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Ecological Status of Bats (Chiroptera) in Winter Roosts in Eastern Fennoscandia

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Abstract—Data of field observations on bats hibernating in the Republic of Karelia (61°–63° N, 30°–36° E) are presented. Various bat winter roosts have been surveyed to reveal the species composition of the animals, the pattern of their spatial arrangement, mortality, and specific regional features and general trends of their hibernation. The results provide a more integrated feature of ecological adaptations of these mammals to the conditions of the North.

Keywords: ecology, bats, hibernation, abundance, mortality, eastern Fennoscandia

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A widespread means to save energy resources and maintain energy body balance during periods of food deficit and low ambient temperatures is to enter into a hypometabolic state. Such a mechanism for minimizing the energy cost of adaptation to the influencing environmental factor (Slonim, 1979) is characteristic of many mammals, either small (e.g., bats and the northern birch mouse *Sicista betulina* Pallas, 1775) or large (the brown bear *Ursus arctos* Linnaeus, 1758 and raccoon dog *Nectereutes procyonoides* Gray, 1834).

In bats, preferences for winter roosts are species-specific and vary between regions. The main criterion for choosing a certain roost is a favorable microclimate, primarily air temperature and humidity that prevent the animals from freezing and desiccation (Kuzyakin, 1950; Kalabukhov, 1985). A shortage in natural shelters with such conditions accounts for migrations of many species to new wintering sites as well as for their movement between several winter roosts and redistribution within the roosts (Mazing, 1990; Kokurewicz, 2004). Bats are known to prefer roosts with microshelters, including mechanically excavated adits and galleries with numerous grooves on the walls (Bondarenko, 2005). Artificially made grooves and cracks improve conditions for the animals and attract increasing numbers of bats to such winter roosts (Klawitter, 1984).

When conditions for hibernation are optimal, bats can regulate their energy expenditures, reducing them to a minimum (Kokurewicz, 2004), However, certain weather and physiological stimuli periodically make them awaken from hibernation, and the animals in such cases show various kinds of activity (move, eat, drink, mate, etc.).

Numerous publications are available on specific features of bat winter roosts in Europe, but only a few authors have characterized in detail the conditions of hibernation and the behavior of bats during this period (Strelkov, 1971; Siivonen and Wermundsen, 2008a; Wermundsen and Siivonen, 2010). Therefore, our research was focused on the winter ecology of vesper bats (Vespertilionidae) in the Republic of Karelia, where inhabited winter roosts have been found as far as 63° N. No such investigations have yet been made in this region of eastern Fennoscandia.

MATERIAL AND METHODS

Field studies were performed in the middle taiga subzone of southern Karelia (61°–63° N, 30°–36° E). Surveys were made of six underground winter roosts located at distances of 70 to 300 km from each other (Fig. 1), which have not been studied previously and are not mentioned in the special literature. In terms of Mazing's (1990) classification, they fall into categories of artificial caves (nos. 2, 3, 4, and 6) and lined tunnels (nos. 1 and 5). Caves in Sona (61°43′ N, 32°14′ E; near the village of Kolatselga, Pryazha district) and Shunga (62°35′ N, 34°55′ E; near the village of Shunga, Medvezhyegorsk district) were formed as a result of ore mining in the 19th century. Underground tunnels are up to 100 m long, with their heights and width averaging 1.0 and 1.5 m in the former and 3.0 and 3.5 m in the latter site. The Sona cave is flooded at the base all year round, and the Shunga cave is very dangerous and accessible only partially (in a 60-m segment), although water does not accumulate there. In Ruskeala (61°57′ N, 30°35′ E; near the village of Ruskeala, Sortavala dis-

