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Infestation of mice and voles with *Ixodes ricinus* ticks in Lithuania and Norway

Algimantas Paulauskas[a✉], Jana Radzijevskaja[a], Olav Rosef[b], Jurga Turcinaviciene[c], and Daiva Ambrasiene[a]

[a] Department of Biology, Vytautas Magnus University, Vileikos 8, LT-44404 Kaunas, Lithuania
[b] Telemark University College, Hallvard Eikas plass, Bø i Telemark, Norway
[c] Department of Zoology, Vilnius University, M. K. Čiurlionio 21/27, LT-03101 Vilnius, Lithuania
✉ Corresponding author, a.paulauskas@gmf.vdu.lt

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Abstract. A total of 693 small rodents were live-trapped in Lithuania and Norway. In Lithuania, the mice *Apodemus flavicollis* and *A. agrarius* were more frequently infested with ticks than the voles *Microtus arvalis* and *Myodes glareolus*. The overall prevalence of infestation with *Ixodes ricinus* in different sampling locations of Lithuania ranged for *A. flavicollis* from 0% to 92.3%, for *M. glareolus* from 5.9% to 100%, and for *M. arvalis* from 0% to 37.8%. In Norwegian sites the prevalence of infestation was higher for *A. flavicollis* (62.7–98% in different sites) than for *A. sylvaticus* (42.9–77.8%). The most intensive infestation of rodents with *I. ricinus* larvae was observed in May and June. Contrasting patterns of infestation with larvae and nymphs were observed in males and females of *M. glareolus* and *A. flavicollis*.

Key words: small rodent, *Ixodes ricinus*, larvae, nymphs, prevalence of infestation.

INTRODUCTION

Small rodents play an important role in the transmission of many infectious diseases. They harbour viruses, bacteria, protozoans, helminths, and are often infested with ticks. Ticks, who transmit a wide spectrum of pathogenic micro-organisms, are currently considered to be second in importance, surpassed by mosquitoes as vectors of human infectious diseases in the world (Goodman et al., 2005). Over the past two decades, cases of tick-borne zoonoses (like tick-borne encephalitis, Lyme borreliosis, human granulocytic anaplasmosis, babesiosis) have increased and now constitute a major health problem in many parts of Europe and North America. For understanding the ecology of tick-borne zoonosis the interaction among pathogens, vectors, and vertebrate hosts should be investigated. The density and diversity of hosts and their infestation with ticks in particular habitats are important for the evaluation of possible risk in transmission of pathogens and the determination of foci of infection.

Small rodents are important hosts of the immature stages of the tick *Ixodes ricinus* (Acari: Ixodidae). However, not all rodent species are equally heavily infested by immature ticks and rodent infestation rates depend on the particular species of rodent and habitat. Knowledge concerning these abundant zoonotic reservoirs is still limited and scarce in Lithuania and in other European countries. However, results on some studies (Gray et al., 1999; Hanincova et al., 2003; Pawelczyk et al., 2004; Sinski et al., 2006) showed that the bank vole *Myodes glareolus* and the yellow-necked mouse *Apodemus flavicollis* are infested by high numbers of immature stages of ticks. It seems that the abundance of ticks strongly depends on the available host community and abundance of particular rodent species.

The aim of the present study was to investigate the prevalence and intensity of infestation with ticks in different rodent species in certain habitats in Lithuania and Norway and to evaluate the dynamics of host species and ixodid ticks during a season.

MATERIAL AND METHODS

Sampling sites

Small rodents were live-trapped in deciduous mixed forest and ecotonal areas in Lithuania and Norway from June till October 2005–2007. Five sampling sites were chosen in Lithuania and six in Norway (Table 1). Site 1 (Kaunas District),

Table 1. Sampling locations, coordinates, sampling time, and type of biotopes

Site	Location	Lat N	Long E	Sampling time	Biotopes
	LITHUANIA				
1	Kaunas District				
	Kaunas Botanical Garden (KBG)	54°87′	23°90′	2005.06–07 2006.08	Ecotone (fields–deciduous and coniferous trees) in BG park
2	Zarasai District				
	Dusetos	55°75′	25°87′	2006.06	Ecotone (fields–mixed forest)
3	Šilutė District				
	Bložiai	55°38′	21°26′	2005.09	Shrubs
	Kintai	55°42′	21°26′	2006.08 2005.09	Ecotone (fields–mixed forest)
	Muižė	55°39′	21°24′	2006.06, 08	Shrubs
	Ventė	55°34′	21°20′	2005.09	Shrubs
4	Biržai District				
	Biržų giria	56°27′	24°99′	2005.09	Mixed forest, shrubs
5	Vilnius District				
	Skauduliškės	54°51′	25°10′	2006.04–2007.06	Mixed forest
	NORWAY				
6	Stranda	62°03′	06°56′	2005.08	Ecotone (fields–mixed forest)
7	Svanøy	61°28′	05°05′	2005.08	Mixed forest
8	Hinnebu	58°5′	08°28′	2005.08	Mixed forest
9	Tjore	58°19′	08°3′	2005.07–08	Ecotone (fields–mixed forest)
10	Jomfruland	58°52′	09°36′	2006.10	Shrubs
11	Lista	58°7′0″	06°40′	2006.10	Ecotone (fields–spruce forest)

