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Composition and seasonal changes of mesostigmatic mites (Acari) and fleas fauna (Siphonaptera) in the nests of *Mus spicilegus* (Mammalia: Rodentia)

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Abstract: Together 22,119 individuals and 47 species of mesostigmatic mites, and 485 individuals of fleas belonging to 6 species were obtained from 16 winter nests of mound-building mouse, *Mus spicilegus.* The most abundant mite species were *Laelaps algericus* (38.2%), *Androlaelaps fahrenholzi* (20.9%), *Proctolaelaps pygmaeus* (16.9%) and *Alliphis halleri* (8.3%). *Ctenophthalmus assimilis* (87%) was the highly predominant flea, present in all the positive nests. On the basis of trophic and topic relations, mites were assorted into four ecological groups; parasites had the highest abundance (67% of all individuals). The density peak values of individual ecological mite groups differed the during season. The population peak of the predominant mite species *L. algericus* was in December, predominance of females was registered throughout the study period. The maximum abundance of fleas was reported in January and May.

Key words: nest fauna; mites; fleas; seasonal changes; *Mus spicilegus;* Slovakia

Introduction

The mound-building mouse *Mus spicilegus* (Petényi, 1882) prefers natural vegetation of steppes, open areas along water streams and areas of cereal cultivation, rarely open woods remote from human settlements and is continuously distributed from Ukraine to eastern part of Austria through Moldavia, Romania, northern Bulgaria, Serbia, Croatia, Hungary and Slovakia (Musser & Carleton 1993; Macholán 1999; Bauer 2000). Some isolated populations of mound-building mouse were described from the Adriatic coast of Montenegro and from several localities of Albania and Greece (Macholán & Vohralík 1997; Kryštufek & Macholán 1998; Mitsainas et al. 2009).

In Slovakia, *M. spicilegus* occurs in several lowland areas of southern and eastern part of the country, up to the altitude of 200 m above the sea level (Krištofík & Danko 2003). In these areas this mice species occurs sympatrically with the morphologically similar and commensal *Mus musculus* L., 1758. However, *M. spicilegus* differs from *M. musculus* and also from other European species of the genus *Mus* by a number of ecological and behavioural features. For instance, in autumn, it begins to construct large mounds, which can be built from plant material and covered with soil. In these mounds the animals spend winter and leave them in early spring (Pisareva 1948; Mikeš 1971; Muntyanu 1990; Sokolov et al. 1990; Unterholzner & Willenig 2000; Gouat et al. 2003; Poteaux et al. 2008). This behaviour is genetically determined (Orsini et al. 1983) and besides the use of molecular methods, it is commonly considered to be the most conclusive method for the identification of the mound-building mouse species.

The specific type of nests of *M. spicilegus* and their localization under the ground may affect the composition of the mesostigmatic mite nest fauna. Nests of small mammals represent a closed system with a specific microclimate, separated from the surrounding biotope (Daniel 1988). Despite this fact, the nest conditions may be influenced by several factors such as seasonal changes of the surrounding environment or a direct activity of mammals – nest pollution by urine and faeces, remains of food etc. This way, these factors affect the composition of nest arthropods communities. Mites and fleas associated with small mammals are important vectors of a number of pathogens. Both arthropod groups are capable to transmit viral, rickettsial and bacterial pathogens in natural foci of diseases to animals and humans(Rosický et al. 1979; Krasnov 2008).

Although there are a lot of publications dealing with mite communities in nests of small mammals, information about parasitic arthropod fauna associated with *M. spicilegus* (Mikeš 1966, 1971; Popescu et al. 1974; Stanko et al. 2007) and its nests are limited (Mikeš 1966; Mašán & Stanko 2005). There is only one published study documenting both flea and mite infestations of *M. spicilegus* nests from South-East Slovakia

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Table 1. Survey of mites (Mesostigmata) in the nests of *Mus spicilegus*.

