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ORIGINAL ARTICLE

Communities of ectoparasitic arthropods associated with the root vole *Microtus oeconomus* in north-eastern Poland

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Abstract

Ectoparasitic arthropods communities associated with root voles *Microtus oeconomus* (Pallas, 1776) were analysed in north-eastern Poland. The first *M. oeconomus* parasites recorded in the history were the fleas *Palaeopsylla similis* Dampf, *Ctenophthalmus congerer* Rothschild, *C. bisoctodentatus* Kolenati, and *C. solutus* Jordan et Rothschild. *Ctenophthalmus uncinatus* (Wagner) and *Doratopsylla dasycnema* (Rothschild) fleas and the *Ixodes apronophorus* Schulze tick were recorded on *M. oeconomus* in Poland for the first time. These species are relatively rare in Poland and specific to other species of small mammals. The incidence of *M. oeconomus* infestations with *I. apronophorus*, *D. dasycnema* and *C. uncinatus* ranged from 0.5 to 0.8 %, respectively. There are large differences in the infestation of *Dermacentor reticulatus* larvae and nymphs between July and August. In July, *D. reticulatus* may be considered the dominant ectoparasite species, in August, it is partly replaced by *I. ricinus* and fleas and is subdominant.

Keywords *Microtus oeconomus* · Ticks · Fleas · Lice · Mesostigmata

Introduction

The root vole *Microtus oeconomus* (Pallas, 1776) belongs to the most widespread members of the Cricetidae family. The root vole is a medium-sized rodent characterized by short ears and a short tail. Its fur is yellowish brown with lighter sides and silvery white on the ventral side. Its size is 92–135 mm, body weight 23–48 g. The preferred habitats of this species are moist fields and meadows, and wet forests. It digs burrows and is able to build nests above the ground in bushes or grass (Pucek 1981).

The root vole is a boreal species; the contiguous area in Europe does not extend south of the 50° latitude. It is found in the northern and central parts of Europe, from the Scandinavian Peninsula to the Pyrenees, Alps and Carpathians in the south, throughout Eastern Europe, Siberia and the northern parts of Mongolia and China. In the Nearctic Region, it occurs in the north-western part of North America, including Alaska and in the northwest of Canada (Pucek 1981; Brunhoff et al. 2003). Within the widespread distribution area, six distinct subspecies and 30 subspecies of this vole have been described in Europe (Lance and Cook 1998) and worldwide (Shenbrot and Krasnov 2005), respectively. Apart from the adjacent area of occurrence in Europe, there are isolated populations of root voles in the Netherlands, Norway, Finland, and Central Europe (Austria, Hungary, Slovakia) below the 50° latitude, considered as relict populations from the last glaciation (Racz et al. 2005; Thissen et al. 2015; Hulejová Sládkovičová et al. 2018).

Rodents host many parasites: arthropods, helminths and protozoa. The structure of the communities of parasites, pathogens and the other accompanying organisms in the root vole is determined by the wide distribution of this species and also depends on local conditions and the structure of the habitat. Among the pathogens found in the root vole there are causative agents of zoonoses in humans and pets, such as *Babesia microti* (França, 1912), *Borrelia burgdorferi* Johnson et al., 1984, *Anaplasma phagocytophilum* (Foggie, 1949), tick-borne encephalitis (TBE) virus, and others (Fay and Rausch 1969; Karbowiak 2004; Karbowiak et al. 2005,

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2016; Grzeszczuk et al. 2006). The group of non-pathogenic or low pathogenic parasites is also large and comprise, e.g., *Trypanosoma microti* Laveran and Pettit, 1909, *Hepatozoon microti* Coles, 1914, and *Bartonella* spp. (Karbowiak et al. 2005; Tołkacz et al. 2018). An important group of rodent parasites are blood-sucking arthropods. These include fleas, lice, poorly investigated mesostigmatic mites and ixodid ticks. They are a component of the parasite fauna of every small mammal, including *M. oeconomus*. These arthropods are closely related to their hosts and their existence depends on mammals, while at the same time being external parasites they are influenced by environmental factors. Thus, the structure of the groups of arthropods associated with a single mammalian species such as the root vole may vary across several geographic locations.

