough idea about the suspected complex movements of horseshoe bats, a fact illustrated by the following, and still fragmentary, recapture histories:

R. ferrumequinum N 00448 was marked as adult postlactating female in summer 2001 at cave Nanin Kamăk, found in the following winter hibernating in cave Parnitcite, 60 km to the southwest. In the following summer it was captured several times reproducing back at cave Nanin Kamăk. In September it was found in copula with a male in a small mine near Sumovit, 10 km northwest of cave Nanin Kamăk. In the following summer it was back and reproduced in cave Nanin Kamăk. It was only found three years later dead in the mine near Sumovit, killed together with more than 30 other bats by children.

The adult female *R. ferrumequinum* N 01176 was marked in spring 2002 at cave Nanin Kamăk and follwed by radio-telemetry for the next 6 days. The home-range covered at least 200 hectares, most of it north to the cave in distances of more than 10 km. The bat even crossed the Danube to forage in Romania and covered 2.0-2.5 km of open water. In the same summer it was recaptured in cave Nanin Kamăk and in a temporary day roost in a bridge 8 km north to the cave. In the following year it was found on 14.04.2003 in a mine near Sanadinovo and already the following day in a small cave system ("twin cave") 14 km further north, were it was recaptured two more times in summer 2003.

3.5 Seasonal movements between nurseries and hibernacula

A high proportion of the long-distance recaptures occurred during autumn (end of Sep-

Table 3. Distances of movements of horseshoe bats (*Rhinolophidae – Rhinolophus*) between the nursery colony (cave Nanin Kamăk) and hibernation sites. Abbreviations: f – female, m – male, ad – adult, subad – subadult. Statistics are given in the text. – Überflüge von Hufeisennasen (*Rhinolophidae – Rhinolophus*) zwischen der Wochenstube (Höhle Nanin Kamăk) und den Winterquartieren. Abkürzungen: f – Weibchen, m – Männchen, ad – adult. subad – subadult (= nicht reproduktiv)

Species	sex and age	distance of hibernacula from summer roost (km) mean +/- SD (n) min – max
R. ferrumequinum	♂ all	68.4 +/- 13.1 (8) 58.8-89.6
	♂ ad	67.6 +/- 14.1 (4) 58.8-88.7
	♂ sad	69.1 +/- 14.2 (4) 58.8-89.6
	♀ all	57.5 +/- 11.5 (42) 41.9-88.4
	♀ ad	57.9 +/- 13.1 (25) 41.9-88.4
	♀ sad	56.9 +/- 8.9 (17) 44.9-68.8
	all	58.8 +/- 12.0 (50) 41.9-89.6
R. euryale	all	44.9-58.8 (2)
R. mehelyi	all	89.6 (3)

tember, beginning of October) or in winter in caves. If the bats were already torpid and if the roosts were occupied by the same species in winter for hibernation, we counted these recaptures as movements to hibernacula, the distances between the nursery colony and the hibernacula are given in table 3.

In *R. ferrumequinum*, the distances covered towards the hibernacula were significantly larger in males than in females [Man-Whitney-U-test, U = 85.0, p = 0.0281]. Within the sexes no differences could be detected between subadult and adult bats [males: Man-Whitney-U-test, U = 7.5, p = 0.8838; females: Man-Whitney-U-test, U = 195.5, p = 0.8159]. It is quite obvious that most of the long distance recaptures were made in caves situated in the same or in neighbouring river systems of the initial ringing site. Our telemetry data also support the hypothesis that horseshoe bats use valleys and rivers as major flight paths to commute between different parts of their annual home range.

4 Discussion

The greater horseshoe bat is regarded as a sedentary species that rarely migrates longer distances (Roer 1995, HUTTERER et al. 2005). The longest movements of the species have so far been reported from Hungary (320 km: DOBROSI 1998) and Spain (180 km: DE PAZ et al. 1986 cited in SERRA-COBO & BALCELLS 1991). Our recorded distances are far below these records, but the proportion of relatively far travelled individuals in the hibernacula and the mean distance between nursery and hibernacula are much higher than usually found in the species (e. g. HOOPER & HOOPER 1956, ISSEL & ISSEL 1960, BROSSET & POILLET 1985, HUTTERER et al. 2005). However, like in other facultative migrant bats the distance of movements might depend mainly on the availability of suitable roosts for hibernation. E. g. in *Myotis dasycneme* from the plains on the Netherlands and Northern Germany migrate 200 km (up to 330 km) to the south to reach the caves and mines of the mountains (SLUITER et al. 1971), in contrast populations in Denmark are quite sedentary and move only small distances between their summer roosts and limestone caves (EGSBAEK et al. 1971). In our study area, the main site of nursery colony could be regarded as possible hibernacula as well, however all the bats left this place to hibernate somewhere else. Bats prefer to hibernate in caves with stable and low temperatures to spend the winter with lowest possible energy expenditure (RANSOME 1968, 1971, NAGEL & NAGEL 1991, WEBB et al. 1996), a fact that might explain, that horseshoe bats migrate to caves at higher altitudes and avoid hibernating in the Danube plain at low altitudes with relatively high roost temperatures. Due to the absence of caves in the Romanian part of the Danube plain, we expect those populations also to migrate to the caves of the Bulgarian Prebalkan. Most probably there exists a high gene-flow between horseshoe bats of different colonies inhabiting the lowland of northern Bulgaria: The bats spread over a considerably large area of several thousand square-kilometres for hibernation and copulations occurred regularly in late autumn in caves used for hibernation (own data), so a more or less panmictic population structure can be expected. During our study the knowledge of the whole territory used by the studied subpopulations increased strongly with the number of recapture data, accordingly we do not believe that a separation of several populations based on a limited number of recapture data is meaningful (contra BIHARI 2001).

In *R. euryale* and *R. mehelyi*, the recapture rate was too small to draw further conclusions, but the recorded distances clearly show that both species can cover large distances even within a short time. While movements of *R. euryale* of up to 134 km in France (HEYMER 1964) and 83 km in Italy (DINALE 1967) have been already reported, our Bulgarian recaptures of three *R. mehelyi* in distances up to 94.1 km represent the new record for this species.

Longest movements recorded

The longest movements recorded of the five horseshoes bat species in Europe are so far: *R.*

ferrumequinum – 320 km (DOBROSI 1998) and 180 km (DE PAZ et al. 1986 cited in SERRA-COBO & BALCELLS 1991), *R. hipposideros* – 152 km (HEYMER 1964), 150 km (BELS 1952) and 146 km (HARMATA 1992), *R. euryale* – 134 km (HEYMER 1964) and 83 km (DINALE 1967), *R. mehelyi* – 94 km (this study) and *R. blasii* – 6.4 km (PAUNOVIĆ 1997a, 1997b).

Conclusions

All three studied species spread over a considerable part of the north-Bulgarian lowland and Prebalkan area in the course of annual movements. While the majority of female *R. ferrumequinum* came back to the banding site for reproduction, several *R. mehelyi* and *R. euryale* changed the roosts and reproduced in other colonies. Based on similar observations in *R. euryale*, ANDERA & HORÁČEK (1982) assumed panmictic assemblies of several colonies. Our data show that the subpopulations of all three species seem to be well connected and therefore a high gene-flow is likely. For conservation it is important to maintain the interchange of colonies to guarantee a high gene flow between subpopulations. Protection measures should therefore also include migration routes, especially along rivers and the main hibernacula as meeting points and mating sites.

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