Mite species	S (f)	S (m)	S (dn)	S (i)	D (%)	F (%)
Ectoparasites						
Androlaelaps fahrenholzi (Berlese, 1911)	2356	714	1547	4617	20.87	93.75
Eulaelaps stabularis Vitzthum, 1925	576	124	42	742	3.35	100
Haemogamasus nidi Michael, 1892	368	167	204	739	3.34	93.75
Hirstionyssus sunci Wang 1962	22	–	–	22	0.10	43.75
Hirstionyssus isabellinus Oudemans, 1913	247	–	2	249	1.13	93.75
Laelaps algericus Hirst, 1925	4475	1730	2241	8446	38.18	93.75
Laelaps hilaris C.L. Koch, 1836	2	–	–	2	0.01	12.5
Nidicoles						
Androlaelaps casalis (Berlese, 1887)	1	–	–	1	<0.01	6.25
Androlaelaps sardous (Berlese, 1911)	1	–	–	1	<0.01	6.25
Arctoseius semiscissus (Berlese, 1892)	35	–	–	35	0.16	68.75
Hypoaspis heselhausi Oudemans, 1912	19	45	19	83	0.38	37.5
Paragarmania dentritica (Berlese, 1918)	1	–	–	1	<0.01	6.25
Vulgarogamasus remberti (Oudemans, 1912)	103	83	425	611	2.76	75
Edaphic species						
Amblyseius sp.	24	–	–	24	0.11	43.75
Ameroseius corbiculus (Sowerby, 1806)	23	–	–	23	0.10	43.75
Ameroseius plumigerus (Oudemans, 1930)	47	–	–	47	0.21	31.25
Arctoseius cetratus (Sellnick, 1940)	13	–	–	13	0.06	43.75
Asca bicornis (Canestrini et Fanzago, 1887)	7	–	–	7	0.03	25
Cyrtolaelaps chiropterae Karg, 1971	1	1	12	14	0.06	25
Dendrolaelaps sp.	1	–	1	2	0.01	12.5
Geholaspis hortorum (Berlese, 1904)	9	–	–	9	0.04	6.25
Geholaspis mandibularis (Berlese, 1904)	2	–	–	2	0.01	6.25
Hypoaspis aculeifer (Canestrini, 1883)	6	1	–	7	0.03	31.25
Hypoaspis miles (Berlese, 1982)	4	–	–	4	0.02	6.25
Lasioseius berlesei (Oudemans, 1938)	25	–	–	25	0.11	12.5
Pachylaelaps brachyperitrematus Koroleva, 1977	7	–	–	7	0.03	12.5
Pachylaelaps pectinifer (G. et R. Canestrini, 1881)	38	1	–	39	0.18	12.5
Pachylaelaps sp.	2	–	–	2	0.01	6.25
Parasitus beta Oudemans et Voigts, 1904	–	–	1	1	<0.01	6.25
Parasitus loricatus (Wankel, 1861)	1	6	6	13	0.06	12.5
Pergamasus brevicornis Berlese, 1903	77	27	22	126	0.57	62.5
Pergamasus crassipes (L., 1758)	–	1	–	1	<0.01	6.25
Pergamasus sp.	4	4	–	8	0.04	6.25
Proctolaelaps pygmaeus (J. Müller, 1860)	3123	6	599	3728	16.85	87.5
Rhodacarellus silesiacus Willmann, 1935	1	–	–	1	<0.01	6.25
Veigaia agilis (Berlese, 1916)	1	–	–	1	<0.01	6.25
Veigaia cervus (Kramer, 1876)	4	–	–	4	0.02	6.25
Veigaia nemorensis (C.L. Koch, 1839)	7	–	1	8	0.04	25
Veigaia sp.	2	–	2	4	0.02	6.25
Vulgarogamasus kraepelini (Berlese, 1905)	1	–	12	13	0.06	25
Vulgarogamasus oudemansi (Berlese, 1903)	65	29	120	214	0.97	62.5
Coprophilous species						
Alliphis halleri G. et R. Canestrini, 1881	1521	264	40	1825	8.25	93.75
Cornigamasus lunaris (Berlese, 1882)	–	–	2	2	0.01	6.25
Gamasodes spiniger (Trägardh, 1910)	1	–	14	15	0.07	25
Macrocheles matrius (Hull, 1925)	212	2	11	225	1.02	68.75
Macrocheles rotundiscutis Bregetova et Koroleva, 1960	1	–	–	1	<0.01	6.25
Parasitus fimetorum (Berlese, 1903)	–	2	153	155	0.70	56.25
Total	13436	3207	5476	22119	100.00	100.00

Explanations: f – females, m – males, dn – deutonymphs, i – individuals; D – dominance, F – frequency.

