Levels of Helminth Infection of Small Rodents in Two Interspersed Habitats – the Forest and Beaver Sites

GINTARĖ SKYRIENĖ[1*], ALIUS ULEVIČIUS[2] AND ARŪNAS SAMAS[2]
[1]*Faculty of Natural Sciences of Vytautas Magnus University, Vileikos 8, LT- 44404 Kaunas, Lithuania*
[2]*Faculty of Natural Sciences of Vilnius University, M. K. Čiurlionio 21/27, LT – 03101 Vilnius, Lithuania*
** Corresponding author, e-mail address: butautyte@gmail.com, phone number: +370 615 97073*

Skyrienė, G., Ulevičius, A. and Samas, A. 2011. Levels of Helminth Infection of Small Rodents in Two Interspersed Habitats – the Forest and Beaver Sites. *Baltic Forestry* 17(2): 299–307.

Abstract

Helminth infection in small rodents (*Apodemus flavicollis* and *Myodes glareolus*) was studied in forest and in beaver sites that were tightly spatially interspersed. Beaver sites were regarded as disturbed habitats inhabited by these two typical forests dwelling small rodent species. We tested the hypothesis that beaver sites, as disturbed habitats, can influence the abundance of infections with helminths, typical of forest rodent species. The composition of helminth species overlapped fully in the two tested habitats for *M. glareolus* (8 species of parasites) and nearly completely also for *A. flavicollis* (7 species at beaver sites and 6 species in the forest). *M. glareolus* were more heavily infected with *Syphacia petrusewiczi* at beaver sites than in the forest in autumn and winter. The mean abundance of all helminths in *M. glareolus* was significantly higher at beaver sites only in the winter, with no significant differences in any other season. For *A. flavicollis*, we did not find statistically significant differences in mean abundance of helminths between the habitats neither for any particular helminth species nor for all helminth species taken together. We found some changes in the helminth community structure (as reflected in dominance hierarchies of helminths species) between the two studied habitats. *S. petrusewiczi* dominating markedly over the other helminth species in *M. glareolus* at the beaver sites, whereas dominance with this helminth was much weaker in the forest. For *A. flavicollis,* we found different dominant helminth species in each of the two habitats: *Syphacia montana* was strong dominant at beaver sites, but it was not found in mice dwelling in the forest, where *Syphacia stroma* dominated at the beaver sites. The patterns of taxonomic diversity of helminths and the distribution of parasites among host individuals did not reveal any significant differences between the tested habitats which were variable among host species and seasons. Our study has revealed habitat differences only in some aspects of the helminth infections of the two typical forest dwelling rodent species, whereas other tested parameters were highly variable and did not show significant inequalities between habitats. These findings suggest a rather weak impact of the beaver sites on the epidemiology of helminth infections in typical forest dwelling small rodent species.

Key words: *Apodemus flavicollis*, *Myodes glareolus*, helminths, helminth infection levels, forest, beaver sites, habitat disturbance

Introduction

Small rodents are good models for investigating the host-parasite relationship in different habitats due to abilities of these mammals to inhabit a wide range of different environments (Lafferty et al. 2008). Infections of small rodents caused by helminths are usually studied in separate habitats, such as forests, grasslands, mountains, rural and urbanized environments (Behnke et al. 2000, Ferrari 2005, Mažeika et al. 2003, Montgomery and Montgomery 1989) but few data exist on comparative helminthological analysis of small rodents in different habitats or habitat complexes with respect of their cardinal changes.

Forest habitats, despite their very uneven species composition and succession stage, can be regarded as the last stages of succession within a landscape ecosystem in temperate zones, thus, suggesting a relatively long development of ecological relationships among various trophic levels, including the host-parasite system in small rodents. Various ecological factors might be considered to have the potential to influence the host-parasite relations, especially when the mature forest ecosystems are disturbed in some way.

Beavers (*Castor fiber* and *C. canadensis*) are widely acknowledged as a source of natural disturbance in forest ecosystems (Johnston and Naiman 1987, King and Antrobus 2001, Wright et al. 2002). Generally, beaver sites have very specific habitat qualities, and their numbers have increased significantly in the landscape ecosystem during recent decades (Ulevičius 2008). Beaver sites are usually tightly interspersed with forest habitats, thus, providing an opportunity for colonization by species of forest small rodent. The bank vole (*M. glareolus*) and the yellow-necked mouse (*A. flavicollis*) are considered as typical forest rodents (Juškaitis 1999, Juškaitis et al. 2001, Mažeikytė et al. 1999, Prūsaitė 1988) also inhabiting the environments of beaver sites with high relative abundance (Ulevičius and Janulaitis 2007).

Due to the wet and swampy conditions of beaver sites and abundant intermediate hosts of helminths (snails and other mollusks) the parasitological state of small rodents may be different than in the forest (Ferrari 2005, Pulido-Flores et al. 2005). Mobile rodents have the potential to transfer helminths to the forest and other habitats, in this way influencing the parasitological state of the whole landscape ecosystem. The relationships between the individual biota components of the biota of beaver modified habitats, including the host-parasite system, have not been investigated across the whole range of the Eurasian beaver.

The aim of this study was to compare the helminth fauna notably the abundance of helminths in small rodents in the forest and beaver sites. We tested the hypothesis that beaver sites, as disturbed habitats, influence infection levels of helminths, typical of the forest rodent species.

