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Bats hibernating in Kaunas Fortress, Lithuania

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Abstract. Kaunas Fortress is one of the largest bat hibernation sites known in northeastern Europe. Bat counts have been carried out there during two periods (1978–1995 and 2007). In 2007, 52 underground and semi-underground roosts belonging to seven forts and two bunkers were inspected. In all, 958 bats of 8 species were found. Slightly more bats were apparently present as some parts of the roosts were inaccessible for study. Comparison of the counting data collected from 15 selected roosts during two periods shows that *Myotis daubentonii* and *M. nattereri* had increased significantly while *Plecotus auritus* and *Barbastella barbastellus* had decreased. Comparison of bat counting data collected from the whole Kaunas Fortress shows that bat numbers (all species together) had not changed much during three decades, but differences existed between species. Thus, in three bat species (*Myotis dasycneme*, *Plecotus auritus*, and *Barbastella barbastellus*) the numbers had decreased, while in *Myotis brandtii* the numbers had increased threefold. The reasons for this increase are not known. Bat hibernation conditions prevailing in Kaunas Fortress have remained largely the same over decades, but some changes caused by humans have occurred.

Key words: Chiroptera, hibernation, population monitoring, Lithuania, Europe.

INTRODUCTION

In areas where long periods of cold occur annually, sedentary bats hibernate. Underground sites like caves and other places with similar conditions provide suitable hibernation sites for bats. In northeastern Europe not many places are known where bats hibernate in great numbers. Probably the reason is that regular ice ages prevented the formation of large natural caves. However, during the last one or two hundred years large man-made underground rooms such as mines, fortification buildings, tunnels etc. have appeared in this area (Strelkov, 1958; Randla, 1969; Masing, 1990; Gustavson, 1993; Racis, 2004). Thus, it is not surprising that bats use these underground sites during winter when outside temperature falls too low for hibernation (Masing & Lutsar, 2007). Underground roosts provide excellent conditions for hibernating bats because they provide a humid and cool

microclimate and in these dark sites bats remain often undisturbed (Ryberg, 1947; Kuzyakin, 1950; Ling, 1953; Poots, 1956; Strelkov, 1958, 1971; Randla, 1969; Buša, 1984; Masing, 1984a, 1990; Baranauskas, 2006).

In northeastern Europe large hibernation colonies including several hundreds or even thousands of sedentary bats are found in the following places: (1) abandoned sandstone mines at Piusa in southeastern Estonia (Ling, 1953; Poots, 1956; Lutsar et al., 2000); (2) underground tunnels of Peter the Great Sea Fortress and one abandoned mine near Tallinn (Ling, 1953; Randla, 1969; Masing, 1990; Masing & Lutsar, 2007); (3) abandoned sandstone mines in the vicinity of St. Petersburg in Russia (Strelkov, 1958, 1971); (4) natural caves in the Ural Mountains (Strelkov, 1958; Bol′shakov, 1981); (5) abandoned mines at Samarian Luka by the Volga River (Il′in et al., 1999); (6) Kaunas Fortress (Masing & Buša, 1983; Pauža & Paužienė, 1996); (7) an abandoned railway tunnel in Vilnius (Baranauskas, 2006); (8) Daugavpils's Fortress in Latvia (Vintulis & Pētersons, 2007).

Kaunas Fortress, one of the largest bat hibernation sites known in northeastern Europe, is the remains of a fortress complex in Kaunas, Lithuania. It was constructed and renovated between 1882 and 1915. Forts 1–8 were constructed at the end of the 19th century, while Fort 9 was built at the beginning of the 20th century (Racis, 2004). During World War I, this complex was the largest defensive structure in Lithuania.

Today, Kaunas Fortress is a well-known place where bats (Chiroptera) concentrate to hibernate during autumn, winter, and early spring. It consists of nine completed forts, each including several separate underground roosts. At least eight forts have underground rooms suitable for bat hibernation. Additionally, there are a number of separate underground bunkers in Kaunas, which are also used by bats during winter.