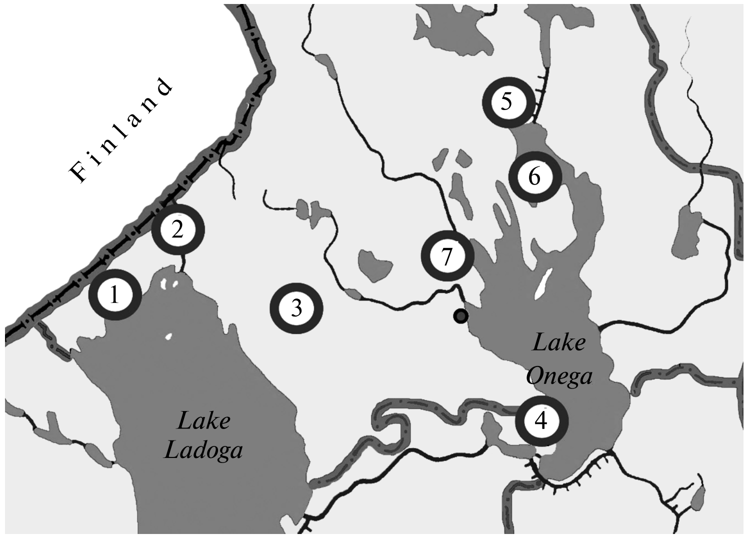

Fig. 1. Locations of underground bat winter roosts in Karelia: (1) Lahdenpohja, (2) Ruskeala, (3) Sona, (4) Shcheleiki, (5) Medvezhyegorsk, (6) Shunga (our censuses), (7) Conchozero (censuses by Strelkov, 1958).

trict), marble was extracted until 1954. The cave is 150 m long, 3.0 m wide, and up to 2.5 m high, with a permanent accumulation of water. In Sheleiki (61°07′ N, 35°40′ E; near the village of Gimreka, at the border of Karelia and Leningrad oblast), granite was extracted in the early 20th century. The cave is only 17 m long, its height and width are 1.8 and 1.5 m, respectively. Caves in Lahdenpohja (61°32′ N, 30°12′ E; near the village of Huuhkanmäki) and in the vicinity of Medvezhyegorsk (62°54′ N, 34°26′ E) are rock-cut vaults (530 and 380 m^2 in area, 4.5 and 3.0 m high) lined and paved with bricks or concrete, which have been used by the military until the 1980s–1990s. There are no permanent pools of water, and relative air humidity appears to be lower than in other caves.

Censuses of bats in winter roosts were taken in November to April (2009–2012) by surveying their entire area. In caves, special attention was paid to cracks and remains of boreholes (4–6 cm in diameter, 10–25 cm deep) left after mining of stone, which were located both on the walls and on the ceiling and entered the rock at different angles to the surface. In vaults, all internal surfaces were examined, including those in spaces between concrete or brick lining and bedrock.

Well-distinguishable species such as the brown long-eared bat (*Plecotus auritus* Linnaeus, 1758) and northern bat (*Eptesicus nilssonii* Keyserling, Blasius, 1839) were identified visually. Mouse-eared bats (*Myotis*) were examined for the pattern of wing membrane attachment to the leg, which is the main character allowing their species identification in the field. Differentiation between the Brandt's bat (*Myotis brandtii* Eversmann, 1845) and whiskered bat (*M. mystacinus* Kuhl, 1819) was made only in males, based on the shape of the penis (Strelkov and Buntova, 1982; Kozhurina, 1997; Schober and Grimmberger, 1997). Some specimens, including those of the Daubenton's bat (*M. daubentonii* Kuhl, 1819), were species-identified during analysis of craniological material. The remaining bats of this genus were phenotypically similar and, hence, were attributed to the mixed *M. brandtii/mystacinus* group, as in the study by Siivonen and Wermundsen (2008a). Bats that died during hibernation were collected and examined in the laboratory. On the whole; we recorded 121 bats, and additional data on Lahdenpohja (2002–2003) were provided by V.Yu. Kusakina (personal communication); thus, the total sample size was 125 ind. Censuses in Medvezhyegorsk and Shunga were taken only once; in Sona, twice (in the spring and late autumn of 2012); in caves with higher abundance and diversity of bats, several times over 3–4 years (Table 1).

The data were processed by conventional methods of variation statistics (Ivanter and Korosov, 2003).

RESULTS AND DISCUSSION

Data on the bat fauna of Karelia obtained in the mid-20th century are scarce. These are mainly the results of single summer observations showing that the region is inhabited by *M. brandtii/mystacinus*, *M. daubentonii*, *P. auritus*, and *E. nilssonii*. The same follows from subsequent information about summer sightings of bats, which is also fragmentary (Korosov, 2007). Winter censuses of bats were taken by Strelkov (1958) in the cave near the village of Konchozero (no. 7 in Fig. 1; 62°08′ N, 33°59′ E), where the author recorded one *M. daubentonii* and four *M. brandtii/mystacinus* bats. No more data on bats wintering in Karelia have been obtained since then, and relevant information from Murmansk oblast is unlikely to

