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Abundance and species diversity of small mammals on beaver lodges

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A study on the abundance and diversity of small mammals was carried out on beaver lodges in a hilly moraine landscape of Eastern Lithuania. Small mammals were sampled using snap traps three times per year (in April, in July and in October). Small mammals of nine species were caught on beaver lodges: *Sorex araneus, S. minutus, Neomys fodiens, Mus musculus, Apodemus flavicollis, Apodemus agrarius, Clethrionomys (Myodes) glareolus, Microtus arvalis,* and *M. agrestis. Clethrionomys glareolus* strongly dominated in relative abundance (RA) and frequency of occurrence (FO) (RA = 14.1 ind./100 trap-days and FO = 44.3%). The subdominant species was *Apodemus flavicollis* (RA =1.3 ind./100 trap-days and FO = 14.8%). The total average RA of small mammal community on beaver lodges was 17.4 ind./100 trap-days and the total FO = 88.6%. With the aim to have some "background" abundance and diversity of small mammals in the study area, they were captured in three habitats not influenced by beavers (mixed forest with the *Corylus avellana* under storey, abandoned cultural meadow, and meadow along a canal), but using another method of trap spacing (25 traps in standard lines) than on beaver lodges (5 traps in squares). In these three habitats, small mammals of four species were caught: *Sorex minutus, Apodemus flavicollis, Clethrionomys glareolus, Microtus arvalis*, and the total average RA for small mammal community (10.2 ind./100 trap-days in the forest) was less than on beaver lodges. Despite the high number of registered species, the strong domination of *Clethrionomys glareolus* determined the low species diversity of small mammal community on beaver lodges (the Shannon diversity index varied from 0 to 1.32 when log_2 was used and from 0 to 0.91 when *ln* was used). Seasonally, most small mammals were caught on beaver lodges in autumn; however, the absolutely highest RA of *Clethrionomys glareolus* on beaver lodges during the whole period of investigations was registered in spring 2002. Results of our investigation suggest beaver lodges being important habitats for small mammals, especially for *Clethrionomys glareolus*.

Key words: small mammals, abundance, diversity, beaver lodges, *Castor fiber*, *Clethrionomys (Myodes) glareolus*, Lithuania

INTRODUCTION

The main role of beavers (*Castor fiber* and *C. canadensis*) in an ecosystem is determined by their ability to alter the environment. Beaver is defined as a keystone species or the so-called ecosystem engineer in a riparian zone and wetlands (Самусенко, 1984; Müller-Schwarze, Sun, 2003). Various aspects of beaver impact were emphasized – from water chemistry alterations to the development of specific ecosystems (e. g., Легейда, Сергиенко, 1981; Naiman, Mellilo, 1984; Remillard et al., 1987).

Beavers influence the environment for a number of animals (Rosell et al. 2005, for a review), however, studies on beaver and small mammal ecological interrelations are rather scanty. One work dealing with small mammal abundance in the-beaver-influenced sections of streams is known from Oregon, North America (Suzuki, McComb, 2004). Earlier investigations in some beaver populations in Russia showed the importance of beaver burrows as shelters for more than 20 species of small vertebrates (mammals, reptiles and amphibians). Among them, nine species of small mammals were registered (Барабаш-Никифоров, 1950). Studies on the importance of beaver lodges for the wild are still unknown, at least we have not found such data.

Beaver lodge is one of the very conspicous elements of a beaver site environment. A closer look to the interior of this beaver building revealed a rather complicated structure characterized by various cavities within thick walls and beaver-made-hollows (Ulevičius, unpubl.). They offer a good habitat for small mammals. Beaver lodges are relatively permanent elements of the environment, even after their abandoning, and persist at least for several years. In a hilly landscape of Lithuania, beaver lodges are characteristic of more than 80% of beaver sites (Ulevičius, unpubl.), thus, these elements of the environment infrastructure are quite common under conditions of a dense beaver population. Beaver lodges are especially common in fens. The mean

estimated density of beaver population in Lithuania was ca. 0.2 beaver sites per km^2 (Ulevičius, 1999).

Small mammals of many species that are distributed in Lithuania inhabit wet biotopes (Prūsaitė, 1988, for a review), therefore environments of beaver sites might be important habitats, and beaver lodges are potential shelters of these animals. The aim of the present study was a pilot estimation of the abundance and species diversity of small mammals on beaver lodges.