Blood-sucking arthropods are vectors of many pathogens, such as viruses (TBE virus), rickettsiae, bacteria (*Borrelia* spp., *A. phagocytophilum*) and parasitic protozoa mentioned above (*Hepatozoon* sp., *Trypanosoma* sp.). In addition to blood-sucking arthropods, an important group are small, free-living mites associated with rodent nests. These are predators, sarcophagi, phoretic species, etc., which can sometimes be facultatively hematophagous. The species associated with the nests are the subject of extensive research, but some aspects of their biology and their interactions with other organisms are poorly understood (Mašán and Stanko 2005; Krawczyk et al. 2015). In this study, we examined the composition of ticks, gamasid mites, fleas and lice communities infesting the root vole *M. oeconomus* in north-eastern Poland.

Studies on the fauna of ectoparasites of mammals are usually carried out conventionally by focusing on a selected group - fleas, ticks, or mites. On the contrary, this study is comprehensive, and its aim is to present a complete grouping of all arthropods associated with a mammal.

Materials and methods

Long-term studies of the fauna of external arthropods associated with *M. oeconomus* were carried out in the Białowieża Primeval Forest in 2004, 2005 (August), 2006 (July), 2007 (July) and 2008 (August), along the southern border of the Białowieża National Park (52˚42'29" N, 23˚52'42" E) and in Śmietki Małe (53˚48'55" N, 21˚26'03" E, commune of Mikołajki, Masurian Lake District) in 2009 and 2010 (August). Small mammals were caught live in seed baited traps. Live traps were set randomly overnight along transects and checked each morning and evening. Arthropods were brushed from the fur of the mammals and harvested from the trap material (grain residues, faeces, contaminants carried in by the animal), and then preserved in 70 % ethanol. After the parasites were harvested and examined, the mammals were released. Small mites and tick larvae were mounted in Berlese liquid; adult ticks, lice and fleas were identified immediately under a stereoscope and microscope, or, if necessary, embedded in Canadian balsam. Then the arthropods were identified by using the appropriate identification keys (Skuratowicz 1967; Bregetova 1977; Siuda 1993; Mašán and Fenďa 2010).

The structure of tick communities was characterised by the prevalence and intensity of infestation, the factors commonly used in the description of parasitocenoses. According to Bush et al. (1997) and Czachorowski (2004), parasites occurring in more than 10 % of hosts were considered dominant; subdominants showed a prevalence in the range of 5–10 %. Moreover, these parasites were present at every study site and during each round of studies. As accessory species are considered arthropods occurring in less than 5 % of the voles, or slightly more. Rare species were found in less than 0.8 % of all voles, however, they were present in most of the sites and during most field excursions. Replicated goodness-of-fit test (G-statistic) (Sokal and Rohlf 1995) was used to compare the levels of vole infestation with ticks between months.

Results

In total, 374 individuals of *M. oeconomus* voles were examined. The ectoparasites found were Ixodidae (3 species), Mesostigmata (6 species), Siphonaptera (13 species) and Anoplura (1 species). The prevalence of infestation in particular years and localities is presented in Table 1.

Dominants - the most common parasites, over 10 % infested voles – were the fleas *Megabothris walkeri* (Rothschild, 1902), *Ctenophthalmus agyrtes* (Heller, 1896), *Hystrichopsylla orientalis* Smit, 1965, two species of ticks - *Dermacentor reticulatus* Fabricius, 1794 (larvae and nymphs), and *Ixodes ricinus* Linnaeus, 1758 (larvae and nymphs). The prevalence of infestation (in percentages) with these parasites was 26.1–66.7 (mean 31.6), 16.7–88.9 (mean 26.5), 5.6–23.8 (mean 20.6), 6.5–100.0 (mean 13.9), 3.9–61.1 (mean 11.0), respectively. These parasites were found on *M. oeconomus* voles in all locations and at almost every study visit and can be considered a persistent component of the parasite fauna of this rodent.