Table 1. Abundance of bats in winter roosts in southern Karelia

Underground shelters	Recorded number of bats*			
	2009	2010	2011	2012
Lahdenpohja**	4 *E. ni*	1 *P. au*, 7 *E. ni*	3 *E. ni*	4 *E. ni*
Ruskeala		2 *M. br*, 1 *M. br/my*, 20 *E. ni*	2 *M. br*, 4 *M. br/my*, 19 *E. ni*	1 *M. da*, 1 *M. br/my*, 17 *E. ni*, 1 ND
Sona				8 *E. ni* (spring); 3 *M.br/my*, 1 *M. my*, 2 *E. ni* (autumn)
Shcheleiki	3 *M. br*, 3 *M. br/my*, 1 *P. au*, 3 *E. ni*	1 *P. au*, 2 *E. ni*	2 *E. ni*	2 *P. au*, 1 *E. ni*
Medvezhyegorsk		1 *E. ni*		
Shunga		1 *E. ni*		

* Designations: *M. br*, *Myotis brandtii*; *M. my*, *Myotis mystacinus*; *M. br/my*, *Myotis brandtii/mystacinus; M. da*, *Myotis daubentonii*; *P. au*, *Plecotus auritus*, *E. ni*, *Eptesicus nilssonii*; ND, not determined.

** One *E. nilssonii* and two *P. auritus* bats were recorded in 2002, and two *E. nilssonii* bats, in 2003 (V.Yu. Kusakina, personal communication).

come up, since almost all its territory lies beyond the Arctic Circle.

The results of our censuses of bats in winter roosts showed that at least five species hibernated there: *M. brandtii* (5.6% of the total recorded number), *M. mystacinus* (0.8%), *M. daubentonii* (0.8%), *P. auritus* (4.9%) and *E. nilssonii* (78.2%). Some animals were attributed to the *M. brandtii/mystacinus* group (9.7%). The observed species ratio markedly differs from those reported for southeastern Finland (Siivonen and Wermundsen, 2008a), northern Leningrad oblast (Strelkov, 1958) and northern Arkhangelsk oblast (Rykov, 2008). The differences are as follows (Fig. 2): winter bat communities at latitudes below 61° N are dominated by species of the genus *Myotis*, with their relative abundance reaching 64.8% in Leningrad oblast and 74.0% in Finland; the proportion of *P. auritus* in Karelia is low (4.9%), as in Finland (4.0%), whereas that in Leningrad oblast reaches 32.1%; *E. nilssonii* is absolutely dominant in Karelia (78.2%), but its proportion proved to be still higher (over 98%) in Arkhangelsk oblast, in the vicinity of Pinega Nature Reserve (64°33′ N, 43°11′ E), where two *M. brandtii* bats were also recorded (Rykov, 2008).

Data on the wintering of bats in more southern regions of Russia and in Estonia (Fig. 2) generally confirm the general pattern of latitudinal change in the species structure of bat communities: below 61° N, four to five *Myotis* species are obviously dominant while the relative abundance of *E. nilssonii* is low, but the latter species gains dominance at higher latitudes. The distribution of *P. auritus* in winter roosts is also illustrative: the relative abundance of this species reaches a peak in Leningrad oblast (59°–60°30′ N), where it is equally high in natural caves (32.1%) and concrete-lined vaults (37.5%) (Strelkov, 1958; Chistyakov, 2009), and decreases both southward (in Tver and Samara oblasts, 53°–56° N) and especially northward, in southern Finland and Karelia (60°30′–63° N) and Arkhangelsk oblast (64°33′). In Estonia (57°–59° N), the proportion of *P. auritus* was found to be markedly higher in small and medium-sized caves than in large caves: 31.1 vs. 12.2% (Mazing, 1990).

The distribution range of bats in summer is significantly wider, compared to that inferred from data on winter roosts. Summer censuses taken in Finland using electronic tags have shown that *M. daubentonii* is widespread and regularly occurs at latitudes of up to 64°52′ N, but its range at 66°14′–66°41′ N is limited to river valleys (Siivonen and Wermundsen, 2008b); *M. brandtii/mystacinus* occurs up to 66°21′ N; *P. auritus,* up to 64°25′ N; and *E. nilssonii*, up to 66°16′ N. According to other authors (Rydell et al., 1994; Speakman et al., 2000), the summer range of *E. nilssonii* in Norway, Sweden, and Finland extends northward to 69°–70° N. Stebbings and Griffith (1986) have shown that the northern range boundary of the pond bat (*Myotis dasycneme* Boie, 1825) passes in southern Sweden and southernmost Finland at about 60° N; that of *M. daubentonii* extends markedly farther north, to southern Norway; and that of *P. auritus* lies at about 63° N. Single *P. auritus* and *E. nilssonii* bats have been sighted in summer beyond the Arctic Circle in Murmansk oblast and, along with *M. daubentonii*, north of Lake Onega in Karelia (Kuzyakin, 1950; Bobrinskii et al., 1965; Semenov-Tyan-Shanskii, 1982; Bogdarina and Strelkov, 2003).