Study area

The research covered approximately 100 km^2 of a territory located in the Molėtai and Širvintos districts, East Lithuania. The geographic co-ordinates of the centre of this territory: 55°08'N, 25°20'E.

A landscape of hilly morainic eminences with numerous lakes is characteristic of the study area. Forests are fragmented and mixed stands; usually *Picea abies* with other deciduous species prevail. The average woodedness of the study area is ca. 26%. A lot of abandoned cultural meadows and extensively used pastures intersperse with fragmented forests. Fens, usually overgrown by *Salix* spp., *Alnus* spp. and *Betula* spp., are common in depressions between hills. The average density of the hydrographical network in the study area is 1.11 km/km^2. Lakeshores dominate, making 41% of the whole hydrographical network, followed by land reclamation canals (40%) and natural streams (17%). The majority of beaver lodges were located in fens neighboured by small forests. Around the lodges, usually *Salix* spp. or *Frangula alnus* shrubs grow, and in the grass layer *Carex* spp. dominate. The beaver lodges studied were not isolated by open water from land, thus being easily available for migrating small mammals.

The beaver population density in the study area was ca. 1.9 beaver sites per km^2 (Bluzma, 2003). The age of many beaver sites varied between 10–20 years, however, they are not permanently active: the average duration of permanent occupation of a site by beavers reaches 2–3 years, then they are usually abandoned for the same period and again re-colonized (Bluzma, 2003), and beaver lodges rebuilt.

MATERIALS AND METHODS

Small mammals were sampled on 9–13 beaver lodges in 2002–2005 during 8 catching sessions. In 2002 and 2005, there were three catching sessions per year: in spring (April), summer (July) and autumn (October). In 2003, small mammals were sampled only in spring and in 2004 only in autumn.

Five snap traps were exposed for three nights on every beaver lodge: one on the top, and four around the base of a lodge, thus delineating a square figure. Traps were baited with a piece of brown bread moistened in sunflower oil and were tested once per day. The total of the trapping efforts on beaver lodges amounted to 1320 trap-days.

Simultaneously, small mammals were sampled also in three other habitats that were not influenced by beavers (1 – mixed forest with the *Coryllus avellana* under storey; 2 – abandoned cultural meadow; 3 – meadow along canal), but using a different method of trap spacing (standard lines, each containing 25 traps) than on beaver lodges. The aim of this sampling was just to have some overall context of the abundance and species diversity in the study area. Some discrepancies between the estimates of relative abundance and frequency of occurrence on beaver lodges and in these habitats are possible because of different trap spacing methods. Therefore, data from beaver lodges and these habitats were not compared to test the statistical hypotheses. The total amount of the trapping efforts was 975 trap-days in three habitats.

Relative abundance of small mammals was expressed by the number of individuals caught during three days on one beaver lodge (or in one trap line) and recalculated for 100 trap-days (ind./100 trap-days). Mean relative abundance was calculated from a sample of catching events (one catching event = one three-day-catching on a beaver lodge or in a trap line).

The frequency of occurrence was estimated by the number of positive catching events and expressed in percentage from the total number of catching events. Totally, there were 88 catching events on beaver lodges and five events in each of the other three habitats.

The Shannon diversity index was used to estimate the small mammal species diversity. The problem is that this index can be calculated differently by different authors, i. e. using a logarithm with the base *e*, or 2, or even 10. In each case the result will be different and data not comparable. Usually, a logarithm with the base *e* was used (Hubalek 2000, for a review), however, in Lithuania the Shannon diversity index for small mammal diversity estimation was usually calculated using a logarithm with the base 2 (e. g., Balčiauskas, Juškaitis, 1997). To avoid this problem, we calculated the Shannon index in two ways: using logarithms with the bases *e* (H_1) and 2 (H_2):

1) $H_1 = -\Sigma(n/N) \ln(n/N)$, where n = the number of individuals of a certain species, N = the total number of individuals of all species, ln = logarithm with the base *e*;

2) $H_2 = -\Sigma(n/N) \log(n/N)$, where log = logarithm with the base 2.