site 2 (Zarasai District), and site 5 (Vilnius District) are situated on the continental area of Lithuania in its central, north-eastern, and south-eastern parts, respectively. Site 3 (Šilutė District) is situated in the coastal area of the Curonian Lagoon in the western part of Lithuania. In site 3 rodents were trapped in four locations: Bložiai, Kintai, Muižė, and Ventė. Site 4 (Biržai District, location Biržų giria) is located in the continental area in the northern part of Lithuania, near the border with Latvia. In Norway, two sampling sites (site 6 – Stranda and site 7 – Svanøy Island) are situated in the coastal zone of western Norway. Three other sampling sites are located in southern Norway: site 8 (Hinnebu) is in the continental area, and sites 9 (Tjore) and 10 (Jomfruland Island) are in the coastal area. Site 11 (Lista) is in the south-eastern part of Norway.

The rodents collected in this study harboured two species of the genus *Ixodes*: *I. ricinus* (larvae and nymphs) and *I. trianguliceps* (larvae). Parasitic mites from the suborder Mesostigmata (Gamasida), family Laelapidae, genus *Laelaps* were also identified.

From the rodents trapped in Lithuania a total of 2408 ticks were collected. Of these 1469 were identified as *I. ricinus* (1329 larvae and 140 nymphs) (Table 2). The rodents trapped in Norway harboured 1657 ticks. From them, 1266 (1172 larvae and 94 nymphs) were *I. ricinus* (Table 3).

Data analysis and statistics

Host infestation by *I. ricinus* was described using the following parasitological indices: prevalence of infestation – percentage of hosts carrying ticks; abundance of infestation – average number of ticks per host considering the entire host population sampled; intensity of infestation *I*min and *I*max – minimum and maximum number of ticks per host; mean intensity of infestation – average number of ticks per tick-infested hosts; and the percentage of hosts infested with infected ticks.

Parameter values were statistically analysed by means of Pearson's X^2 test and the Mann–Whitney U-Test using the statistical package STATISTICA for WINDOWS 5.5.

RESULTS

Infestation of mice and voles with *I. ricinus* ticks in different locations of Lithuania (sites 1–4) and Norway (sites 6–11)

In Lithuania, 90 from 248 (36.3%) rodents carried immature *I. ricinus*. The infestation varied between rodent species. The overall prevalence of infestation with immature stages of *I. ricinus* was 52% for *A. flavicollis*, 40% for *A. agrarius*, 31% for *Microtus arvalis*, and 28% for *Myodes glareolus* (Table 4). The values of abundance and mean intensity of infestation with immature stages of *I. ricinus*

Table 2. Number of small rodents and ticks collected from different rodent species in Lithuania

Location		Rodent species								Total
		Myodes glareolus	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Apodemus agrarius*	*Microtus arvalis*	*Microtus agrestis*	*Mus musculus*	*Rattus norvegicus*	
Kaunas, KBG	No. of rodents	17	34		4	12		1		68
	No. of ticks	1	241		10	12		0		264
	No. of *I. ricinus*	0	68		8	13		0		89
Dusetos	No. of rodents	7	1			37				45
	No. of ticks	8	2			88				98
	No. of *I. ricinus*	4	0			37				41
Bložiai	No. of rodents		2		11					13
	No. of ticks		4		0					4
	No. of *I. ricinus*		0		0					0
Kintai	No. of rodents	7	13		4		1			25
	No. of ticks	125	216		37		0			378
	No. of *I. ricinus*	114	118		36		0			268
Muižė	No. of rodents	15	25		10	4	8			62
	No. of ticks	10	167		11	0	6			194
	No. of *I. ricinus*	4	9		4	0	1			18
Ventė	No. of rodents	1	5						1	7
	No. of ticks	6	13						10	29
	No. of *I. ricinus*	4	3						0	7
Biržų giria	No. of rodents	10	5	1	1	2	9			28
	No. of ticks	3	153	8	3	18	8			193
	No. of *I. ricinus*	1	2	0	2	0	0			5
Skauduliškės	No. of rodents	205	87			3				295
	No. of ticks	508	729			11				1248
	No. of *I. ricinus*	398	632			11				1041
Total	No. of rodents	262	172	1	30	58	18	1	1	543
	No. of ticks	661	1525	8	61	129	14	0	10	2408
	No. of *I. ricinus*	525	832	0	50	61	1	0	0	1469

varied between species of hosts and were different for larval and nymphal ticks (Tables 4, 5). Abundance of infestation with immature *I. ricinus* was higher on *A. flavicollis* (2.4±0.6), a little lower on *M. glareolus* (2.3±1.5), followed by *A. agrarius* (1.7±0.58) and *M. arvalis* (0.9±0.36). Therefore, the mean intensity of infestation was the highest in *M. glareolus* (8±3.6), followed by *A. flavicollis* (4.6±1), *A. agrarius* (4.2±1.1), and *M. arvalis* (2.9±1) (Mann-Whitney U-Test, $P < 0.05$; Table 4). The abundance of larval infestation was highest in *A. flavicollis*; however, that of nymphal infestation was highest in *M. glareolus*. Rodent infestation with *I. ricinus* varied between sampling sites and ranged from 0% to 92% in Lithuania and from 33.3% to 98% in Norway (Fig. 1).