The composition and ratio of bat species hibernating in Karelia markedly differed between winter roosts (Table 1), but *E. nilssonii* dominated both in caves and in artificial underground structures. In the latter, *E. nilssonii* was also found to be dominant in the Karelian Peninsula (Leningrad oblast), where its relative abundance reached 53.1% (Chistyakov, 2009). This species occurred every year in all winter roosts surveyed in this study (1–20 ind. in each); *M. brandtii/mystacinus*, in three caves (2–6 ind.), but not regularly; *P. auritus*, in one cave and one concrete under-

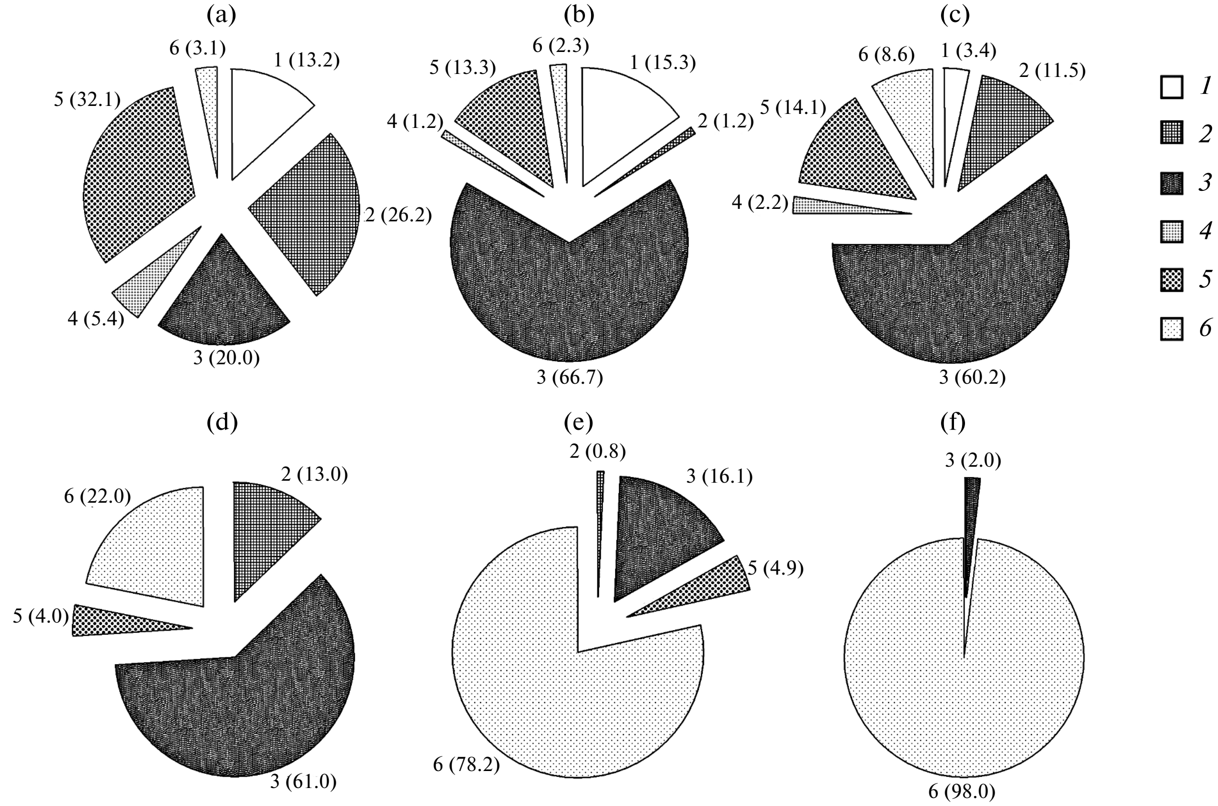

Fig. 2. Species composition of bats in winter roosts (percentages of the total recorded numbers): (a) Leningrad oblast (Strelkov, 1958), (b) Tver oblast (Glushkova et al., 2006), (c) Samara oblast (Smirnov et al., 2012), (d) Finland (Siivonen and Wermundsen, 2008a), (e) Karelia (our data), (f) Arkhangelsk oblast (Rykov, 2008); (*1*) *M. dasycneme*, (*2*) *M. daubentonii*, (*3*) *M. brandtii/mystacinus*, (*4*) *M. nattereri*, (*5*) *P. auritus*, (*6*) *E. nilssonii*.