Study area

The study sites were located in Vilnius, Molėtai and Širvintos districts, Eastern Lithuania (Fig. 1). The geographic co-ordinates of the approximate centre of this territory: 55°00'N, 25°14'E.

Morainic hills with numerous lakes are characteristic of the study area. Forests are highly fragmented (Fig. 1) and successional mixed stands (usually *Picea abies* with some deciduous species, *Alnus incana, Populus tremula, Betula pendula*) prevail. Average forest cover of the study area is ca. 29 %. A number of abandoned meadows and extensively used pastures intersperse with fragmented forests. Fens, usually overgrown or fringed by *Salix* spp., *Alnus* spp. and *Betula* spp. stands, are common in depressions between hills. The majority of beaver sites are located

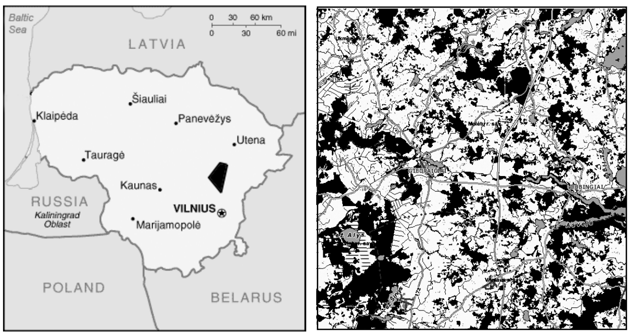

Figure 1. Study area. The black polygon on the left map covers the whole study area. On the right map is shown the characteristic pattern of the forest (black patches) fragmentation in the study area

in fens at the margins of small forests. At beaver sites, usually *Salix* spp. or *Frangula alnus* shrubs grow, and in the grass layer *Carex* spp. dominate. Mean density of beaver sites was 4.5 sites/1000 ha. The age of beaver sites varied between 10 – 25 years. Beavers disturb forests by raising the water level of the ground and leaving trees to die or removing the majority of large trees by cutting them.

Materials and methods

Small rodents were sampled in the forest and at beaver sites from 2007 to 2009 four times per year: in spring (April), in summer (July – August), in autumn (October) and in winter (February). Snap traps were set in standard lines (25 traps at intervals of 5 meters) or trap quadrates (five traps, one in the centre and four in the corners of an approximately 3x3 m square) for three days and nights. Trap lines and trap quadrates were used in the forest, whereas trap quadrates were used only at beaver sites. Trap quadrates were set on beaver lodges (one trap on the top and four around the base of a lodge) (Ulevičius and Janulaitis 2007). Small pieces of brown bread crust moistened with sunflower oil were used as bait. Sampling of small mammals by snap traps were permitted by the Ministry of Environment (license No. (11-)-D8-3650).

In total 390 individual small rodents were caught and examined helminthologically: *M. glareolus* – n = 128 at beaver sites and n = 159 in the forest; *A. flavicollis* – n = 21 and n = 82, respectively. Small rodents of other species were caught but these were not studied helminthologically due to their low relative abundance and frequency of occurrence.

We dissected the entire intestinal tracts of small rodents and examined these for helminths. The content of the intestines was studied by the method of consistent flushing. The helminths were fixed in 70% ethanol. Nematodes and trematodes were studied on temporary water – glycerin preparations (Ивашкин и др. 1971).

Two indices of infection level were used. Mean abundance is the total number of individuals of particular parasite species in a sample of a particular host species divided by the total number of hosts of that species examined (Bush et al. 1997). The other indicator used was prevalence of infection which was calculated as the percentage of the infected individuals from among all the dissected rodents (Bush et al. 1997). Significance of differences of mean abundance and prevalence of infection was tested using the Mann- Whitney U test and the Chi-square test, respectively ($p < 0.05$).

Age (juveniles, subadults, adults) and gender difference were tested using tests of independence on infection levels of *M. glareolus* (because of larger samples than *A. flavicollis*) within seasons. Statistically significant differences among age groups were found only in the autumn (Kruskal-Wallis test, p=0.006). Statistically significant differences between sexes of this host were found only in summer (Mann-Whitney test, p=0.01). In the remaining cases, we did not find statistically significant differences neither among age nor sex groups of *M. glareolus* probably due to remarkably smaller samples of individuals tested in other particular seasons. Thus, we have omitted the age and sex factors from further analysis by pooling together all groups of age and sex within seasons.

The Shannon – Wiener diversity index (H') (May 1975) and the Berger–Parker dominance index (May 1975) were used to express diversity of the helminth species and dominance of helminth species in small rodents from different habitats. The Jaccard's similarity coefficient (J) (Magurran 1988), which measures numerical similarity of helminth species, shared between component communities. The helminth aggregation was assessed using the variance-to-mean ratio (dispersion coefficient, CD) of helminths number per one host individual (Poulin 1998). Statistical significance of differences from random distribution of helminths (CD=1) (was tested using the Student's t-test (Kershaw 1978).

Results

In total, including both small rodent species (*M. glareolus* and *A. flavicollis*) and both treatments (beaver sites and forest), 66 % of the examined small rodent individuals were infected by helminths. Helminths of 9 species and 3 not identified to species level (5821 specimens) were found: 1 cestode (tapeworms), 6 nematodes (roundworm), 2 trematodes (fluke) species and 1 cestode and 2 nematodes not identified to species level (Table 1).

M. glareolus were infected by 8 species of helminths and there was no difference in the number of helminth species between *M. glareolus* caught at beaver sites and in the forest. All parasite species were the same in both habitats for *M. glareolus* (Table 1).