Systematic counts of hibernating bats have been carried out at these sites since the late 1970s. Thus far the following eight sedentary bat species have been found hibernating in this vast fortress: *Barbastella barbastellus* (Schreber, 1774), *Eptesicus nilssonii* (Keyserling & Blasius, 1839), *Eptesicus serotinus* (Schreber, 1774), *Myotis brandtii* (Eversmann, 1845), *Myotis dasycneme* (Boie, 1825), *Myotis daubentonii* (Kuhl, 1817), *Myotis nattereri* (Kuhl, 1817), and *Plecotus auritus* (Linnaeus, 1758) (Masing & Buša, 1983; Masing, 1984b; Pauža & Paužienė, 1996).

The study of bats in Kaunas Fortress can be divided into the following periods: (1) occasional finds of bats, with no aim of counting all or nearly all bats present (during the 20th century until 1977); (2) systematic counts of bats with the aim to get both qualitative and quantitative data on the bat population hibernating in underground rooms of the fortress (since 1978) (Masing & Buša, 1983; Masing, 1984b; Pauža & Paužienė, 1996; present work).

Between 1978 and 1980 three expeditions were carried out by Estonian and Latvian student-scientists to count bats in Kaunas. For various reasons only some of the underground rooms were inspected during that period. Some forts were closed to visitors, while on other occasions the students did not have resources to

visit underground sites. As a result of these expeditions the following underground systems were inspected by this research team in Kaunas: Fort 2, Fort 8, Fort 9, Bunker 9A, and Bunker 9B (Masing & Buša, 1983; Masing, 1984b). At about the same time (1978) a group of local amateurs started to study bats on a scientific basis in Lithuania, including Kaunas (Pauža & Paužienė, 1996).

The aim of this article is to present new data on bats hibernating in Kaunas Fortress. Additionally, comparisons of bat counting data collected from Kaunas during two periods are given.

STUDY AREA AND METHODS

The underground systems of Kaunas Fortress include about 80 subsystems (roosts) belonging to forts and solitary bunkers. Over 50 of these roosts belonging to Forts 1–6, 8, and 9 and solitary bunkers 9A and 9B have been studied by chiropterologists over time (Figs 1–4). Fort 7 as well as several underground parts in other forts have thus far been inaccessible to bat researchers, but bats probably