(Mašán & Stanko 2005) and some preliminary results exist about mite communities of mound-building mouse nests from several sites of the western and eastern parts of Slovakia (Várfalvyová et al. 2010).

In this paper, we studied the composition of mesostigmatic mites in nests of *M. spicilegus* from Eastern Slovakia and compared it with the mite fauna in the nests of other small mammals with similar nidobiology [*Talpa europea* L., 1758, *Microtus arvalis* (Pallas, 1779)], since they often build nests in the same habitats. This is also the first published study describing the seasonal population fluctuation of mites (Mesostigmata) in the nests of the mound-building mouse.

Material and methods

Altogether 16 nests of the mound-building mouse were examined. The nests were collected from Košická kotlina basin; on the sites near the Kechnec village (21°16′ E, 48°33′ N). The examined fields were located in farming areas; in the surroundings, there were fields with several windbreaks and drainage canals.

The subterranean nests were obtained by excavation of the mounds. The nests were usually located in the depth of 30–50 cm under the ground. The food storages contained mainly seeds of grass and weeds (*Setaria* sp., *Stipa* sp. and *Amaranthus* sp.). The nests were sampled from October 2004 to May 2005, two nests every month. Each excavated nest was put into a plastic bag, the top of which was sealed to prevent the escape of ectoparasites and other arthropods.

In the laboratory, each nest was placed into modified Berlese-Tullgren funnels for 72 hours. The arthropods were collected in 70% ethylalcohol in a catch-bottle which was fitted to the base of the funnel. The extracted mites and fleas were mounted by usual methods to permanent microscopic slides.

Morisita index *M* (Morisita 1959) was used to compare the diversity of mite species over the study period.

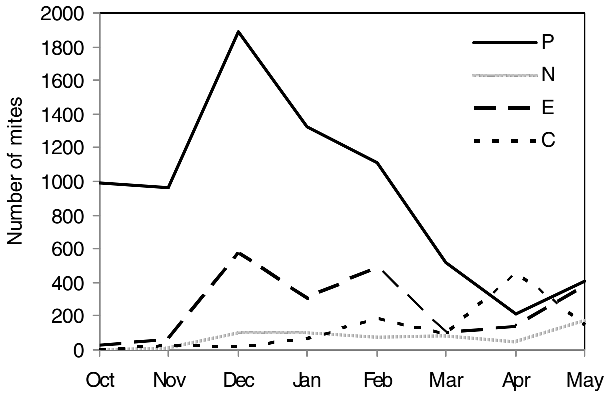

Fig. 1. Seasonal changes in the abundance of mites of each ecological group in nests of *Mus spicilegus*. P – parasites, N – nidicoles, E – edaphic species, C – coprophilous species.

Results

Mites

From 16 nests of mound-building mouse, 22,119 specimens of mesostigmatic mites belonging to 47 species were collected (Table 1). The average number of mites per one nest was 1,382, and their abundance varied between 116 and 2,766 individuals in one nest.

The most abundant species were *Laelaps algericus* (563 individuals per one nest), *Androlaelaps fahrenholzi* (308 ind.), *Proctolaelaps pygmaeus* (266 ind.), *Alliphis halleri* (122 ind.), *Vulgarogamasus remberti* (51 ind.), *Haemogamasus nidi* (49 ind.) and *Eulaelaps stabularis* (46 ind.).

The mites were identified in all the examined nests; the most frequent species were *Eulaelaps stabularis*, found in all the nests. *Alliphis halleri, Androlaelaps fahrenholzi*, *Haemogamasus nidi, Hirstionyssus isabellinus* and *Laelaps algericus* were present in 93.8% of nests, *Proctolaelaps pygmaeus* in 87.5%, *Vulgarogamasus remberti* in 75%, *Arctoseius semiscissus* and *Macrocheles matrius* in 68.8%, *Pergamasus brevicornis* and *Vulgarogamasus oudemansi* in 62.5% of nests. *Parasitus fimetorum* were present in 56.3% of nests, other mite species occurred in less than 50% of all nests.