ground shelter (1–2 ind.), also not regularly; and *M. daubentonii* and *M. mystacinus* were found only once, with the former bat being already dead. A specialist from the Ruskeala Mountain park, where one of the caves is located, reported that only *P. auritus* bats hibernated in this cave in the winter of 2005 and that every summer a pair of bats could be seen foraging over an artificial pond (about 0.5 ha in area) at the cave entrance, occasionally touching the water surface. Judging from their behavior, these probably were *M. dasycneme* or *M. daubentonii*. The absence of permanent pools of water in some winter roosts accounts for low air humidity, which obviously has an impact on their occupancy by bats (Smirnov et al., 2008; Lesinski, 1986; Siivonen and Wermundsen, 2008a, 2008b).

The spatial distribution of bats markedly differed between winter roosts of different types. In artificial shelters, 90% of animals were found on the walls, 1 m above the floor, with half of them concentrating at the junction with the ceiling; 20% were in spaces behind the concrete lining, on both concrete and bedrock surfaces; and only 10% were on the ceiling. In caves, two-thirds of bats roosted on the walls, usually at least 1 m above the ground, while the remaining one-third were on the ceiling, and most of the latter (66.7%) preferred open places, avoiding numerous boreholes. However, as follows from Table 2, the distribution pattern of some species had certain specific features that have also been observed in caves of the Urals (Bol'shakov et al., 2005) and artificial caves of the Samarskaya Luka (Smirnov et al., 2008), which are located much farther south (Fig. 3). In particular, pairwise comparisons of this pattern between artificial caves in Karelia (see Table 2) showed that *Myotis* bats preferred roosting on the walls rather than on the ceiling ($\chi^2 = 65.6$, $p = 0.01$) and in boreholes rather than in open places ($\chi^2 = 11.2$, $p = 0.01$), whereas *E. nilssonii* were found mainly in the open ($\chi^2 = 32$, $p = 0.01$); *Myotis* bats usually roosted in groups of 2–4 ind. ($\chi^2 = 18.3$, $p = 0.01$), whereas *E. nilssonii* occurred mainly as singles ($\chi^2 = 63$, $p = 0.01$). In contrast, the majority of *E. nilssonii* bats found in old underground concrete bunkers in Finland (60.8%) preferred roosting in cracks on the walls (Wermundsen and Siivonen, 2010).

The death of bats during hibernation was observed only in the larges artificial cave in Ruskeala, where 68 bats were recorded over 3 years. Among them, five bats (7.4%) were found dead, including three *E. nilssonii* (4.4%), one *M. brandtii* (1.5%), and one *M. daubentonii* (1.5%). Mortality among all bats recorded over the observation period ($n = 125$) was 4%; among 97 *E. nils-*

Table 2. Distribution of bats within winter roosts in artificial caves (percentages of the total numbers of conspecific bats recorded during censuses)

Distribution pattern	*Myotis* bats (*M. brandtii*, *M. mystacinus*, *M. daubentonii*) (*n* = 21)	*Plecotus auritus* (*n* = 4)	*Eptesicus nilssonii* (*n* = 74)	Total (*n* = 99)
On the walls:	90.5	75.0	58.1	65.7
in open places	33.3	–	40.5	37.4
in boreholes	57.2	75.0	17.6	28.3
On the ceiling:	9.5	25.0	41.9	34.3
in open places	–	25.0	37.8	29.3
in boreholes	9.5	–	4.1	5.0
CT:				
single individuals	28.6	100.0	89.7	79.8
pairs	9.5	–	10.3	9.7
groups	61.9	–	–	10.5

sonii bats, 3.1%; and among 21 *Myotis* bats of three species, 9.5%. All six *P. auritus* bats were recorded alive.

The winter seasons of 2010–2012 were characterized by frequent and sharp weather changes, with monthly average temperatures in December to March markedly deviating from long-term average values (by 7.1°C during cooling and 6.8°C during warming), which is generally typical for the climate of Karelia. Dead bats were found in the middle of March 2010 and 2012 but not in early February 2011. Although this series of observations is insufficient for any definite conclusions, it may well be that bats die mainly at the end of the winter season (March–April), as suggested by Strelkov (1965). Data on the mortality of bats in other winter roosts are very scarce and concern only single death cases (Strelkov, 1965; Merzlikin, 2002; Anufriev, 2007).