Table 3. Number of small rodents and ticks collected from different rodent species in Norway

Location		Rodent species					Total
		Myodes glareolus	*Apodemus flavicollis*	*Apodemus sylvaticus*	*Microtus agrestis*	*Sciurus vulgaris*	
Stranda	No. of rodents	5	1				6
	No. of ticks	5	4				9
	No. of *I. ricinus*	1	1				2
Svanøy	No. of rodents			9			9
	No. of ticks			36			36
	No. of *I. ricinus*			22			22
Hinnebu	No. of rodents			14			14
	No. of ticks			13			13
	No. of *I. ricinus*			10			10
Tjore	No. of rodents	1		18	1	1	21
	No. of ticks	14		120	5	113	252
	No. of *I. ricinus*	14		51	5	113	183
Jomfruland	No. of rodents		49				49
	No. of ticks		1075				1075
	No. of *I. ricinus*		976				976
Lista	No. of rodents		51				51
	No. of ticks		272				272
	No. of *I. ricinus*		73				73
Total	No. of rodents	6	101	41	1	1	150
	No. of ticks	19	1351	169	5	113	1657
	No. of *I. ricinus*	15	1050	83	5	113	1266

Table 4. Infestation on different species of rodents with immature *I. ricinus* in Lithuania and Norway

	Host species	No. of ticks collected on infested hosts	Prevalence of infestation, % (No. infested/ No. captured)	*I*min–*I*max (intensity of infestation)	Abundance of infestation $\pm s_x$	Mean intensity of infestation $\pm s_x$
Lithuania	*M. glareolus*	128	28 (16/57)	1–46	2.3 ± 1.5	8 ± 3.6
	A. flavicollis	201	52 (44/85)	1–33	2.4 ± 0.6	4.6 ± 1
	M. arvalis	50	31 (17/55)	1–18	0.9 ± 0.36	2.9 ± 1
	A. agrarius	50	40 (12/30)	1–12	1.7 ± 0.58	4.2 ± 1.1
Norway	*A. flavicollis*	1052	79.2 (80/101)	1–108	10.4 ± 1.68	13.15 ± 2
	A. sylvaticus	86	58.5 (24/41)	1–13	2.1 ± 0.5	3.58 ± 0.74

s_x – standard error of the mean.

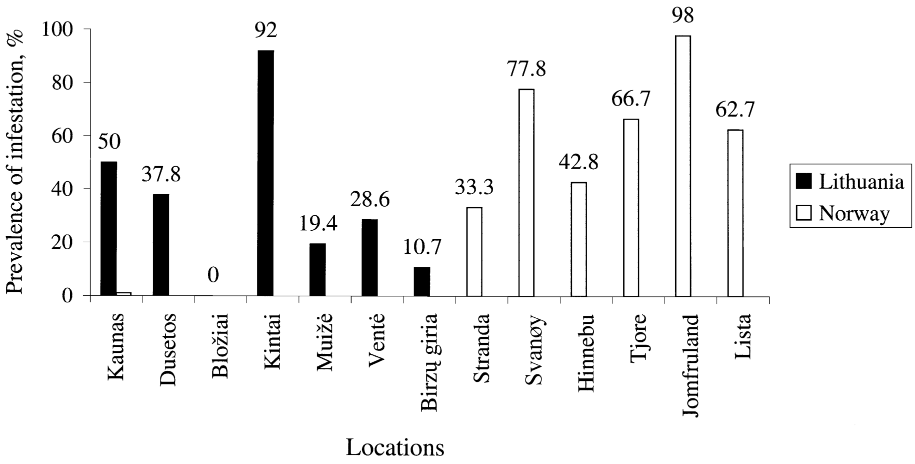

Fig. 1. Prevalence of infestation of rodents with immature stages of *I. ricinus* in Lithuania and Norway.

The highest prevalence of immature stages of *I. ricinus* was found in Kintai (site 3) (Fig. 1). In this location all (100%) of *M. glareolus* and 92.3% of *A. flavicollis* were infested. In Kaunas Botanical Garden (site 1), 73.5% of the *A. flavicollis* were infested with immature *I. ricinus* (Fig. 2). None of the collected rodents was infested with ticks in Bložiai (Fig. 1).

The numbers of immature *I. ricinus* infesting individual hosts are shown in Table 4. In Lithuanian locations the maximum number (*I*max) of immature *I. ricinus* – 46 per host (13 larvae and 33 nymphs) – was found on *M. glareolus*, followed by *A. flavicollis* with 33 per host (25 larvae and 8 nymphs).