The second group – subdominants – consisted of parasites, which are less common, but they occurred everywhere and at almost every visit. They included the flea *Megabothris turbidus* (Rothschild, 1909), and the mites *Haemogamasus nidi* Michael, 1892, *Haemogamasus ambulans* (Thorell, 1872) and *Macrocheles glaber* (Műller, 1860). The prevalence of these species in percentages was 2.0–22.2

Table 1 Ectoparasitic arthropods found on root voles *Microtus oeconomus* from north-eastern Poland

	Drt	Irc	Iap	Hys	Met	Mwl	Cag	Csl	Cas	Ccn	Cbs	Eun	Dds	Psr	Psm	Pbd	Par	Han	Hhl	Ham	Mgl	Hop
Białowieża 2004																						
N = 153 n:	10	6		31	3	40	30	1	7	1	3			2	1		2	1	2	1	1	2
p%	6.5	3.9		20.3	2.0	26.1	19.6	0.7	4.6	0.7	2.0			1.3	0.7		1.3	0.7	1.3	0.7	0.7	1.3
Białowieża 2005																						
N = 164; n:	13	16		39	21	56	50	8	9		4	1		5	3	6	4	5	3		1	3
p%	7.9	9.8		23.8	12.8	34.1	30.5	4.9	5.5		2.4	0.6		3.1	1.8	3.7	2.4	3.0	1.8		0.6	1.8
Białowieża 2006																						
N = 9; n:	6	4		2	1	4	3		1								2	4		2	1	
p%	66.7	44.4		22.2	11.1	44.4	33.3		11.1								22.2	44.4		22.2	11.1	
Białowieża 2007																						
N = 9; n:	9	4	1		1	6	8		1				1			1		2		1	1	1
p%	100.0	44.4	11.1		11.1	66.7	88.9		11.1				11.1			11.1		22.2		11.1	11.1	11.1
Białowieża 2008																						
N = 19; n:	6			1	4	6	5				1						3	6	1	3	1	2
p%	33.3			5.6	22.2	33.3	27.8				5.6						15.8	31.6	5.3	15.8	5.3	10.5
Śmietki 2009																						
N = 2; n:	2					1				1			1									
p%	100.0					50.0				50.0			50.0									
Śmietki 2010																						
N = 18; n:	6	11	1	4	4	5	3		4			1						2		1	1	2
p%	33.3	61.1	5.6	22.2	22.2	27.8	16.7		22.2			5.6						11.1		5.6	5.6	11.1
In total																						
N = 374; n:	52	41	2	77	34	118	99	9	23	2	8	3	2	7	4	7	10	21	5	9	6	10
p%	13.9	11.0	0.5	20.6	9.1	31.6	26.5	2.4	6.1	0.5	2.1	0.8	0.5	1.9	1.1	1.9	2.7	5.6	1.3	2.4	1.6	2.7

Abbreviations: N – total number of voles investigated in a given year and locality; n – number of voles infested with a given ectoparasite; p% – prevalence in %, Cag – *C. agyrtes*; Cas – *C. assimilis*; Cbs – *C. bisoctodentatus*; Ccn – *C. congerer*; Csl – *C. solutus*; Dds – *D. dasycnema*; Drt – *D. reticulatus*; Eun – *C. uncinatus*; Hhl – *H. hirsutosimilis*; Ham – *H. ambulans*; Han – *H. nidi*; Hop – *H. acanthopus*; Hys – *H. orientalis*; Iap – *I. apronophorus*; Irc – *I. ricinus*; Met – *M. turbidus*; Mgl – *M. glaber*; Mwl – *M. walkeri*; Pbd – *P. bidentata*; Par – *P. oudemansi*; Psm – *P. similis*; Psr – *P. soricis*.

(mean 9.1), 0.7–44.4 (mean 5.6), 0.7–22.2 (mean 2.4) and 0.6–11.1) (mean 1.6), respectively.