The wintering of bats under severe natural conditions of the north is possible due not only to the availability of suitable winter roosts and the choice of optimal roosting places within them but also to specific physiological features of these animals, which can control their metabolic level and reduce it during hibernation to only 0.2–0.4% of that in active state (Anufriev and Revin, 2006). Moreover, recent data on the concentrations of alpha-tocopherol in the organs and tissues of *M. brandtii*, *P. auritus*, and *E. nilssonii* wintering in Karelia show that the level of this vitamin is higher in *E. nilssonii*, the most winter-hardy species (Il'ina et al., 2011). This may be evidence that vitamin supply to bats at the end of hibernation is adequate for coming breeding season.

Thus, the core of bat fauna in Karelian winter roosts consists of widespread, resident boreal species: *M. brandtii*, *P. auritus*, and *E. nilssonii*. Other mouse-eared bats (*M. mystacinus* and *M. daubentonii*) are much more rare, with the occurrence of *M. dasycneme* and the Natterer's bat (*M. nattereri* Kuhl, 1818) has not yet been confirmed even in summer. European nemoral species are unlikely to winter in Karelia (Bogdarina and Strelkov, 2003). All the above species occur in southern Finland; in addition, a single case of wintering of the parti-colored bat (*Vespertilio murinus* Linnaeus, 1758) was recorded in Leningrad oblast, at the border with Karelia (Novikov et al., 1970; Siivonen and Sulkava, 1999; Siivonen and Wermundsen, 2003). Apparently, the list of bat species wintering in Karelia is expanding.

The species diversity of bats in summer is markedly higher: this parameter in Finland and Leningrad oblast reaches 11 species (Bogdarina and Strelkov, 2003; Siivonen and Sulkava, 1999; Siivonen and Wermundsen, 2003), but half of them have not been recorded in Karelia, where climatic conditions are more severe. A comparison of these data with the results obtained in central and southern regions of Russia (Strelkov and Il'in, 1990; Zolina et al., 2007; Bezrukov and Kamenek, 2008; Sitnikova et al., 2009) shows that the species diversity of bats decreases at

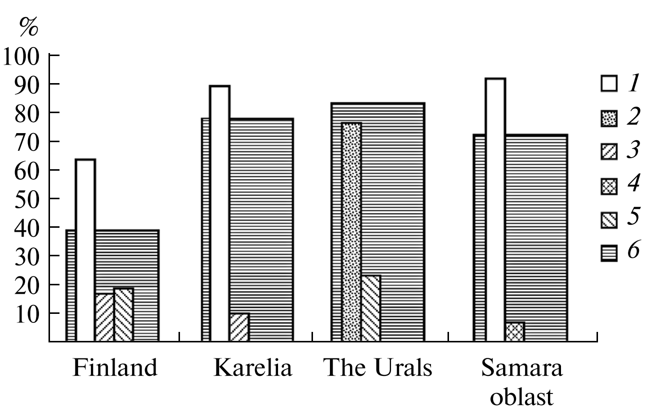

Fig. 3. Distribution pattern of *E. nilssonii* bats within winter roosts in Finland (Siivonen and Wermundsen, 2008a), Karelia (our data), the Urals (Orlov, 2000; Bol'shakov et al., 2005), and Samara oblast (Smirnov et al., 2008; Smirnov and Vekhnik, 2009): (*1*) single individuals, (*2*) single individuals and pairs, (*4*) pairs and groups, (*5*) groups, (*6*) occurrence in open places.

higher latitudes and drops to a minimum in the boreal belt of the Palearctic, between 60° and 63° N, as in the east of the country (Anufriev, 2008). However, this latitudinal decrease is not so abrupt as in other European countries (Pereswiet-Soltan, 2007). According to Ulrich et al. (2007), the size of geographic area, latitude, and annual amplitude of temperatures are the factors that explain 73% of the total variance of bat species richness in 58 European countries. The representation of bat families, genera, and species is the highest in the Mediterranean region and decreases across Europe to a minimum in Estonia and Finland.

Taking into account specific features in the distribution and composition of vesper bats in the north of European Russia (Bogdarina and Strelkov, 2003), it appears that the lowest parameters of species richness and abundance of this animal group in Europe are characteristic of the eastern margin of Fennoscandia, where climatic conditions are most severe (Karelia and Murmansk oblast), and probably of other regions lying above the 60th parallel.

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