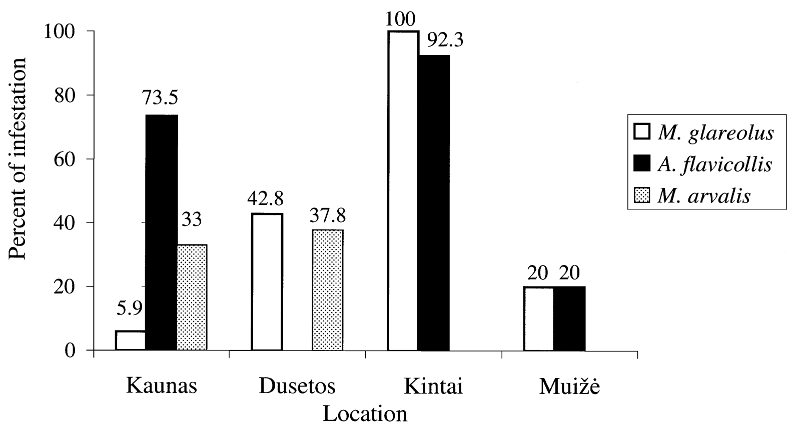

Fig. 2. Infestation rates with immature *I. ricinus* in rodent species by sampling locations in Lithuania.

In Norway, 109 from 150 (72.7%) rodents carried *I. ricinus* larvae and nymphs. The overall prevalence of infestation with immature stages of *I. ricinus* was 79.2% for *A. flavicollis* and 58.5% for *A. sylvaticus* (Table 4). The numbers of immature *I. ricinus* infesting individual hosts in Norwegian locations ranged from 1 to 108 for the yellow-necked mouse *A. flavicollis* and from 1 to 13 for the wood mouse *A. sylvaticus*. The values of abundance and mean intensity of infestation with immature *I. ricinus* were higher on *A. flavicollis* (10.4 ± 1.68 and 13.15 ± 2) than on *A. sylvaticus* (2.1 ± 0.5 and 3.58 ± 0.74) (Mann-Whitney U-Test, $P < 0.05$; Table 4). In Norway, infested rodents were captured in all sampling sites and the prevalence of infestation was quite high in all locations, ranging from 33.3% to 98% (Fig. 1). The most frequently infested were *A. flavicollis* from Jomfruland (prevalence of infestation 98%) followed by *A. sylvaticus* from Svanøy (prevalence of infestation 77.8%).

Two stages of *I. ricinus* were found on trapped rodents: larvae and nymphs. Generally, more rodents were infested with larvae than with nymphs (Table 5). However, of the *M. arvalis* captured in Lithuania a higher percentage were infested with nymphs (20%) than with larvae (18.2%). Moreover, in Lithuania only about 1.5 times more larval *I. ricinus* fed on *M. arvalis* and *M. glareolus* than nymphs. The highest difference in the number of feeding larval and nymphal ticks was found on *A. agrarius* (larva : nymph ratio 49 : 1) (Table 5).

In Norway all three rodent species studied were more frequently infested with larvae than with nymphs (Table 5). Larval ticks feeding on *A. flavicollis* outnumbered nymphal ticks by 31 to 1 and on *A. sylvaticus* by 6.8 to 1. On the red squirrel *Sciurus vulgaris* 66 larvae and 47 nymphs were found.

Seasonal infestation of *M. glareolus* and *A. flavicollis* with *I. ricinus*

The seasonal dynamics of infestation of host species of ticks was evaluated in site 5 (Vilnius District, Skauduliškės). The most intensive infestation of rodents with *I. ricinus* larvae was observed in May and June (Fig. 3).

In autumn rodents' infestation with ticks decreased. It could be explained by a dilution effect due to the increasing abundance of rodents in autumn. The great deviation in spring 2007 reflects some sporadical infected individuals (one *A. flavicollis* adult had 64 larvae). In 2007 infestation was noticed a month earlier than in 2006. It could be related to the much warmer winter and earlier spring in 2007. Statistically, infestation was not significant (Mann-Whitney U-Test, $p = 0.855$). Infestation of rodents with *I. ricinus* nymphs was at the same level all the seasons and no differences in activity were noticed.

Infestation of rodents with *I. trianguliceps* was rather low. Larvae were collected from rodents at the end of summer and in autum, while females and nymphs were found in all seasons. Even a few males of this species were found on rodents, although they usually do not infest rodents. *Ixodes trianguliceps* mostly infested *M. glareolus*. Other (not Ixodidae) ticks were active in springtime while in summer and autumn infestations were only sporadic.