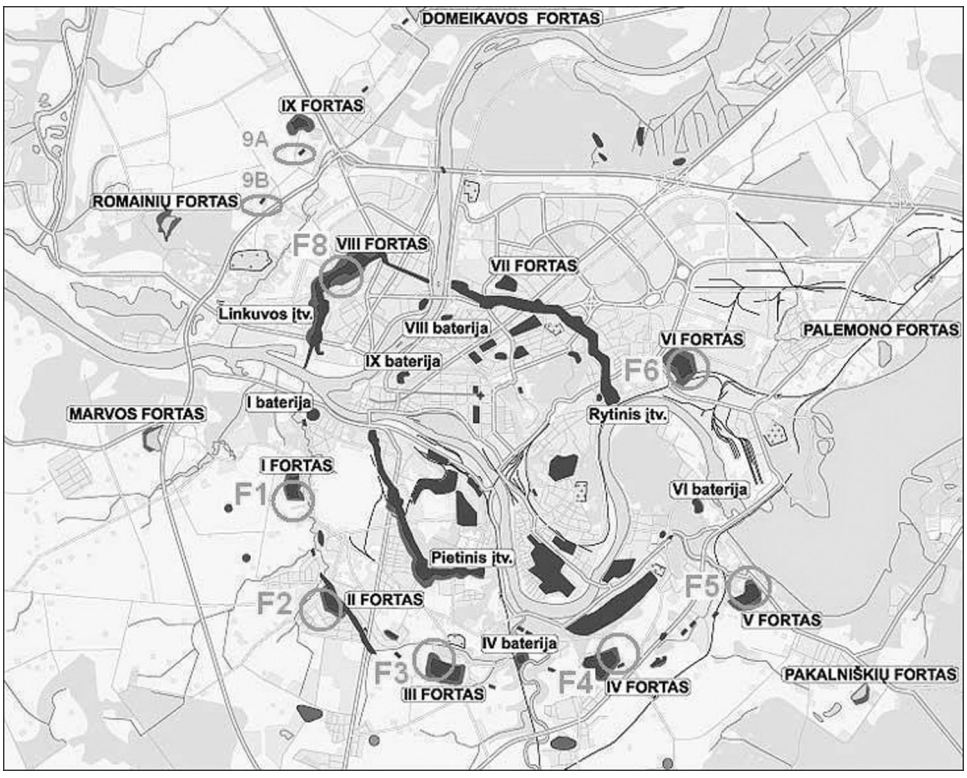

Fig. 1. Map of Kaunas showing places of study in 2007. The studied forts are marked with a light circle, and bunkers 9A and 9B are marked with an ellipse (Kauno tvirtovė, 2009).

Fig. 2. Main building of Fort 1 in February 2007 (*all photos by Matti Masing*).

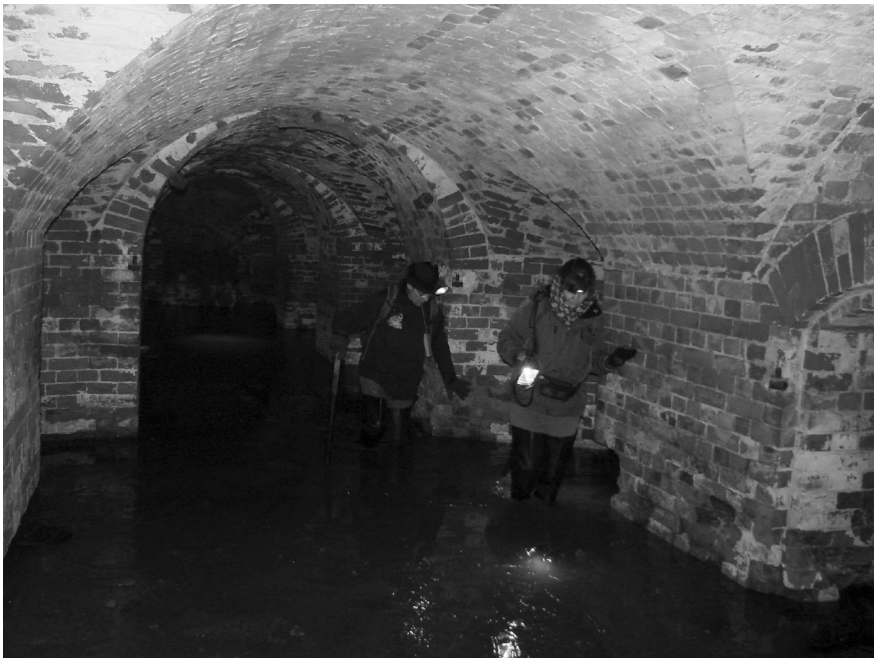

Fig. 3. An underground system built of red bricks in Fort 6. The floor is covered with ice and water.

Fig. 4. A small white building on underground roost No. 1/4 situated in the southern part of Fort 1. In deep wall crevices of this room 31 Barbastelles, representing 29% of the total hibernating community of this species found in Kaunas Fortress in 2007, were found hibernating in chilly conditions.

hibernate there, too. Fort 9 is probably not suitable for bat hibernation any more because there is a museum, although hibernating bats were found there during earlier counts (Masing & Buša, 1983; Pauža & Paužienė, 1996). In 2007 bat counts were carried out at forts 5 and 6 probably for the first time.

Fifteen roosts of Kaunas Fortress studied by an Estonian–Latvian team during 1978–1980 were studied again in 2007. Thus, it became possible to compare these results. Also, in 2007 an attempt was made to find bats banded at the same sites in November 1978 (42 bats) and in February 1979 (68 bats).