A. flavicollis were infected by 7 helminth species at beaver sites and 6 in the forest. The nematode *S. montana* was found only in mice dwelling at beaver sites (Table 1).

Comparing the two rodent species, they had three common taxa of helminths (*Cestoda* g. sp., *Heligmosomum costellatum, Heligmosomum mixtum*), whereas other helminths were found to be rodent-specific. This pattern was identical between the two tested habitats (Table 1).

Table 1. Helminth species (or unidentified taxa) composition and their distribution among hosts from beaver sites and the forest

Class	Family	Helminth species or unidentified taxa	Life cycles	Beaver sites		Forest	
				Myodes glareolus	*Apodemus flavicollis*	*Myodes glareolus*	*Apodemus flavicollis*
Cestoda	*Taeniidae*	*Hydatigera taeniaeformis*	Indirect	+	-	+	-
		Cestoda g. sp.		+	+	+	+
Nematoda	*Capillariidae*	*Capillaria* sp.	Direct	+	-	+	-
	Heligmosomatidae	*Heligmosomum costellatum*		+	+	+	+
		Heligmosomum mixtum		+	+	+	+
	Syphaciidae	*Syphacia montana*		-	+	-	-
		Syphacia petrusewiczi		+	-	+	-
		Syphacia stroma		-	+	-	+
		Syphacia sp.		-	+	-	+
	Trichocephalidae	*Trichocephalus muris*		+	-	+	-
Trematoda	*Plagiorchidae*	*Plagiorchis elegans*	Indirect	-	+	-	+
	Notocotylidae	*Notocotylus noyeri*		+	-	+	-
Total number of helminth species				8	7	8	6

Analyzing particular species of helminths in different seasons, the mean abundance index showed only slight and statistically insignificant differences between habitats (Table 2), except two cases, when *M. glareolus* were more heavily infected by *S. petrusewiczi* at beaver sites than in the forest (Mann-Whitney test: autumn, p = 0.03 and winter, p = 0.02). In other cases, the mean abundance of helminths in *M. glareolus* and *A. flavicollis* were not statistically significant between habitats (Table 2).

Total mean abundance of all parasites in *M. glareolus* showed a higher infection level of this rodent at beaver sites than in the forest, especially in winter (Mann-Whitney test: winter, p = 0.049). A similar tendency was observed in *A. flavicollis* showing higher abundance of all parasites in autumn; however these differences between habitats were not statistically significant (Table 2).

Similarly, analysis of the prevalence of infection did not reveal any significant differences between habitats in different seasons, except in two cases (Table 3). A contrasting pattern of prevalence of infection was found in *M. glareolus* infected by *S. petrusewiczi* and *H. mixtum*. This index of *S. petrusewiczi* in *M. glareolus* in autumn was significantly higher at beaver sites (χ^2 = 9,283, df = 1, p = 0.0023), and prevalence of *H. mixtum* in the same host species and in season was higher in the forest (χ^2 = 6.493, df = 1, p = 0.0108). For the rest of the parasite species differences in infection prevalence between two habitats in different seasons were not significant neither in *M. glareolus* nor *A. flavicollis* (Table 3).

Table 2. Mean abundance of helminths in small rodents at beaver sites and in the forest in different seasons (n – number of dissected individuals of small rodents, B – beaver sites, F – forest)

Helminth species or unidentified taxa	Habitat	*Myodes glareolus* Spring n=23(B) n=22(F)	Summer n=26(B) n=43(F)	Autumn n=66(B) n=80(F)	Winter n=13(B) n=14(F)	*Apodemus flavicollis* Spring n=3(B) n=12(F)	Summer n=8(B) n=18(F)	Autumn n=10(B) n=46(F)	Winter n=0(B) n=6(F)
Capillaria sp.	B	-	-	0.3	-	-	-	-	-
	F	-	-	0.3	-	-	-	-	-
Cestoda g. sp.	B	0.09	0.07	0.1	0.2	0.3	-	0.2	-
	F	0.1	0.2	0.09	0.07	0.3	0.06	0.1	-
Heligmosomum	B	6.3	0.5	1.2	4.2	1.3	0.3	1.0	-
mixtum	F	4.6	1.4	2.8	2.4	3.0	0.7	0.4	4.7
Heligmosomum	B	-	1.0	1.1	-	-	0.3	-	-
costellatum	F	-	2.6	0.8	-	-	0.2	0.4	-
Hydatigera	B	0.09	-	-	-	-	-	-	-
taeniaeformis	F	0.05	-	-	-	-	-	-	-
Notocotylus	B	13.4	0.7	0.08	-	-	-	-	-
noyeri	F	11.0	0.09	0.01	-	-	-	-	-
Plagiorchis	B	-	-	-	-	-	0.4	-	-
elegans	F	-	-	-	-	-	0.2	0.04	-
Syphacia	B	-	-	-	-	-	12.3	2.0	-
montana	F	-	-	-	-	-	-	-	-
Syphacia	B	6.1	18.6	8.9*	9.8*	-	-	-	-
petrusewiczi	F	-	14.2	2.4*	0.1*	-	-	-	-
Syphacia	B	-	-	-	-	-	3.8	1.0	-
stroma	F	-	-	-	-	2.8	11.8	3.6	7.7
Syphacia sp.	B	-	-	-	-	10.7	-	-	-
	F	-	-	-	-	0.3	0.7	4.0	0.5
Trichocephalus	B	0.04	-	0.02	0.08	-	-	-	-
muris	F	-	-	0.01	0.07	-	-	-	-
Totally for all	B	26.0	20.5	12.2	14.2	1.7	16.9	22.5	-
helminth species	F	15.8	18.5	6.6	2.7	6.4	13.6	8.5	12.8