Table 5. The larvae to nymphs ratio of *I. ricinus* on different species of rodents from Lithuania and Norway

	Rodent species	No. collected		Larvae : nymphs ratio	Prevalence of infestation, % (No. infested/No. captured)		Abundance of infestation $\pm s_x$		Mean intensity of infestation $\pm s_x$	
		Larvae	Nymphs		Larvae	Nymphs	Larvae	Nymphs	Larvae	Nymphs
Lithuania	*M. glareolus*	78	50	1.56 : 1	24.6 (14/57)	10.5 (6/57)	1.7 ± 0.57	0.9 ± 0.6	4.87 ± 1.8	3.1 ± 2.08
	A. flavicollis	180	21	8.57 : 1	48.2 (41/85)	10.6 (9/85)	2.1 ± 0.47	0.25 ± 0.1	4.1 ± 0.83	0.48 ± 0.23
	M. arvalis	30	20	1.5 : 1	18.2 (10/55)	20 (11/55)	0.53 ± 0.2	0.4 ± 0.14	1.7 ± 0.6	1.2 ± 0.4
	A. agrarius	49	1	49 : 1	40 (12/30)	3.3 (1/30)	1.7 ± 0.56		4.8 ± 1.08	
Norway	*A. flavicollis*	1017	33	31 : 1	77.2 (78/101)	22.8 (23/101)	10.1 ± 1.6	0.3 ± 0.07	12.7 ± 1.98	0.4 ± 0.08
	A. sylvaticus	75	11	6.8 : 1	53.6 (22/41)	17.1 (7/41)	1.88 ± 0.4	0.27 ± 0.1	3.4 ± 65	0.48 ± 0.2
	S. vulgaris	66	47	1.4 : 1						

s_x – standard error of the mean.

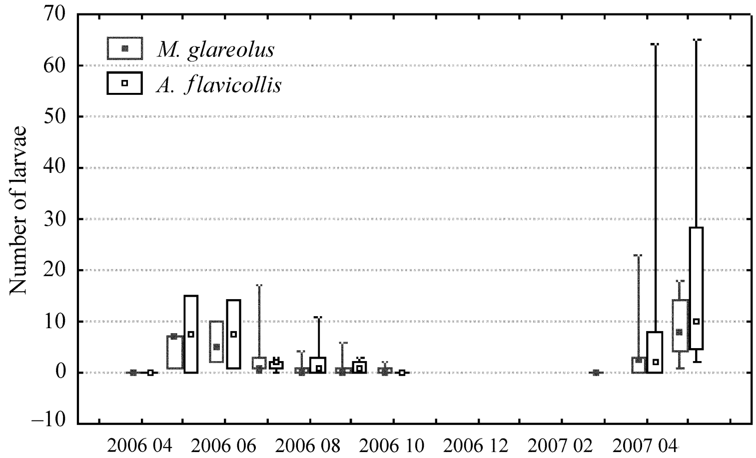

Fig. 3. Infestation with larvae of *I. ricinus* in *M. glareolus* and *A. flavicollis* (median, 25%–75% quartiles, min–max).

Infestation rates with larvae of *I. ricinus* in *M. glareolus* and *A. flavicollis*

The average level of tick infestation in rodents appeared to decrease from spring to autumn. Although *M. glareolus* was more abundant, *A. flavicollis* was on average more infested ($p = 0.000004$). However, there was no difference in the infestation of these two species when data were compared every month (Mann-Whitney U-Test, $P > 0.5$) (Fig. 3).

Abundance of infestation in *M. glareolus* and *A. flavicollis* in different sex categories

Contrasting patterns of infestation with larvae and nymphs were observed in males and females of *M. glareolus* and *A. flavicollis*. Males of *M. glareolus* were infested by 1 to 3 larvae or nymphs mostly (some with 24 ticks), while *A. flavicollis* had from 1 to 9 ticks, some individuals even 67 ticks. Females of *A. flavicollis* also showed various distribution patterns (some individuals had 33 ticks) and were infested more than *M. glareolus*, although these differences were not significant. However, the seasonal dynamics of infestation of *M. glareolus* showed significant differences between males and females in spring 2007 (Fig. 4).

During the spring of 2007 *M. glareolus* males were mostly infested with 3 to 6 larvae, while females had mostly from 1 to 3 ticks. This pattern reflects the population structure of these species: in spring most individuals are adults, and males and females have different homeranges. The homerange of males increased with age and maturation, and this behavioural difference could be reflected as differences in infestation.

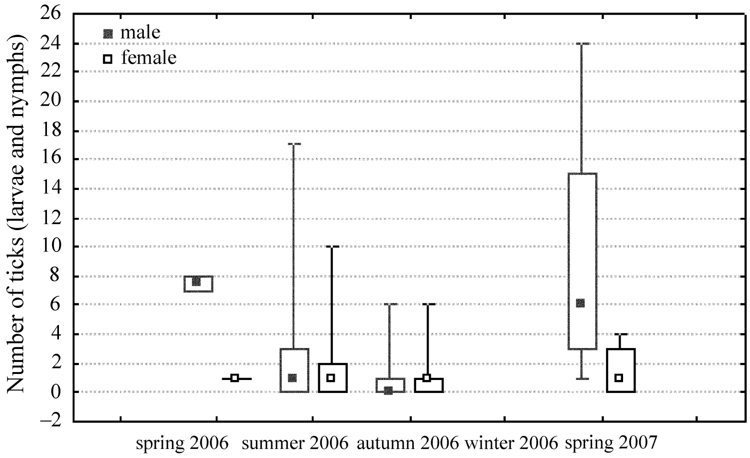

Fig. 4. Abundance of infestation of *M. glareolus* in different seasons (median, 25%–75% quartiles, min–max).