Between 29 January and 6 February 2007 the following underground and semi-underground sites were inspected for the presence of hibernating bats in Kaunas: forts 1, 2, 3, 4, 5, 6, and 8, and bunkers 9A and 9B (numeration by Masing & Buša, 1983). Hibernating bats were counted visually, most bats were not touched during the count. Hand torches were used to orientate in dark underground rooms and to find bats (Figs 5 and 6). We could identify nearly all bats on species level, except some of the *Myotis* bats, which hibernated in deeper crevices. On some occasions a 1.5 m long bendable wire was used to occasionally take bats from crevices for species identification and, sometimes, to touch them to reveal if they belonged either to the Daubenton's Bat (*Myotis daubentonii*)

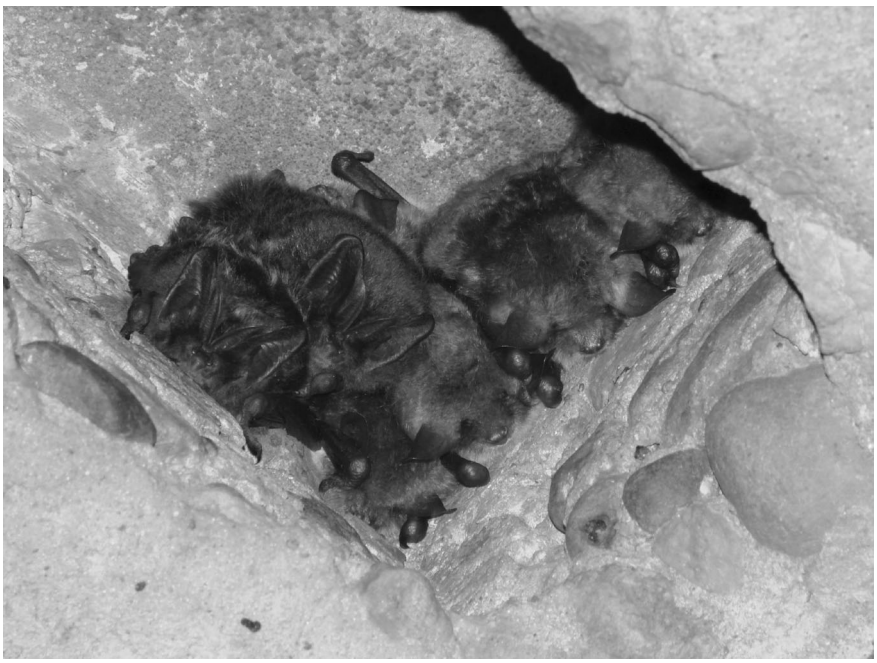

Fig. 5. Two Barbastelles and five Natterer's Bats hibernating in a hole situated in the ceiling of a tunnel in roost No. 2/8 of Fort 2.

or the whiskered bats group (*Myotis brandtii* or *M. mystacinus*) (P. Strelkov's method of 'bending ears' in *M. daubentonii*; Strelkov, 1963). Separating the sibling species of *M. brandtii* and *M. mystacinus* was done using external characters, e.g. the shape of ears and the colour of face, ears, and tragus (Masing, 1987, 1996; Schober & Grimmberger, 1998). Brandt's Bats (*M. brandtii*) usually hibernated on walls of underground roosts (Fig. 6); thus their field identification characters could be examined easily. We found no animals bearing the characters of *M. mystacinus*.

In some of the rooms belonging to forts 2 and 3 we found bat-boxes similar of Schwegler's 'Fledermaushöhle 2F (universell)' (Schwegler-Vogelschutzgeräte, 1983) attached to walls below the ceiling. Bats hibernating in those boxes were counted and identified correctly, except on two occasions when the doors of the boxes were closed and perhaps not all bats were visible through the entrance opening.

At all roosts we counted bats relatively silently and quickly. So this activity did not cause a mass arousal of bats, which occurred during earlier studies when bats were handled and banded (Strelkov, 1974; Masing & Buša, 1983). Air temperature and relative humidity were measured both outdoors and in the vicinity of hibernating bats, on the level of 2 m from the ground, using a VAISALA HM34 humidity and temperature meter. Colour photographs were taken of hibernating bats and roosting sites.