The nonparametric Mann–Whitney (pair wise comparison) and Kruskal–Wallis (multiple comparisons) tests were used to evaluate statistical differences in relative abundance on beaver lodges among seasons, years or small mammal species.

RESULTS

Small mammals of nine species were caught on beaver lodges during the period of investigations; however, the numbers of individuals caught, as well as the frequency of occurrence (FO) and mean relative abundance (RA) were very variable among species (Table 1). Differences in mean relative abundance among species were statistically significant (Kruskal–Wallis test: H = 25.79; df = 8; p = 0.0011).

Clethrionomys (Myodes) glareolus was the distinct dominant in the small mammal community on beaver lodges according to the mentioned indices (mean RA = 14.1; FO = 44.3%), and *Apodemus flavicollis* was the subdominant species (mean RA = 1.3; FO = 14.8%) (Table 1). *Sorex araneus* was slightly more abundant among the rest of small mammal species on beaver lodges, but its occurrence was low (FO = 2.3%). A low frequency of occurrence was also characteristic of the other rarely caught species (it varied from 1.2 to 4.5%). High values of

relative abundance of some species were registered during solitary catching events; e. g., six individuals of *Mus musculus* were caught on one beaver lodge in summer 2002.

The relative abundance of the small mammal community varied in a wide range – from 0 up to 60 ind./100 trap-days – among catching events on beaver lodges in the period of investigations (17.4 ind./100 trap-days in average) (Table 1). The zero catching events were rather rare, making only 11.4% from all events.

The mean relative abundance of small mammal community differed among all the eight catching sessions on beaver lodges (Kruskal–Wallis test: H = 31.55; df = 7; p = 0.0000). Among different years, the highest relative abundance of small mammal community on beaver lodges was estimated in all seasons of the year 2002 (Table 2), and differences among seasons in this year were insignificant (Kruskal-Wallis test: H = 0.03; df = 2; p = 0.9851). The highest relative abundance of small mammal community in spring 2002 is a highly unexpected result in this study. Comparing the years 2002 and 2005 (in these two years small mammals were sampled during three seasons), a significant decrease of the relative abundance of small mammal community was revealed in 2005 (Mann–Whitney test: U = 16.5; p = 0.0009; all seasons pooled together).

Different estimates of mean relative abundance of the small mammal community were characteristic of the same seasons but in different years. This parameter statistically significantly differed among springs of 2002, 2003 and 2005 (Kruskal–Wallis test: H = 15.42; df = 2; p = 0.0004) and among summers of 2002 and 2005 (Mann–Whitney test: U = 11.5; p = 0.0394). It should be stressed that the relative abundance of small mammal community on beaver lodges was much higher in spring and summer 2002 than in the same seasons of other years (Table 2). In the autumnal catching sessions of 2002, 2004 and 2005, the estimates of mean relative abundance differed insignificantly (Kruskal–Wallis test: H = 5.38; df = 2; p = 0.0679), though the mean relative abundance in autumn 2005 was half as much than in autumns of the previous years (Table 2).

Table 1. **Species composition, mean relative abundance, frequency of occurrence of small mammals caught on beaver lodges in the study territory in Eastern Lithuania in 2002–2005 (all seasons and years are pooled together)**

Species and parameter	Number of individuals caught	Relative abundance, *ind./100 trap-days, mean (min - max)*	Frequency of occurrence, % n* = 88
Sorex araneus	10	0.8 (0–53.3)	2.3
S. minutus	2	0.2 (0–13.3)	1.2
Neomys fodiens	1	0.1 (0–6.7)	1.2
Mus musculus	6	0.5 (0–40.0)	1.2
Apodemus agrarius	5	0.4 (0–13.3)	4.5
A. flavicollis	17	1.3 (0–13.3)	14.8
Clethrionomys glareolus	186	14.1 (0–46.7)	44.3
Microtus arvalis	2	0.2 (0–6.7)	2.3
M. agrestis	1	0.1 (0–6.7)	1.2
Small mammal community	230	17.4 (0–60.0)	88.6
Shannon diversity index, H_1	0.81	–	–
Shannon diversity index, H_2	1.19	–	–