The third group – accessory species – consisted of less common parasites that were present at least in some sites and visit. Here belonged the fleas *Ctenophthalmus assimilis* (Taschenberg, 1880), *Ctenophthalmus bisoctodentatus* Kolenati, 1863, *Ctenophthalmus uncinatus* (Wagner, 1898), the mites *Haemogamasus hirsutosimilis* Willmann, 1952, *Parasitus oudemansi* (Berlese, 1903), and the louse *Hoplopleura acanthopus* (Burmeister, 1839). The prevalence (in percentages) of these parasites was 4.6–22.2 (mean 6.1), 2.0–5.6 (mean 2.1), 0.6–5.6 (mean 0.8), 0.7–5.3 (mean 1.3), 1.3–22.2 (mean 2.7), and 1.3–11.1 (mean 2.7), respectively.

Rare species occurred as single individuals in less than 0.8 % of all voles. However, they can be found on root voles in all studied locations and every visit and can also be recognized as a persistent parasite. Single or two *M. oeconomus* were infested with the *Ixodes apronophorus* Schulze, 1924 tick, and the fleas *Ctenophthalmus congerer* Rothschild, 1907, *Ctenophthalmus solutus* Jordan et Rothschild, 1920, *Doratopsylla dasycnema* (Rothschild, 1897), *Palaeopsylla soricis* (Dale, 1878), *Palaeopsylla similis* Dampf, 1910 and *Peromyscopsylla bidentata* (Kolenati, 1860) (Table 1).

The prevalence of ectoparasites was basically similar in all locations and visits. However, there was a noticeable difference in the tick's infestation which was very high in July and low in August. For example, in July the mean (over a few years) prevalence of infestation of voles with *D. reticulatus* was 83.35 %, whereas it decreased to 36.20 % in August. The difference between months was statistically significant (replicated goodness-of-fit test: G = 19.11, $p < 0.001$). Similarly, the infestation with *I. ricinus* ticks was twice higher in July (44.4 %) than in August (mean 22.62 %) and this difference was also significant (G = 7.21, $p < 0.01$). The prevalence of infestation with ectoparasites in particular years and localities is presented in Table 1.

Discussion

In our research carried out in Masurian District and Białowieża Primeval Forest, we confirmed the presence of 22 species of arthropods associated with the root vole. The structure of their taxonomic and ecological association (3 ticks, 5 mites, 13 flea species and 1 lice species) and proportions are typical of small rodents and similar to earlier data published elsewhere (Savitskiy and Kulnazarov 1988; Kononova 1996; Krylov 1996). Geographically, 12 species of ectoparasites occurring on *M. oeconomus* (ticks: *I. ricinus, I. apronophorus, D. reticulatus*; mites: *P. oudemansi, H. hirsutosimilis* fleas: *C. uncinatus, C. assimilis, C. congerer, M. turbidus, M. walkeri, P. soricis, P. bidentata*) are typical of the Palaearctic zone, another four (*H. nidi*, *H. ambulans*, *M. glaber* mites, *H. acanthopus* louse) occur throughout the Holarctic zone, five species of fleas (*C. agyrtes, C. bisoctodentatus, C. solutus, P. similis, D. dasycnema*) occur only in Europe, and one – *H. orientalis* – occurs in Central and Eastern Europe and Asia. The mixed structure of arthropod communities associated with *M. oeconomus* populations in north-eastern Poland is characteristic of this biogeographic region, on the border of boreal and temperate forest zones. The Białowieża Primeval Forest is one of the last primeval forest complexes in Western and Central Europe. Moreover, it is a particularly interesting place for biological research due to its geographical location on the border of boreal and temperate forest zones. This fact causes the mixing of fauna and flora of both zones (Faliński 1968; Gutowski and Jaroszewicz 2001).