Fig. 6. Twenty-six Brandt's Bats and one Natterer's Bat hibernating in a cluster on the brick wall of one of the roosts situated in Fort 4. Such clusters have appeared in Kaunas relatively recently, as they can only occur when the number of hibernating bats is very high (Strelkov, 1958; Bol′shakov, 1981; Lutsar et al., 2000).

Data analysis

We used SPSS 14.0 for Windows (SPSS Inc., 1989–2006) to analyse the data. We compared the total numbers of bats (*M. daubentonii*, *M. brandtii*, *P. auritus*, *M. nattereri*, *B. barbastellus*) hibernating in Fort 2, Fort 8, Bunker 9A, and Bunker 9B in 1979 and in 2007 using the Chi-Square Test. A p value <0.05 was considered significant.

RESULTS AND DISCUSSION

Bats found in Kaunas in 2007

During bat counts carried out in the winter of 2007 a total of 958 bats belonging to eight species were found (Table 1). In seven bat-boxes found in Fort 2 and Fort 3 a total of 37 bats were counted, including 14 Barbastelles (*B. barbastellus*), 12 Daubenton's Bats (*M. daubentonii*), 10 Natterer's Bats (*M. nattereri*), and 1 Pond Bat (*M. dasycneme*). No banded bats were found.

Table 1. The results of bat counts carried out in seven forts and two bunkers (9A, 9B) of Kaunas Fortress between 29 January and 6 February 2007

	System of roosts									
	Fort 1	Fort 2	Fort 3	Fort 4	Fort 5	Fort 6	Fort 8	9A	9B	Total
Number of roosts (separate underground rooms) studied	11	9	5	7	8	3	7	1	1	52
Myotis dasycneme	4	0	1	6	0	0	0	0	0	11
Myotis daubentonii	54	47	40	108	10	10	3	8	0	280
Myotis brandtii	19	4	84	164	2	1	0	0	0	274
Myotis nattereri	34	64	23	122	3	1	13	2	1	263
Myotis sp.	4	2	0	5	0	0	0	0	0	11
Plecotus auritus	0	1	2	0	1	2	0	0	0	6
Barbastella barbastellus	39	23	11	28	1	1	2	0	3	108
Eptesicus serotinus	0	0	0	0	1	0	0	0	0	1
Eptesicus nilssonii	0	0	0	3	1	0	0	0	0	4
Total	154*	141	161*	436	19*	15*	18*	10	4	958*

* Not all roosts or parts of roosts were accessible, so some bats were probably missed.

Temperature and humidity in 2007

Air temperature measured at underground sites close to the hibernating bats varied between +0.8 and +7.6°C, and relative humidity varied between 65% and 100%. During the study, outside temperature was relatively high, varying between –5 and +2°C.

Comparison of bat counting data collected from 15 selected roosts during two different periods (comparison A)

We selected 15 roosts (belonging to Fort 2, Fort 8, Bunker 9A and Bunker 9B) for the present comparison. These are roosts for which bat count data were available from two different periods, 1979 and 2007. This comparison shows that the numbers of *Myotis daubentonii* and *M. nattereri* had increased significantly while the numbers of *Plecotus auritus* and *Barbastella barbastellus* had decreased remarkably (Table 2). However, the relatively low numbers of animals belonging to the last two species found at underground roosts in 2007 might have been caused by the relatively warm winter when both species probably had a better chance to hibernate outside underground roosts. Furthermore, the changes in bat numbers revealed in Table 2 cannot be generalized to the whole Kaunas Fortress as those 15 roosts embraced only about 20% of all underground roosts bats use in this vast fortress.