* Number of catching events

Table 2. **Number of individuals caught, mean relative abundance, and species diversity indices of small mammals on beaver lodges among seasons in the study territory in Eastern Lithuania in 2002–2005. Sp – spring, Sm – summer, A – autumn**

Species and parameter	Number of individuals caught / mean relative abundance, ind./100 trap-days							
	2002			2003	2004	2005		
	Sp n* = 135	Sm n = 135	A n = 195	Sp n = 195	A n = 150	Sp n = 195	Sm n = 135	A n = 180
Sorex araneus	2/1.5	–	8/4.1	–	–	–	–	–
S. minutus	2/1.5	–	–	–	–	–	–	–
Neomys fodiens	1/0.7	–	–	–	–	–	–	–
Mus musculus	–	6/4.4	–	–	–	–	–	–
Apodemus agrarius	1/0.7	–	1/0.5	–	2/1.3	–	1/0.7	–
A. flavicollis	–	4/3.7	6/3.1	1/0.5	4/2.7	–	1/0.7	–
Clethrionomys glareolus	31/23.0	26/19,3	37/19.0	12/6.2	32/21.3	13/6.7	12/8.9	23/12.8
Microtus arvalis	1/0.7	1/0.7	–	–	–	–	–	–
M. agrestis	–	–	–	–	1/0.7	–	–	–
Small mammal community	38/28.1	38/28.1	52/26.7	13/6.7	39/26.0	13/6.7	14/10.4	23/12.8
Shannon diversity index, H_1	0.76	0.91	0.86	0.27	0.64	0	0.51	0
Shannon diversity index, H_2	1.10	1.32	1.23	0.39	0.93	0	0.73	0

* Number of trapping efforts (trap-days).

Table 3. **Number of individuals caught, mean relative abundance, frequency of occurrence, and species diversity of small mammals in the three habitats not influenced by beavers in the study territory in Eastern Lithuania in 2002–2005. F – forest, M – abandoned cultural meadow, MC – meadow along canal (all seasons and years are pooled together)**

Species and parameter	Number of individuals caught / mean relative abundance, *ind./100 trap-days*			Frequency of occurrence, %		
	F n* = 375	M n* = 375	MC n*=375	F n** = 5	M n** = 5	MC n** = 5
S. minutus	–	–	1 / 0.3	–	–	20
A. flavicollis	9 / 2.8	–	1 / 0.3	60	–	20
C. glareolus	24 / 7.4	–	5 / 1.5	80	–	20
M. arvalis	–	7 / 2.2	–	–	40	–
Small mammal community	33 / 10.2	7 / 2.2	7 / 2.2	80	40	20
Shannon diversity index, H_1	0.58	0	0.80	–	–	–
Shannon diversity, H_2	0.84	0	1.14	–	–	–

* Number of trapping efforts. ** Number of catching events.

Despite the high number of the registered species, the distinct domination of *Clethrionomys glareolus* determined the relatively low diversity of the small mammal community on beaver lodges (H_1 = 0.81; H_2 = 1.19) (Table 1). The species diversity of small mammals on beaver lodges varied also among years and seasons. The relatively highest Shannon index was estimated in all seasons of 2002. In the later years, this index was lower, and individuals of only one species (*Clethrionomys glareolus*) were caught in the spring and autumn of 2005 (Table 2).

A relative abundance of small mammals lower than on beaver lodges was estimated in the other three habitats that were not influenced by beavers. It means that much more catching efforts were needed to catch one individual in these habitats than on beaver lodges. The highest mean relative abundance of the small mammal community was estimated in the forest (mean RA = 10.2 ind./100 trap-days), whereas in the two other habitats it was still lower (Table 3). Small mammals of only four species were caught in three habitats; *Clethrionomys glareolus* was the dominant species. The diversity indices (H_1 and H_2) in them were rather similar to those on beaver lodges, showing the highest diversity in meadow along a canal (H_1 = 0.80; H_2 = 1.14). The lowest diversity was estimated in the abandoned meadow where individuals of only one species were caught (Table 3).