* – statistically significant

Table 3. Infection prevalence (%) of helminths in small rodents at beaver sites (B) and in the forest (F) in different seasons (N - number of dissected individuals of small rodents)

Helminth species or unidentified taxa	Habitat	*Myodes glareolus* Spring n=23(B) n=22(F)	Summer n=26(B) n=43(F)	Autumn n=66(B) n=80(F)	Winter n=13(B) n=14(F)	*Apodemus flavicollis* Spring n=3(B) n=12(F)	Summer n=8(B) n=18(F)	Autumn n=10(B) n=46(F)	Winter n=0(B) n=6(F)
Capillaria sp.	B	-	-	4.5	-	-	-	-	-
	F	-	-	5.0	-	-	-	-	-
Cestoda g. sp.	B	8.7	8.3	3.0	23.1	33.3	-	10.1	-
	F	9.1	20.9	8.8	7.1	33.3	5.6	6.5	-
Heligmosomum	B	43.5	19.2	21.1*	77.0	66.7	12.5	30.0	-
mixtum	F	68.2	32.6	42.5*	57.1	25.0	11.1	13.0	33.3
Heligmosomum	B	-	7.7	9.1	-	-	12.5	-	-
costellatum	F	-	20.9	10.0	-	-	5.6	6.5	-
Hydatigera	B	4.5	-	-	-	-	-	-	-
taeniaeformis	F	4.5	-	-	-	-	-	-	-
Notocotylus	B	17.4	7.7	1.5	-	-	-	-	-
noyeri	F	18.2	2.3	1.3	-	-	-	-	-
Plagiorchis	B	-	-	-	-	-	25.0	-	-
elegans	F	-	-	-	-	-	5.6	2.2	-
Syphacia	B	-	-	-	-	-	25.0	10.1	-
montana	F	-	-	-	-	-	-	-	-
Syphacia	B	13.0	30.8	25.6*	30.8	-	-	-	-
petrusewiczi	F	-	14.0	6.3*	14.3	-	-	-	-
Syphacia	B	-	-	-	-	-	25.0	10.1	-
stroma	F	-	-	-	-	33.3	5.6	13.0	16.7
Syphacia sp.	B	-	-	-	-	33.3	-	-	-
	F	-	-	-	-	16.7	5.6	15.2	16.7
Trichocephalus	B	4.3	-	1.5	7.7	-	-	-	-
muris	F	-	-	1.3	7.1	-	-	-	-
Totally for all	B	73.9	61.5	60.6	76.9	100.0	75.0	50.0	-
helminth species	F	86.4	74.4	70.0	64.3	75.0	33.3	34.8	50.0

* – statistically significant

Total prevalence of all helminths combined (all parasites) also did not differ significantly between the two tested habitats, although there were some differences between two rodent species with respect to this: the percent of infected *M. glareolus* was similar between habitats in all seasons, whereas the percent of infected *A. flavicollis* was somewhat higher (statistically not significant) at beaver sites in all seasons (Table 3).

There were 3 dominant species of helminths in *M. glareolus* and 4 species in *A. flavicollis*. The species abundance patterns of helminth species in *M. glareolus* varied more among seasons but less between the two tested habitats, except in autumn and winter (Table 4). *S. petrusewiczi* dominated in *M. glareolus* at beaver sites in summer, autumn and winter, whereas it was numerically dominant in the forest only in summer. These rodents contained the same dominant helminth species in both tested habitats in spring and summer but not in autumn and winter.

The relative abundance of the helminth domination in *A. flavicollis* was very variable with no single species dominant in the two habitats within one season. *S. montana* was more dominant at beaver sites, whereas *S. stroma* – in the forest (Table 4).

Table 4. Dominant species of helminths (Berger-Parker Dominance Index) in small rodents at beaver sites (B) and in the forest (F) in different seasons

Host species	Dominant helminth species	Spring		Summer		Autumn		Winter	
		B	F	B	F	B	F	B	F
Myodes glareolus	*Heligmosomum mixtum*	-	-	-	-	-	0.43	-	0.89
	Notocotylus noyeri	0.52	0.69	-	-	-	-	-	-
	Syphacia petrusewiczi	-	-	0.89	0.77	0.77	-	0.69	-
Apodemus flavicollis	*Heligmosomum mixtum*	-	0.47	-	-	-	-	-	-
	Syphacia montana	-	-	0.70	-	0.90	-	-	-
	Syphacia stroma	-	-	-	0.87	-	-	-	0.60
	Syphacia sp.	0.86	-	-	-	-	0.46	-	-

The diversity of the helminth community indices for *M. glareolus* were slightly higher at beaver sites (H' = 1.27; infected by 8 helminth species) than in the forest (H' = 1.11; also infected by 8 helminth species). *A. flavicollis* contained a little more diverse helminth community in the forest (H' = 1.17) than at beaver sites (H' = 0.91), helminth species numbers were 7 and 6, respectively (Table 5).

reached peak levels in autumn (H' = 1.31; infected by 7 helminth species). *A. flavicollis* were infected by a more diverse helminth community in the forest compared to beaver sites in spring and in autumn, but not in summer (Table 5).