Table 2. Comparative results of bat counts carried out at exactly the same roosts situated in two forts and two bunkers of Kaunas Fortress in February 1979 (before slash) and in January/February 2007 (after slash)

	System of roosts				Total in 1979	Total in 2007	Comparisons of 1979 and 2007
	Fort 2	Fort 8	9A	9B			
Number of roosts studied	8	5	1	1	15	15	
Myotis daubentonii	6/47	6/3	0/8	1/0	13	58	$p < 0.001$
Myotis brandtii	1/4	0/0	0/0	0/0	1	4	NS
Myotis nattereri	2/64	2/13	0/2	0/1	4	80	$p < 0.001$
Myotis sp.	0/2	0/0	0/0	0/0	0	2	–
Plecotus auritus	0/1	6/0	2/0	9/0	17	1	$p < 0.001$
Barbastella barbastellus	0/23	57/2	5/0	60/3	122	28	$p < 0.001$
Eptesicus serotinus	4/0	1/0	0/0	0/0	5	0	–
Total	13/141	72/18*	7/10	70/4	162	173*	

NS – nonsignificant.
* Some bats were probably missed.

Chi-Square Test of the counting data (comparison A)

There was a significant difference (Chi-Square Test, $\chi^2 = 176,\ df = 4,\ p < 0.001$) between the occurrence of species (Fort 2, Fort 8, Bunker 9A, Bunker 9B) in 1979 and 2007 (Table 2). According to the binomial tests ($p < 0.001$), all the species except *M. brandtii* (NS) contributed to the significant difference of the Chi-Square Test, i.e. the numbers of all the other species except that of *M. brandtii* differed significantly between 1979 and 2007. In 2007 the numbers of *M. daubentonii* and *M. nattereri* were significantly larger than in 1979. However, the numbers of *P. auritus* and *B. barbastellus* were significantly smaller in 2007 than in 1979. No *E. serotinus* was found in 2007 at the roosts compared, therefore this species could not be included in the Chi-Square Test.

Factors influencing bat numbers in 1979 and 2007

During the two periods climatic conditions were different: e.g. the winter of 1978/1979 was one of the coldest during the past 30 years while the winter of 2006/2007 was one of the warmest. Thus, in 2007 the air temperature within the roosts was from 1 to 2.5 °C higher (varying between +0.8 and +7.6 °C) compared to 1979 (varying between –1 and +6.5 °C). Also other conditions such as human influence were different in some roosts. For instance, bat-boxes were found attached to the wall in one of the roosts of Fort 2 in 2007. On the other hand, in 1979 several roosts of Fort 2 were severely damaged by fire, thus bats could not use them.

The total number of bats hibernating in Kaunas Fortress in a cold winter and in a warm winter did not differ much. Thus, the slight differences in air

temperatures (from 1 to 2.5 °C) measured under the ground in a cold winter and in a warm winter were probably not big enough to cause significant changes in the numbers of hibernating bats in this fortress. However, it can be assumed that differences in the severity of winter can influence the numbers of some species like *Plecotus auritus* and *Barbastella barbastellus*, because in relatively warm winters those species can probably find suitable hibernation sites in aboveground roosts.

Comparison of bat counting data belonging to two different periods (comparison B)

Bat count data collected from the whole Kaunas Fortress during two periods were used for this comparison. When comparing counting data of the Lithuanian team (Pauža & Paužienė, 1996) with our results for 2007 the following differences became evident (Table 3). In some species (*Myotis dasycneme*, *Plecotus auritus*, and *Barbastella barbastellus*) a significant decrease had occurred between the two periods, 1978–1995 and 2007. In one species (*Myotis brandtii*) a noteworthy increase had happened. However, it is not clear whether the increase was a result of population increase, or Brandt's Bat just preferred to hibernate in Kaunas Fortress in greater numbers in 2007. Because no precise data were available from the first count period concerning the whole Kaunas Fortress, it is impossible to statistically compare the data given in Table 3.