DISCUSSION

Results of our investigation suggest beaver lodges to be important habitats for small mammals, first of all for *Clethrionomys glareolus*. Small mammals of other species (probably except *Apodemus flavicollis*) were rather occasional inhabitants of beaver lodges. However, cases of a high relative abundance of some species in solitary catching events might be evidences of the suitability of beaver lodges also for some other species, e. g., *Sorex araneus* and *Mus musculus*. It is possible that these cases were predetermined by breeding events of these two species on particular beaver lodges. However, their occurrence on beaver lodges could be limited by specific peculiarities of habitat distribution of a particular species; e. g., *Mus musculus* do not inhabit wet and swampy habitats (Prūsaitė, 1988) characteristic of beaver lodge environments, and occur rather occasionally there. This might be valid also for some other small mammal species, like *Apodemus agrarius*, *Microtus arvalis*.

Clethrionomys glareolus is usually considered to be the background species among small mammals in the forest habitat (Башенина, 1981), however, it can also frequently occur in other habitats, especially if those located close to a forest and overgrown by scrubs or tall forbs (Prūsaitė 1988). Dense understorey, tall forbs, coarse woody debris, stumps and decaying wood accompanied by rather high dampness were listed among environmental factors that favour the abundance of *Clethrionomys glareolus*; cavities under decaying stumps or among coarse woody debris were considered to be the best shelters of these animals (Башенина 1981). Majority of the mentioned factors are also characteristic for the beaver lodge environments in our study area.

Clethrionomys glareolus was the most frequently caught species among small mammals in different localities of Lithuania (e. g., Balčiauskas, Juškaitis, 1997; Mažeikytė, 2001, 2002). In this context, we have obtained rather similar results demonstrating a distinct domination of this species respective to the rest of small mammals on beaver lodges, too. This is a rather expected result, considering the vicinity of favourable habitats of *Clethrionomys glareolus* to the beaver lodges.

More unexpected in our study are facts concerning the relative abundance of *Clethrionomys glareolus* on beaver lodges in particular seasons. In spring 2002, the relative abundance of this species was the highest on beaver lodges during all the study period. The vernal relative abundance of small mammals is usually described to be much lower than the summery one, and especially than the autumnal relative abundance (Mažeikytė, 1992; Balčiauskas, Gudaitė, 2006; Mažeikytė et al., 2006). Winter is a critical period to small mammal survival; e. g., a greater chance to survive until spring have individuals of *Clethrionomys glareolus* that are born in late autumn and have never reproduced, whereas the once overwintered individuals usually do not survive the second winter in their life (Prūsaitė, 1988).

Such an extremely high vernal relative abundance of *Clethrionomys glareolus* was registered on beaver lodges only in spring 2002, whereas in springs 2003 and 2005 it was much lower. It is possible that this high vernal abundance was predetermined by a population peak in the study area in the year 2001. Numerous migrants could intensively inhabit available

habitats and beaver lodges as well. There are data about the *Clethrionomys glareolus* abundance cycles that occur every two–five years (Башенина, 1981; Prūsaitė, 1988; Löfgren, 1995; Pakeltytė, Andriuškevičius, 2004).

The survival success of small mammals during winter possibly depends also on the quality of wintering stations; e. g., it may be much higher in forest than in open field (Solonen, 2006). Scrubby fens were characterized by the most optimal conditions for the wintering of small mammals in the landscape of sandy plains in Eastern Lithuania (Бальчяускас, 1990). The majority of the beaver lodges in our study were located exactly in scrubby fen-like biotopes. Optimal biotopes combined with positive shelter conditions on beaver lodges could considerably enhance the survival of small mammals during winter. Thus, these two factors – the population peak in a previous reproduction season and the high survival success during winter – could explain the unusually high vernal abundance of small mammals on beaver lodges in spring 2002.

It is hard to identify the features of beaver lodges that could determine the higher survival of small mammals during winter. One of the possible factors could be appropriate microclimate conditions within decaying wood in thick walls of a beaver lodge together with good water drainage. One of the basic factors of *Clethrionomys glareolus* overwintering is the thickness of the snow cover (Башенина, 1981; Karlsson, Potapov, 1998) which protects animals from predation press and provide appropriate microclimate conditions. In Lithuania, the snow cover is very unpredictable; long periods of thaw are frequent and might cause a high probability of flooding of small mammal shelters on the ground surface but not inside beaver lodges. In this context, beaver lodges seem to be very favourable stations of survival.