Infestation of *M. glareolus* and *A. flavicollis* with immature *I. ricinus* in different age classes

The abundance of larvae and nymphs was higher on adult *M. glareolus* during most seasons, but statistically significant differences were found between the infestation of adults and subadults only in autumn (Fig. 5). For *A. flavicollis* however the pattern of infestation was very homogeneous during all seasons.

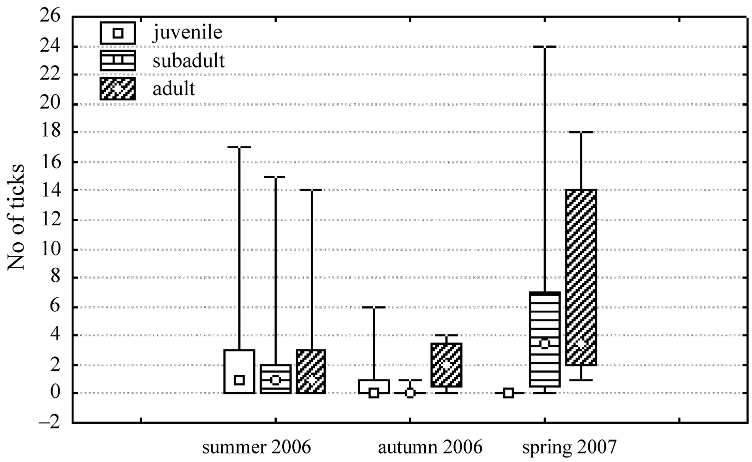

Fig. 5. Infestation of *M. glareolus* with different stages of *I. ricinus* (median, 25%–75% quartiles, min–max).

DISCUSSION

Ecological studies on tick-borne bacterial diseases conducted in Europe have shown that some mammal and bird species frequently infested by *I. ricinus* transmit infection to ticks (Humair & Gern, 2000). Usually *I. ricinus* larvae and nymphs feed on insectivorous rodents, reptiles, and birds; adults feed on medium-sized to large wild and domestic animals. Generally, habitat also influences host selection, because ticks that are adapted to a certain habitat or vegetation type will encounter vertebrates adapted to the same habitat (Parola & Raoult, 2001).

Knowledge on the seasonal pattern of ticks attached on hosts is rather limited. The seasonal occurrence of *I. ricinus* on hosts varies among tick stages and host species. According to data from Switzerland, *I. ricinus* larvae on rodents peaks in May–June and in August–September with a summer depression in July (Humair et al., 1999), whereas the number of larvae per bird is almost constant throughout the season with a slight increase in August (Gern & Rais, 1996). According to these studies, *I. ricinus* nymphs are not abundant on rodents and can be found without any real peak in May, July, August, and October whereas on birds nymphs are abundant and peak in April–May (Gern & Rais, 1996). Our data confirmed that the most intensive infestation with larvae was observed in May and June, but no autumn peak of activity was detected. The possible reason is that in autumn infestation grows in parallel with the increasing number of rodents and a dilution effect appears.

Small rodents are known to be the main hosts for larvae of *I. ricinus* in many forest ecosystems (Matuschka et al., 1992). However, not all rodent species are equally heavily infested by immature ticks. The *Apodemus* mice and *Microtus* voles are known to be more abundantly parasitized with ticks than the *Myodes* voles (Humair et al., 1993). Our study indicated that both mice and voles trapped in Lithuania and Norway hosted immature stages of *I. ricinus*, *I. trianguliceps* ticks, and also mites from the genus *Laelaps*.

In Lithuania, the captured mice *A. flavicollis* and *A. agrarius* were found to be more frequently infested with immature *I. ricinus* than the voles *M. arvalis* and *M. glareolus*. The data are similar to findings of some other studies from Europe (Kurtenbach et al., 1995; Gray et al., 1999; Humair et al., 1999; Randolph et al., 1999; Hanincova et al., 2003; Sinski et al., 2006). We found that prevalence of infestation with *I. ricinus* larvae was approximately two times higher in *A. flavicollis* mice than in *M. glareolus* voles and two times higher on *A. agrarius* mice than in *M. arvalis* voles. However, as shown in Table 5, in Lithuania the prevalence of infestation with *I. ricinus* nymphs was highest for *M. arvalis* followed by *A. flavicollis*, *M. glareolus*, and *A. agrarius*. Although *A. flavicollis* were the most frequently infested with immature stages of *I. ricinus* and on average more larvae parasitized on *A. flavicollis* than on *M. glareolus*, *M. glareolus* were more intensively infested with ticks than *A. flavicollis*. The highest number of *I. ricinus* ticks on an individual rodent was detected in *M. glareolus*. Similarly to our study, in north-central Spain *M. glareolus* was found to be more intensively parasitized by tick larvae than *A. sylvaticus* (Estrada-Peña et al., 2005). However, according to other European studies, greater numbers of *I. ricinus* larvae and nymphs parasitize on *Apodemus* mice than on bank voles (Nilsson & Lundqvist, 1978; Matuschka et al., 1994; Humair et al., 1993; Kurtenbach et al., 1995; Talleklint & Jaenson, 1997; Sinski et al., 2006). Nevertheless, infestation rates with larvae of *I. ricinus* in *M. glareolus* and *A. flavicollis* when compared on monthly basis were not statistically significant. Although *M. glareolus* was the more abundant species at site, *A. flavicollis* was more infested. Data showed that *A. flavicollis* was more active in spring, during the activity peak of *I. ricinus*, while the population of *M. glareolus* increased during summer and was most abundant in the autumn when the abundance of ticks also increased.