Table 3. Bat counting data from Kaunas during two periods

	Estimation of bat numbers hibernating in underground roosts (Pauža & Paužienė, 1996)	Results of bat counts from 52 underground roosts (new data from the present work)	Increase or decrease in bat numbers compared to the first count (first count = 100%)
Counting period	Winters, 1978–1995 (first count)	Winter, 2007 (second count)	
Number of roosts studied	Fewer than 50 (?)	52	
Myotis dasycneme	15–20	11	63%
Myotis daubentonii	300–400	280	80%
Myotis brandtii	80–100	274	304%
Myotis nattereri	200–300	263	105%
Myotis sp.	?	11	Unknown
Plecotus auritus	40–60	6	12%
Barbastella barbastellus	200–300	108	43%
Eptesicus serotinus	A few	1	Not calculated
Eptesicus nilssonii	A few	4	Not calculated
Total	840–1185	958*	81–114%

* Some bats were probably missed.

CONCLUSIONS

Bat hibernation conditions prevailing in the underground rooms of Kaunas Fortress have remained largely the same over decades, but some changes caused by humans have occurred (for example, the addition of bat-boxes and the loss of sites to fire).

Eight bat species were found hibernating in Kaunas Fortress in 2007. These are the same species found there during 1978–1995.

Generally, bat numbers (all species together) have not changed much in Kaunas Fortress during three decades. However, differences exist between species. Thus, in three bat species (*Myotis dasycneme*, *Plecotus auritus*, and *Barbastella barbastellus*) the numbers had decreased, while in *Myotis brandtii* the numbers had increased threefold. The reasons of this increase are not known.

The unusually low numbers of *Plecotus auritus* detected in Kaunas Fortress in 2007 were probably caused by the relatively warm winter when this species may prefer to hibernate outside the fortress.

The slight differences in air temperatures (from 1 to 2.5 °C) measured under the ground in a cold winter and in a warm winter were probably not big enough to cause significant changes in the numbers of hibernating bats in Kaunas Fortress. However, it can be assumed that differences in the severity of winter can influence the numbers of some species such as *Plecotus auritus* and *Barbastella barbastellus*, because in relatively warm winters these species can probably find suitable hibernation sites in aboveground roosts.

Bat counting data of 2007 confirmed that Kaunas Fortress is one of the most important bat hibernation sites in Lithuania as well as in the whole of north-eastern Europe. Therefore it should be efficiently protected against disturbing factors.

Collecting long-term datasets on hibernating bats has a great value in monitoring their populations and making decisions on bat conservation. Unfortunately, full counts of hibernating bats in Kaunas Fortress have been extremely rare. In Europe where bats are vulnerable and protected animals, they should be counted and their populations monitored more precisely.

Analysis of bat counting data collected from other large underground hibernation sites situated in northeastern Europe should be carried out in the future. Such analysis can only be made if hibernating bats are regularly counted at these sites.

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Kaunase kindluses talvituvad nahkhiired

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Kaunase kindlus on üks kaheksast nahkhiirte suuremast talvituspaigast Kirde-Euroopas. Nahkhiiri loendati seal kahel perioodil: aastail 1978–1995 ja 2007. Artiklis on kirjeldatud nahkhiirte loendusi Kaunase kindluse seitsmes fordis ja kahes eraldi seisvas varjendis 2007. aasta talvel. 52 talvituspaigas (maa-aluses käigus jm) loendati kokku 958 talvituvat nahkhiirt 8 liigist. 15 talvituspaiga kohta olid võrdlusandmed 1979. ja 2007. aasta talvest. Need näitasid, et veelendlase ja Nattereri lendlase arvukus oli suurenenud, ent pruun-suurkõrva ning Euroopa laikõrva oma vähenenud. Kaunase kindluse kõigi ligipääsetavate talvituspaikade võrdlusandmed näitasid, et umbes 30 aasta vältel polnud talvituvate nahkhiirte üldarv muutunud, ent muutused olid toimunud konkreetsete liikide arvukuses. Nii oli tiigilendlase, pruun-suurkõrva ja Euroopa laikõrva arvukus vähenenud, kuid tõmmulendlase oma oli kolmekordselt suurenenud. Viimase kasvu põhjused pole teada. Nahkhiirte talvitumistingimused Kaunase kindluses olid 30-aastasel vaatlusperioodil enam-vähem samad, kuid mõnes talvituspaigas olid toimunud inimmõju põhjustatud muutused.