Habitat differences of common species of helminths among *M. glareolus* were the same in summer, autumn and winter (J = 100.0). The helminths fauna of *A. flavicollis* was the most similar between habitats in spring (J = 75.0) (Table 5).

Distribution of helminths among host individuals has revealed a very contrasting pattern between host species, habitats and among parasite species (Table 6). In many cases, this distribution was aggregated (coefficient of dispersion, CD >>1), but it depended on helminth species or taxon. *Cestoda* g. sp., *Hydatigera taeniaeformis* and *Trichocephalus muris* were distributed randomly or nearly randomly (CD varied from 0.8 to 1.2) in *M. glareolus* with no marked differences between habitats and seasons. The distribution of the other helminths in *M. glareolus* was aggregated (CD > 1) with the highest aggregation of helminths found in *S. petrusewiczi* and *N. noyeri* in summer and spring, in forest (CD = 298.2 and CD = 162.8) and at beaver sites (CD = 123.2 and CD = 113.1), respectively. These aggregation indices were statistically different from 1 ($t > t_{kr}$, $p < 0.05$). The total aggregation of all helminths of *M. glareolus* was higher in the forest (CD = 131.3) than at beaver sites (CD = 81.5).

Table 5. The Shannon-Wiener (H') helminth community indices and Jaccard's similarity coefficient (J) of helminth communities and their seasonal variation in small rodents dwelling at beaver sites and in forest habitat (N – number of dissected individuals of small rodents)

Host species	Beaver sites				Forest				J
	N	Total number of helminths	Number of helminth species	H'	N	Total number of helminths	Number of helminth species	H'	
				Spring					
Myodes glareolus	23	578	6	1.05	22	348	4	0.67	66.7
Apodemus flavicollis	3	37	3	0.47	12	77	4	1.02	75.0
				Summer					
Myodes glareolus	26	517	5	0.29	43	796	5	0.75	100.0
Apodemus flavicollis	8	135	5	0.76	18	244	6	0.56	57.1
				Autumn					
Myodes glareolus	66	796	7	0.93	80	528	7	1.31	100.0
Apodemus flavicollis	10	225	4	0.41	46	392	6	1.09	42.8
				Winter					
Myodes glareolus	13	184	4	0.69	14	38	4	0.34	100.0
Apodemus flavicollis	-	-	-	-	6	77	3	0.81	-
				Total					
Myodes glareolus	128	2075	8	1.27	159	1710	8	1.11	100.0
Apodemus flavicollis	21	397	7	0.91	82	790	6	1.17	85.7

Parasite diversity varied considerably between habitats and among seasons and rodent species. For *M. glareolus*, the biggest difference was between beaver sites and forest in spring, when the helminth community at beaver sites was more diverse (H' = 1.05; infected by 6 helminth species) than in the forest (H' = 0.67; infected by 4 helminth species). With the progression of the seasons, the diversity of the helminth community dropped in summer before then rising again in autumn in *M. glareolus* dwelling at beaver sites. In contrast, at the forest sites it increased in summer but

Similar patterns of variation in the aggregation with habitats, seasons and helminth species, were also observed in *A. flavicollis*. The highest aggregation statistics were found for *S. stroma* in summer in the forest (CD = 212.0) and *S. montana* in autumn at beaver sites (CD = 203.0). These indices were significantly different from 1 ($t > t_{kr}$, $p = 0.003$ and $p = 0.02$, respectively). Overall helminths in *A. flavicollis* were more aggregated at beaver sites (CD = 126.4) than in the forest (CD = 81.3).

Discussion and conclusions

The composition of helminth communities overlapped completely in the two tested habitats for *M. glareolus* (8 species of parasites) and nearly completely in *A. flavicollis* (7 species at beaver sites and 6 species in the forest). Among helminths infecting *M. glareolus*, only *S. petrusewiczi* was significantly more abundant at beaver sites than in the forest. No statistically significant differences were found for helminths of *A. flavicollis* with respect to habitat.

Taking into account total infection of rodents regardless of helminth species, the forest might be considered as a more optimal habitat than the disturbed environments of beaver sites at least for *M. glareolus*, as total mean abundance of parasites was significantly higher for this rodent species at beaver sites in winter. For *A. Flavicollis*, we observed only tendencies towards higher abundance of parasites at beaver sites, these tendencies being more clearly pronounced in autumn. Infection prevalences also revealed a few significant differences between habitats but only in *M. glareolus* involving particular species of parasites, but no difference when all helminth species were pooled together.

During our research some helminth species were not identified to species level but species richness was similar in both small rodent species (8 species in *M. glareolus* and 7 in *A. flavicollis*). At a larger regional scale, many more helminth species are recovered e.g. on the territory of Lithuania, more than 20 helminth species were described parasitizing *M. glareolus* and 10 helminth species found in *A. flavicollis* by Prūsaitė (1988), and 42 in *M. glareolus* and 17 in *A. flavicollis*, respectively, by Mažeika (1992). However, at a local scale helminth species richness can be somewhat lower. In a mountain locality of Serbia, *M. glareolus* were infected by seven species of nematodes (Bjelić-Čabrilo et al. 2009). Eleven species of helminths were found infecting *M. glareolus* in three localities in Northern Poland (Behnke et al. 2001). Similar helminth species numbers were reported for *A. flavicollis* on a local territory (Klimpel et al. 2006). In our research, helminth species fully overlapped in two tested habitats for *M. glareolus* and almost fully for *A. flavicollis*. This finding suggests that the species composition of a helminth community in small rodents at a local scale might not be affected by habitat.