Differences in the relative abundance of small mammals between beaver lodges and the other three habitats studied could be predetermined by different methods of trap spacing; however, the assumption of the higher concentration of individuals around beaver lodges than in the other habitats cannot be rejected. Especially this might be true for the winter season when small mammals do not breed and can show a non-territorial behaviour (e. g., Karlsson, Ås, 1987; Ylonen, Viitala, 1991). Our results show that the abundance of small mammals can be higher on beaver lodges than a certain "background abundance" in other habitats which are dominating in the study area but are not wetland habitats.

This pilot study was very preliminary step in trying to assess the importance of beaver lodges as small mammal habitats. Some conclusions can be drawn concerning the scope of future research. First of all, more detailed investigations should be addressed to the winter survival of small mammals on beaver lodges as well as to peculiarities of the spatial distribution of small mammals in the vicinity of beaver lodges and to the ways these parameters might be influenced by the dynamics of small mammal abundance at a larger spatial scale.

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SMULKIŲJŲ ŽINDUOLIŲ GAUSUMAS IR RŪŠINĖ ĮVAIROVĖ ANT BEBRŲ TROBELIŲ

S a n t r a u k a

Atlikti smulkiųjų žinduolių gausumo ir rūšinės įvairovės ant bebrų trobelių tyrimai kalvotame moreniniame Rytų Lietuvos kraštovaizdyje. Smulkieji žinduoliai buvo gaudomi mušamaisiais spąsteliais tris kartus per metus (balandį, liepą ir spalį). Ant bebrų trobelių buvo sugauti devynių rūšių smulkieji žinduoliai: *Sorex araneus, S. minutus, Neomys fodiens, Mus musculus, Apodemus flavicollis, Apodemus agrarius, Clethrionomys (Myodes) glareolus, Microtus arvalis, M. agrestis*. *Clethrionomys glareolus* vyravo pagal santykinį gausumą (SG) ir aptikimo dažnumą (AD) (SG = 14,1 ind./100 spąstų per parą; AD = 44,3%). Subdominantinė rūšis buvo *Apodemus flavicollis* (SG = 1,3 ind./100 spąstų per parą; AD = 14,8%). Bendras vidutinis santykinis smulkiųjų žinduolių bendrijos gausumas ant bebrų trobelių buvo 17,4 ind./100 spąstų per parą, o bendras aptikimo dažnumas – 88,6%. Siekiant įvertinti „foninį“ smulkiųjų žinduolių gausumą ir įvairovę tirtoje teritorijoje, jie buvo gaudomi ir kituose trijuose biotopuose, kuriems bebrai neturėjo įtakos (mišriame miške su *Corylus avellana* traku, apleistoje kultūrinėje pievoje ir pievoje palei melioracijos kanalą), tačiau buvo taikytas kitoks spąstelių išdėstymo metodas (standartinės linijos po 25 spąstelius) negu ant bebrų trobelių (kvadratai po 5 spąstelius). Šiuose biotopuose buvo sugauti keturių rūšių smulkieji žinduoliai (*Sorex minutus, Apodemus flavicollis, Clethrionomys glareolus, Microtus arvalis*), o bendrijos vidutinis santykinis gausumas mišriame miške (10,2 ind./100 spąstų per parą) buvo mažesnis negu ant bebrų trobelių. Nors ant bebrų trobelių buvo sugauta daug rūšių smulkiųjų žinduolių, tačiau rūšinė įvairovė buvo maža dėl stipraus *Clethrionomys glareolus* vyravimo (Šenono įvairovės indeksas kito nuo 0 iki 1,32 naudojant $\log_2$ ir nuo 0 iki 0,91 naudojant ln). Daugiausia smulkiųjų žinduolių ant bebrų trobelių buvo sugauta rudenį, tačiau absoliučiai didžiausias *Clethrionomys glareolus* SG buvo nustatytas 2002 m. pavasarį. Tyrimo rezultatai rodo, jog bebrų trobelės gali būti svarbios smulkiųjų žinduolių, ypač *Clethrionomys glareolus*, buveinės.

Raktažodžiai: smulkieji žinduoliai, gausumas, įvairovė, bebrų trobelės, *Castor fiber*, *Clethrionomys (Myodes) glareolus*, Lietuva