The mite species were divided into four ecological groups on the basis of the trophic relations to the host and habitat requirements to their nests according to Mašán & Stanko (2005) and Fenďa & Kalúz (2009). The classification of certain mite species is difficult because they are found in a wide range of habitats (e.g., *Proctolaelaps pygmaeus*, *Vulgarogamasus oudemansi*, *Macrocheles* sp.).

(1) Parasites (P). This group includes both facultative and obligatory ectoparasites of small mammals, which live in the host hair or in their nests. The hair parasites of *Hirstionyssus* and *Laelaps* genera are specialists and trophically related to several rodent host species. The nest ectoparasites (genera *Androlaelaps*, *Eulaelaps* and *Haemogamasus*) have been described as generalist mite species without any definite preference for a certain group of hosts. They can be found on the mammal's body as well as in their nests.

Ectoparasites were the most abundant ecological group within the examined material; they represented 14.9% of species and 67% of individuals. Two species – *L. algericus* and *A. fahrenholzi* were most abundant (Table 1). The relative abundance of hair ectoparasites (*Laelaps* spp.) was more than half of individuals (55.6%) of all parasitic mites.

(2) Nidicoles (N). The mammal nests represent a unique habitat (higher humidity and smaller temperature range) for many species of free living mites, which can find their food and favourable microclimate conditions for reproduction and development. The largest fraction of nidicoles was represented by predators, feeding on other invertebrates living in the nests. Nidicoles were the least represented group in the nest material, representing 12.8% of species and 3.3% of individuals. *Vulgarogamasus remberti* was most abundant; its dominance was 83.5% out of all nidicole species.

(3) Edaphic species (E). This group of mites includes free living and soil species, which can find food in the nests of small mammals. This group of mites has no trophic or topic relation to the host. They penetrate actively from the soil to nests. This ecological group comprised 59.6% of species and 19.7% of all mites examined. *Proctolaelaps pygmaeus* was highly predominant (85.8%), but the classification of this species is not clear, it is often found in nests of both birds and small mammals (Mašán & Stanko 2005; Krištofík et al. 2009).

(4) Coprophilous species (C). They include species associated with nests with a higher concentration of organic matters in soils, decomposed remains of the host's food, excrements and other products of the host activity. Six species of this group were found; they represented 12.8% of species and 10.1% of individuals. *Alliphis hallerii* was predominant (82.1%).

Distinct seasonal changes in the abundance of the four ecological groups were observed (Fig. 1). The abundance peak of parasites occurred in December, declined from January to April and then increased in May. Among parasitic mites, the specific *M. spicilegus* parasite *Laelaps algericus* markedly dominated. The

Table 2. Values of Morisita index and percentage similarity between months in term of mite species diversity in nests of *Mus spicilegus*.

Month	Morisita index M							
	X	XI	XII	I	II	III	IV	V
X		0.93	0.71	0.58	0.55	0.84	0.03	0.35
XI	73.86		0.88	0.80	0.75	**0.94**	0.17	0.50
XII	50.16	72.30		**0.96**	**0.95**	0.90	0.29	0.76
I	40.33	65.35	84.06		**0.96**	0.83	0.38	0.77
II	39.14	63.47	83.81	82.48		0.82	0.49	0.90
III	59.63	74.67	66.41	60.34	64.64		0.12	0.27
IV	9.88	31.90	43.87	48.44	53.77	37.64		0.11
V	27.87	41.17	58.37	60.05	72.03	60.29	60.29	
	Percentage similarity (%)							

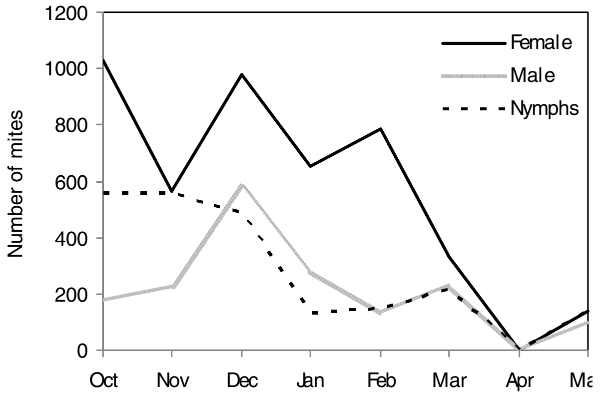

Fig. 2. Seasonal changes in the abundance of *Laelaps algericus* mite in nests of *Mus spicilegus*.