Different species of parasites were sometimes characterized by different patterns of infection in rodent in both habitats tested e.g., the most pronounced differences of infection level (prevalence of infection) of *M. glareolus* by two different species of helminths (*S. petrusewiczi* and *Heligmosomum mixtum*) were different in the two habitats. It might be expected these parasite species having different habitat requirements when infecting the same host species e. g., the crucial factor of reproduction success is humidity for some species of *Syphacia*, and temperature is critical for *Heligmosomum mixtum* (Haukisalmi and Henttonen 1999, Определитель ... 1979). In other studies, the *M. glareolus* infection levels by these two parasites were found to be different in similar habitats from different neighbouring localities (Behnke et al. 2001, Kuliś-Małkowska 2007), indicating probable intrinsic (age, sex) and extrinsic (time, season) factors in both the parasite and the host populations, as well as synergistic and antogonistic interactions between parasite species (Behnke et al. 2005, Ferrari et al. 2003, Ferrari et al. 2004, Kuliś-Małkowska 2007).

We found changes in the numerical composition of helminth communities between habitats. Generally, *S. petrusewiczi* strongly dominated other helminth species in *M. glareolus* at beaver sites, whereas domination of this helminth was much weaker in the forest. For ***A. flavicollis*,** we found completely different dominant species among the two habitats. *S. montana* was strongly dominant at beaver sites but it was not found in mice dwelling in the forest where *S. stroma* dominated.

The domination of one species in a helminth community is rather a common phenomenon and usually one or few species dominate over many other species which are present at low abundance levels (Poulin et al. 2008). Presence or absence of a helminth species may be influenced by abiotic factors to the intermediate hosts (Krasnov et al. 2008), and difference between the species in patterns of helminth domination can be explained by the peculiarities of life cycles in different habitats.

The diversity indices of the helminth community varied considerably among seasons. Nevertheless, we cannot find any regularity in these seasonal patterns that would logically explain differences between habitats. This suggests that parasite diversity varied randomly in both tested habitats.

Our findings did not reveal any obvious differences in parasite distribution among host individuals between habitats and seasons. Parasite distribution among host individuals is determined by many factors (Anderson and Gordon 1982). In our study, helminths of *M. glareolus* and *A. flavicollis*, were mainly aggregated distribution in their host populations (Haukisalmi and Henttonen 1999). The reasons for aggregated distribution in parasites are not well understood and can include: 1) host age at first contact with helminths; 2) social status of host individuals; 3) infection with other helminth species; 4) genetics of host and parasite; 5) diet of host; and, 6) host behavior, as well as many other factors (Anderson 1991). Parasites of small rodents are characterized by an aggregated distribution in host populations, which is considered one of the stabilizing factors of the host-parasite interactions (May and Anderson 1978, Wakelin 1986). In addition, the aggregate distribution of helminths can reduce interactions among helminths (Wakelin 1986).

H. taeniaeformis was found at the larval stage (strobilocercus fasciolaris) in *M. glareolus*. The definitive host of this parasite is a carnivorous mammal but it can also be found in humans. The intermediate host of *H. taeniaeformis* is usually a rodent (Козлов 1977). In Lithuania, this helminth is also found in *Mus musculus*, *Apodemus agrarius*, *A. flavicollis*, *Microtus arvalis*, and *Rattus norvegicus* in Kėdainiai district and Vilnius suburbs (Mažeika 1992), and *Ondatra zibethicus* in Rusnė Island (Mažeika 2009). We did not find any differences at infection levels of this parasite in the bank vole between habitats, and thus beaver sites cannot be regarded as more risky habitats than forests for human or predator health with respect of the *H. taeniaeformis* infection.

Our study revealed differences in some aspects of helminth infection in two forest rodent species (*M. glareolus* and *A. flavicollis*) inhabiting relatively undisturbed forest and beaver sites that intersperse with the forest fragments. This holds true for differences of helminth abundance in *M. glareolus* in winter, as well as helminth community structure (expressed by domination of helminth species) between the two studied habitats for both rodent species. Many other parameters examined were highly variable but did not show significant inequalities between habitats. These findings suggest a rather weak impact of beaver sites on a parasitological state of forest rodent species.

Acknowledgements

We are indebted to dr. V. Mažeika for comments on early drafts of the manuscript and to anonymous referees for valuable remarks and constructive criticism.

References

Anderson, R.M. and Gordon, D.M. 1982. Processes influencing the distribution of parasite numbers within host populations with special emphasis on parasite-induced host mortalities. *Parasitology* 85: 373-398.

Anderson, R. M. 1991. The Eighth Tansley Lecture. Populations and infectious diseases: ecology or epidemiology? *Journal of Animal Ecology* 60: 1-50.

Behnke, J.M., Barnard, C.J., Bajer, A., Bray, D., Dinmore, J., Frake, K., Osmond, J., Race, T. and Sinski, E. 2001. Variation in the helminth community structure in bank voles (*Clethrionomys glareolus*) from three comparable localities in the Mazury Lake District region of Poland. *Parasitology* 123 (4): 401-414.

Behnke, J. M., Barnard, C. J., Mason, N., Harris, P. D., Sherif, N. E., Zalat, S. and Gilbert, F. S. 2000. Intestinal helminths of spiny mice (*Acomys cahirinus dimidiatus*) from St Katherine's Protectorate in the Sinai, Egypt. *Journal of Helminthology* 74: 31-44.