In Norway, the largest part of captured rodents consisted of *A. sylvaticus* followed by *A. flavicollis*, which are known to be the most abundant rodents in woodland habitats in western and southern Norway (Mehl, 1983). The most frequently infested with ticks rodents were *A. flavicollis*. The *A. flavicollis* captured in Norway were found to be three times more intensively infested than those captured in Lithuania. Such differences may be related to the wide distribution of wooded areas in Norway.

The overall prevalence of infestation with larval *I. ricinus* for *A. flavicollis* and *M. glareolus* reported for Poland (84.5–92% and 80–76%, respectively) (Pawelczyk et al., 2004; Sinski et al., 2006) and western Slovakia (73% and 62%) (Hanincova et al., 2003) was higher than in Lithuania. However, the prevalence of nymphal infestation for these rodent species in these studies is consistent with the results obtained in Lithuania. The prevalence of infestation for *M. arvalis* obtained in Lithuania was similar to that reported for north-eastern Poland (Sinski et al., 2006). The larval infestation on *A. flavicollis* (77.2%) in Norway was similar to that in Poland and western Slovakia (Hanincova et al., 2003; Pawelczyk et al., 2004; Sinski et al., 2006).

The larvae : nymphs ratios on rodent species collected in Lithuania (1.56 : 1; 8.57 : 1; 1.5 : 1) and in Norway (31 : 1, 6.8 : 1) contrast to the findings from Spain (451 : 1) (Estrada-Peña et al., 2005) and from Ireland (754 : 1) (Gray et al., 1999) where rodents were many more times infested with larvae than with nymphs. In North America, however, 3.5 times more larvae of *I. scapularis* feed on small rodents than nymphs (Spielman et al., 1984). The larvae : nymphs ratios recorded in a study conducted in Sweden were 37.8 : 1, 42.5 : 1, and 37.8 : 1 for *M. glareolus*, *A. sylvaticus*, and *A. flavicollis*, respectively (Talleklint & Jaenson, 1997).

In Lithuania, prevalence of rodent infestation with *I. ricinus* varied not only between host species, but also between sampling sites and was highest in ecotones (Kintai and Kaunas Botanical Garden Park) where adult ticks and other *I. ricinus* hosts, such as birds and lagomorphs, were abundant. In Norway, the highest rodent infestations were detected in the islands of Jomfruland and Svanøy (Fig. 1).

The higher prevalence of infestation with immature *I. ricinus* ticks on mice than on *M. glareolus* voles has been explained by a host preference by larvae (Nilsson & Lundqvist, 1978) or because *M. glareolus* acquires resistance to

I. ricinus (Dizij & Kurtenbach, 1995). The observed differences in tick infestation on rodent species are related to a balance between the larval questing activity and the abundance of hosts according to the season of the year.

Our study supports previous studies on the importance of *Apodemus* mice and *Myodes* voles in the ecology of immature stages of *I. ricinus* (Humair et al., 1999; Hanincova et al., 2003). Each rodent species showed different infestation, some age and sex differences within the host species were also noticed. The relative contribution of each rodent species as a reservoir could be measured by infestation of each rodent species and could be assessed by further studies.

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REFERENCES

Dizij, A. & Kurtenbach, K. 1995. *Clethrionomys glareolus*, but not *Apodemus flavicollis*, acquires resistance to *Ixodes ricinus* L., the main European vector of *Borrelia burgdorferi*. *Parasite Immunol.*, **17**, 177–183.

Estrada-Peña, A., Osacar, J., Pichon, B. & Gray, J. 2005. Hosts and pathogen detection for immature stages of *Ixodes ricinus* (Acari: Ixodidae) in North-Central Spain. *Exp. Appl. Acarol.*, **37**, 257–268.

Gern, L. & Rais, O. 1996. Efficient transmission of *Borrelia burgdorferi* between cofeeding *Ixodes ricinus* ticks (Acari: Ixodidae). *J. Med. Entomol.*, **33**, 189–192.

Goodman, J. L., Dennis, D. T. & Sonenshine, D. E. (eds) 2005. *Tick-borne Diseases of Humans*. ASM Press, Washington, DC.