The dominant group of ectoparasites – *I. ricinus* larvae and nymphs, *D. reticulatus* larvae and nymphs, *C. agyrtes*, *M. walkeri* and *H. orientalis* fleas – includes typical dominants for small mammals in this region of Europe, as well as for Microtinae rodents (Lachmajer 1959; Savitskiy and Kulnazarov 1988; Kononova 1996; Karbowiak 2000). Among them, the flea *M. walkeri* is a species strongly associated with the root vole (Skuratowicz 1967; Dudich 1985) and is present also in isolated vole populations south of its compact range of occurrence (Matskási et al. 1992). A characteristic feature of the flea communities associated with *M. oeconomus* is the low prevalence and intensity of *C. uncinatus* infestation. This flea is a common and often dominant species among ectoparasites of the bank vole *Myodes glareolus* (Schreber, 1780) and *Apodemus* mice species in Eurasia, mainly in oak-hornbeam forests (Skuratowicz 1967; Bartkowska 1981; Krylov 1996; Kowalski et al. 2014). In Poland, we noted this flea for the first time as a rare parasite of the root vole.

The high prevalence of *D. reticulatus* ticks, reaching up to 100 % in our catching confirms the preference of this species to rodents from the Cricetidae family. Similar trends were observed previously. During a study conducted by Karbowiak (2000) in Masurian District in July, the infestation of the *M. glareolus* vole with larvae and nymphs of *D. reticulatus* reached 43.0 %, while the infestation of the yellow-necked mice *Apodemus flavicolis* (Melchior, 1834), occurring in the same area, was 27.0 %. The higher prevalence of infestation of root voles studied in Białowieża than in the cited studies can be explained in two ways. The first possible explanation is the higher preference of immature *D. reticulatus* to the root vole than to the bank vole. The other explanation is environmental differences. *Dermacentor reticulatus* prefers open areas, favourable to the root vole, so inevitably will be frequent. The bank vole prefers woodland, where these ticks are less numerous.

We confirmed *P. similis*, *C. congerer*, *C. bisoctodentatus* and *C. solutus* and, for the first time in Poland, the fleas

D. dasycnema and *C. uncinatus* as new parasites recorded for the first time on *M. oeconomus* in all areas where this vole occurs. These are rare species in Poland and specific to other small mammal species, e.g. *D. dasycnema* is typical for *Sorex* shrews (Kowalski et al. 2014). Among ticks, *I. apronophorus* is a new species associated with *M. oeconomus* in Poland, although it was recorded from this host in the countries of the former SU (Filippova 1977). These parasites are very rare on *M. oeconomus* and it is possible that the root vole is an accidental host for some of them, because specific hosts – *Apodemus* mice and *Sorex* shrews – are present at the same site. The occurrence and distribution of *I. apronophorus* ticks are poorly known in Poland and throughout Europe. Currently, it is considered a rare species, but it is possible that further research will reveal its wider distribution and host range than described so far (Karbowiak et al. 2007; Nowak-Chmura 2013).

Noteworthy are the seasonal differences in the intensity of infestation by ticks. These are especially visible in the case of the *D. reticulatus* tick; the differences in the intensity of infestation are more than twice bigger in July than in August. In July, *D. reticulatus* may be considered the dominant ectoparasite species affecting the root vole. In August, it is partly replaced by *I. ricinus* and fleas, and in the remaining months it is absent. This phenomenon is related to the short feeding period of the juvenile stages of *D. reticulatus* (Szymański 1987; Karbowiak 2000). Rodents are infested with the immature stages of this tick species – larvae and nymphs. The incidence of tick infestation in July is much higher than in August. While in July there are proportionally more larvae and fewer nymphs on the rodents, in August the proportions are reversed. Outside these months, immature stages of *D. reticulatus* no longer occur during the year (Szymański 1987; Siuda 1993; Nowak-Chmura 2013). Seasonal differences in the incidence of infestations with juvenile *D. reticulatus* have also been observed in other rodent species. In yellow-necked mice and bank voles, a time limitation in the appearance of larvae and nymphs of this tick species during two consecutive months of the year was also observed (Karbowiak 2000).

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval The studies described were in compliance with all ethical principles. The local Ethics Commission in Warsaw has given permission to work with animals.

Informed consent All listed Authors know the content and have given their consent to the publication of the manuscript.

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