Behnke, J. M., Gilbert, F.S., Abu – Madi, M. A. and Lewis, J. W. 2005. Do the helminth parasites of wood mice interact? *Journal of Animal Ecology* 74: 982-993.

Bjelić-Čabrilo, O.N., Popović, E.J., Šimić, S.D. and Kostić, D.S. 2009. Nematofauna of bank vole – *Clethrionomys glareolus* (Schreber, 1780) – from Mt. Fruška Gora (Serbia). *Archives of Biological Sciences* 61 (3): 555–561.

Bush, A. O., Lafferty K. D., Lotz, J. M., Shostak A. W. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. *Parasitology* 83 (4): 575-583.

Ferrari, N., Cattadori, I. M., Nespereira, J., Rizzoli, A. and Hudson, P. J. 2003. The role of host sex in parasite dynamics: field experiments on the yellow – necked mouse *A. flavicollis*. *Ecology Letters* 6: 1-7.

Ferrari, N., Cattadori, I. M., Nespereira, J., Rizzoli, A. and Hudson, P. J. 2004. The role of host sex in parasite dynamics: field experiments on the yellow – necked mouse *A. flavicollis*. *Journal of Animal Ecology* 74 (50): 982-993.

Ferrari, N. 2005. Macroparasite transmission and dynamics in *A. flavicollis*. PhD – doctorate. University of Stirling, Departement of Biological and Environmental science.

Haukisalmi, V. and Henttonen, H. 1999. Determinants of helminth aggregation in natural host populations: individual differences or spatial heterogeneity? *Ecography* 22: 629-636.

Johnston, C.A. and Naiman, R.J. 1987. Boundary dynamics at the aquatic-terrestrial interface: The influence of beaver and geomorphology. *Landscape Ecology* 1 (1): 47-57.

Juškaitis, R. 1999. Pygmy field mouse (*Apodemus uralensis* Pallas) as a new mammal species in Lithuania. *Acta Zoologica Lituanica* 11 (3): 118-119.

Juškaitis, R., Baranauskas, K., Mažeikyte, R. and Ulevičius, A. 2001. New data on the pygmy field mouse (*Apodemus uralensis*) distribution and habitats in Lithuania. *Acta Zoologica Lituanica* 11 (4): 349-353.

Kershaw, K. A. 1978. Ilościowa i dynamiczna ekologija roślin. Warszawa.

King, S.L. and Antrobus, T.J. 2001. Canopy disturbance patterns in a bottomland hardwood forest in northeast Arkansas, USA. *Wetlands* 21 (4): 543-553.

Klimpel, S., Förster, M. and Schmahl, G. 2006. Parasites of two abundant sympatric rodent species in relation to host phylogeny and ecology. *Parasitology Research* 100 (4): 867-875.

Krasnov, B. R., Korallo – Vinarskaya, N. P., Vinarski, M. V., Shenbrot, G. I., Mouillot, D. and Poulin R. 2008. Searching for general patterns in parasite ecology: host identity versus environmental influence on gamasid mite assemblages in small mammals. *Parasitology* 135: 229-242.

Kuliś-Małkowska, K. 2007. The impact of nematode invasions on the pattern of Cryptosporidium parvum infection in wild rodents. *Wiadomości Parazytologyczne* 53 (3): 251-252, (in Polish with English summary).

Lafferty, K. D., Allesina, S., Arim, M., Briggs, C. J., DeLeo, G., Dobson, A. P., Dunne, J. A., Johnson, P. T., Kuris, A. M., Marcogliese, D. J., Martinez, N. D.,

Memmott, J., Marquet, P. A., McLaughlin, J. P., Mordecai, E. A., Pascual, M., Poulin. R. and Thieltges, D. W. 2008. Parasites in food webs: the ultimate missing links. *Ecology Letters* 11: 533-546.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey.

May, R. M. 1975. Patterns of species abundance and diversity. In *Ecology and Evolution of Communities* (ed. M. L. D. Cody, J. M.). Cambridge, Mass.: Harvard University Press.

May, R.M. and Anderson, R.M. 1978. Regulation and stability of host – parasite population interactions. II destabilizing processes. *Journal of Animal Ecology* 249: 68.

Mažeika, V. 1992. Helminth fauna of mouse rodents in Lithuania. *Ekologija* 4: 53-68.

Mažeika, V., Paulauskas, A. and Balčiauskas, L. 2003. New data on the helminth fauna of rodents of Lithuania. *Acta Zoologica Lithuanica* 13 (1): 41-47.

Mažeika, V., Kontenytė, R. and Paulauskas, A. 2009. New data on the helminths of the muskrat (*Ondatra zibethicus*) in Lithuania. *Estonian Journal of Ecology* 58 (2): 103-111.

Mažeikytė, R., Baranauskas, K., Morkūnas, V. and Mickevičius, E. 1999. Distribution of the sibling vole (*Microtus rossiaemeridionalis* Ognev, 1924; Rodentia, Cricetidae in Lithuania. *Acta Zoologica Lituanica* 9 (1): 3-15.

Montgomery, S. S. J. and Montgomery, W. I. 1989. Spatial and temporal variation in the infracommunity structure of helminths of *Apodemus sylvaticus* (Rodentia: Muridae). *Parasitology* 98: 145-150.