Gray, J., Kirstein, F. & Robertson, J. 1999. *Borrelia burgdorferi* sensu lato in *Ixodes ricinus* ticks and rodents in a recreational park in south-western Ireland. *Exp. Appl. Acarol.*, **23**, 717–729.

Hanincova, K., Schafer, S., Etti, S., Sewell, H., Taragelova, V., Ziak, D., Labuda, M. & Kurtenbach, K. 2003. Association of *Borrelia afzelii* with rodents in Europe. *Parasitology*, **126**, 11–20.

Humair, P. F. & Gern, L. 2000. The wild hidden face of Lyme borreliosis in Europe. *Microb. Infect.*, **2**, 915–922.

Humair, P., Turrian, N., Aeschlimann, A. & Gern, L. 1993. *Borrelia burgdorferi* in a focus of Lyme borreliosis: epizootiologic contribution of small mammals. *Folia Parasitol.*, **40**, 65–70.

Humair, P. F., Rais, O. & Gern, L. 1999. Transmission of *Borrelia afzelii* from *Apodemus* mice and *Clethrionomys* voles to *Ixodes ricinus* ticks: differential transmission pattern and overwintering maintenance. *Parasitology*, **118**, 33–42.

Kurtenbach, K., Kampen, H., Dizij, A., Arndt, S., Seitz, H. M., Schaible, U. E. & Simon, M. M. 1995. Infestation of rodents with larval *Ixodes ricinus* (Acari: Ixodidae) is an important factor in the transmission cycle of *Borrelia burgdorferi s.l.* in German woodlands. *J. Med. Entomol.*, **32**, 807–817.

Matuschka, F. R., Fischer, P., Heiler, M., Blümcke, S. & Spielman, A. 1992. Stage-associated risk of transmission of the Lyme disease spirochete by European *Ixodes* ticks. *Parasitol. Res.*, **78**, 695–698.

Matuschka, F. R., Eiffert, H., Ohlenbusch, A. & Spielman, A. 1994. Amplifying role of edible dormice in Lyme disease transmission in central Europe. *J. Infect. Dis.*, **170**, 122–127.

Mehl, R. 1983. The distribution and host relations of Norwegian ticks (Acari, Ixodides). *Fauna Norv., Ser. B*, **30**, 46–51.

Nilsson, A. & Lundqvist, L. 1978. Host selection and movements of *Ixodes ricinus* (Acari) on small mammals. *Oikos*, **31**, 313–322.

Parola, P. & Raoult, D. 2001.Tick-borne bacterial diseases emerging in Europe. *Clin. Microbiol. Infect.*, **7**(2), 80–83.

Pawelczyk, A., Ogrzewalska, M., Zadrozna, I. & Sinski, P. 2004. The zoonotic reservoir of *Borrelia burgdorferi* sensu lato in the Mazury Lakes district of North-Eastern Poland. *Int. J. Med. Microbiol.*, 293, Suppl. **37**, 167–171.

Randolph, S. E., Miklisova, D. & Lysy, J. 1999. Incidence from coincidence: patterns of tick infestations on rodents facilitate transmission of tick-borne encephalitis virus. *Parasitology*, **118**, 177–186.

Sinski, E., Pawelczyk, A., Bajer, A. & Behnke, J. 2006. Abundance of wild rodents, ticks and environmental risk of Lyme borreliosis: a longitudinal study in an area of Mazury Lakes district of Poland. *Ann. Agric. Environ. Med.*, **13**, 295–300.

Spielman, A., Levine, J. F. & Wilson, M. L. 1984. Vectorial capacity of North American *Ixodes* ticks. *Yale J. Biol. Med.*, **57**(4), 507–513.

Talleklint, L. & Jaenson, T. G. T. 1997. Infestation of mammals by *Ixodes ricinus* ticks (Acari: Ixodidae) in south-central Sweden. *Exp. App. Acarol.*, **21**, 755–771.

Hiirlaste ja uruhiirlaste nakatumus puugiga *Ixodes ricinus* Leedus ning Norras

Algimantas Paulauskas, Jana Radzijevskaja, Olav Rosef,
Jurga Turcinaviciene ja Daiva Ambrasiene

Uuriti 693 Leedus ja Norras eluslõksudega püütud pisinärilist. Hiirlased – kaelushiir (*Apodemus flavicollis*) ja juttselghiir (*A. agrarius*) – olid puukidega nakatunud sagedamini kui uruhiirlased: põld-uruhiir (*Microtus arvalis*) ning leethiir (*Myodes glareolus*). Nakatunud isendite protsent kõikides uurimispaikades kokku oli kaelushiirel 0–92,3%, leethiirel 5,9–100% ja põld-uruhiirel 0–37,8%. Norras oli nakatunud isendite protsent kaelushiirtel kõrgem (62,7–98%) kui metshiirtel (*A. sylvaticus*, 42,9–77,8%). Kõige intensiivsem nakatumus *I. ricinus*'e vastsetega oli registreeritud närilistel mais ja juunis. Kahel liigil, leethiirel ja kaelushiirel, olid tuvastatud puugi vastsete ning nümfidega nakatumuse sugulised erinevused.