Poulin, R. 1998. Evoliutionary ecology of parasites: from individuals to communities. Chapmen & Hall, London, 212 pp.

Poulin, R., Luque, J.L., Guilhaumon, F. and Mouillo, D. 2008. Species abundance distributions and numerical dominance in gastrointestinal helminth communities of fish hosts. *Journal of Helminthology* 82: 193–202.

Pulido-Flores, G., Moreno-Flores, Sh. and Monks, S. 2005. Helminths of Rodents (Rodentia: Muridae) from Metztitlįn, San Cristóbal, and Rancho Santa Elena, Hidalgo, Mexico. *Comparative Parasitology* 72 (2): 186-192.

Prūsaitė, J. (editor) 1988. Lietuvos fauna: žinduoliai [Fauna of Lithuania: mammals]. Vilnius, Mokslas. 295 pp, (in Lithuanian).

Solonen, T. 2006. Overwinter population change of small mammals in southern Finland. *Annales Zoologici Fennici* 43: 295-302.

Ulevičius, A. 2008. State of the Eurasian beaver (*Castor fiber* L.) population in Lithuania. Agency of Environment Protection, State Service of Protected Areas at Ministry of Environment, Inst. Ecol. of Vilnius University, Report (unpubl.). 52 pp. (In Lithuanian with English summary)

Ulevičius, A. and Janulaitis, M. 2007. Abundance and species diversity of small mammals on beaver lodges. *Ekologija* 53 (4): 38-43.

Wakelin, D. 1986. The role of the immune response in helminth population regulation // Parasitology quo vadid? Proceedings of the Sixth International Congress of Parasitology: 549-557.

Wright, J.P., Jones, C.G. and Flecker, A.S. 2002. An ecosystem engineer, the beaver, increases species richness at the landscape scale. *Oecologia* 132: 96-101.

Ивашкин, В. М., Контримавичус, В. Л. и Макаров, Н. С. 1971 Методы сбора и изучения гельминтов наземных млекопитающих [Helminth sampling and research methods in terrestrial mammals]. Москва, Наука, 123 сс. (in Russian).

Козлов, Д. П. 1977. Определитель гельминтов хищных млекопитающих СССР [Guide of helminths of the carnivore mammals in USSR]. Москва, Наука, 279 сс. (in Russian).

Определитель гельминтов грызунов фауны СССР (Нематоды и акантосефалы) [Guide of helminths of rodent fauna in USSR (Nematodes and Acanthocephalans], 1979. Москва. Наука, 272 сс. (in Russian).

Received 14 May 2011
Accepted 16 November

УРОВЕНЬ ЗАРАЖЕНИЯ ГЕЛЬМИНТАМИ МЕЛКИХ ГРЫЗУНОВ В ДВУХ ПЕРЕМЕЖНЫХ СРЕДАХ ОБИТАНИЯ – В ЛЕСУ И БОБРОВЫХ ПОСЕЛЕНИЯХ

Г. Скириене, А. Улявичюс и А. Самас

Резюме

Уровень заражения гельминтами мелких грызунов (*Apodemus flavicollis* и *Myodes glareolus*) изучали в лесу и бобровых поселениях, в средах, которые тесно перемежаются между собой, а бобровые поселения могут рассматриваться как своеобразные нарушения лесной среды обитания двух типичных мелких грызунов леса. Мы тестировали предположение о том, что бобровые поселения, являясь нарушенными биотопами, могут влиять показатели зараженности гельминтами двух типичных мелких грызунов леса. Видовой состав гельминтов полностью перекрывался между бобровыми поселениями и лесом у *M. glareolus* (8 видов паразитов) и почти полностью у *A. flavicollis* (7 видов в бобровых поселениях и 6 видов в лесу). Анализируя отдельных видов гельминтов, *M. glareolus* были достоверно сильнее заражены только *Syphacia petrusewiczi* в бобровых поселениях нежели в лесу осенью и зимой. Средняя численность всех гельминтов вместе взятых у *M. glareolus* было достоверно выше в бобровых поселениях только зимой, без достоверных различий между биотопами в другие сезоны. У *A. flavicollis* мы не нашли достоверных различий ни по средней численности гельминтов, ни по отдельным видам ни по их совокупности между биотопами. Были отмечены различия по структуре сообщества гельминтов между тестируемыми биотопами. *S. petrusewiczi* сильно доминировало над другими гельминтами у *M. glareolus* в бобровых поселениях летом, осенью и зимою, в то время как в лесу – только летом. У *A. flavicollis* были обнаружены совсем другие домимнанты в сравниваемых биотопах: *Syphacia montana* доминировало в бобровых поселениях, но вообще необнаружено в лесу, где доминантом было *Syphacia stroma*. Небыло выялено существенных различий между биотопами ни по разнообразию гельминтов, ни по их распределению между индивидами хозяев. Эти показатели сильно варьировали между видами хозяев и между сезонами. Наши исследования показали средовые различия только по нескольким аспектам заражения гельминтами двух типичных видов лесных грызунов. Многие другие параметры их заражения были крайне изменчивыми и не показали значимых различий между биотопами. Полученные результаты предполагают скорее слабое влияние бобровых поселений на паразитологический статус здесь обитающих типичных грызунов леса.

Ключевые слова: *Apodemus flavicollis*, *Myodes glareolus*, гельминты, экстенсивность заражения, интенсивность заражения, сезонная динамика, лес, бобровые поселения, нарушение среды обитания.