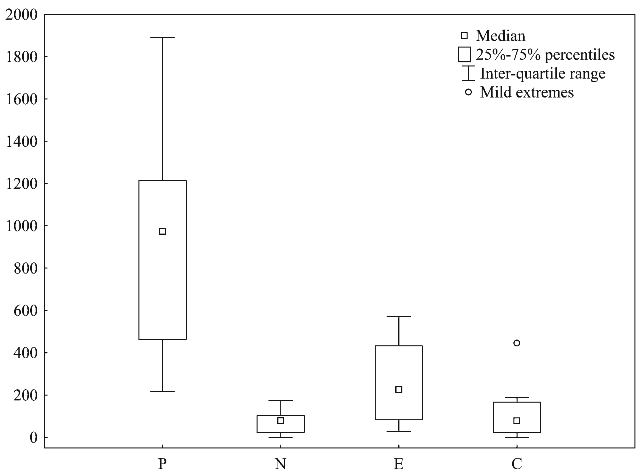

Fig. 3. Box plot of the mean abundance of mites of each ecological group per nest of *Mus spicilegus*.

maximum density of this mite species was recorded in December. Sex ratio and proportion of developmental stages were unbalanced, *L. algericus* females predominated during the whole study period. For females, maximum abundance values were recorded from October to February, for males in December and for nymphs from October to December (Fig. 2). In the group of nidicoles, only a slight increase of abundance was observed

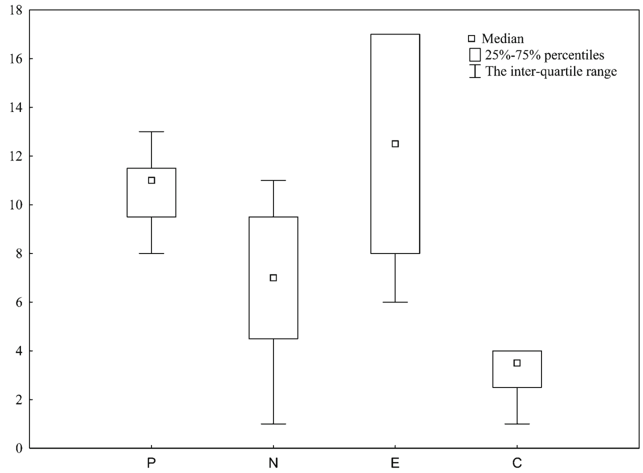

Fig. 4. Box plot of the number of mite species of each ecological group per nest of *Mus spicilegus*.

in December, declining in April and increasing again in May. Edaphic species had two population peaks in the nests: from December to February and again in May. The abundance of coprophilous species gradually increased from January to March, with a population peak in April.

Figures 3 and 4 present a box plot view of the mean number of mites per nest and the number of species of each ecological group over the entire study period. Using the Morisita index (M), the diversity of mites of each month was compared. The highest level of similarity between mite communities was found from December to February and between October and March (Table 2).

Fleas

In total, 485 fleas belonging to 6 species were found in *M. spicilegus* nests (Table 3); five species are typical parasites of small mammals, except *Ceratophyllus hirundinis* with host preference to birds, found mainly in nests of swallows and martins (Krumpál & Cyprich 1995). The fleas were recorded in 15 (93.75%) nests examined. Their abundance fluctuated from 1 to 198 individuals and from 1 to 5 species per one nest. The average number of fleas within one examined nest was 30

Table 3. Survey of fleas (Siphonaptera) in the nests of *Mus spicilegus.*

Flea species	S (f)	S (m)	S (i)	D (%)	F (%)
Ceratophyllus hirundinis (Curtis, 1826)	3	1	4	0.82	12.5
Ctenophthalmus agyrtes (Heller, 1896)	5	3	8	1.65	18.75
Ctenophthalmus asimilis (Taschenberg, 1880)	261	161	422	87.01	93.75
Ctenophthalmus solutus Jordan et Rothschild, 1920	7	5	12	2.47	25.00
Hystrichopsylla orientalis Smit, 1956	1	0	1	0.21	6.25
Nosopsyllus fasciatus (Bosc, 1801)	19	19	38	7.84	37.50
Total	178	120	485	100.00	93.75

For explanations see Table 1.

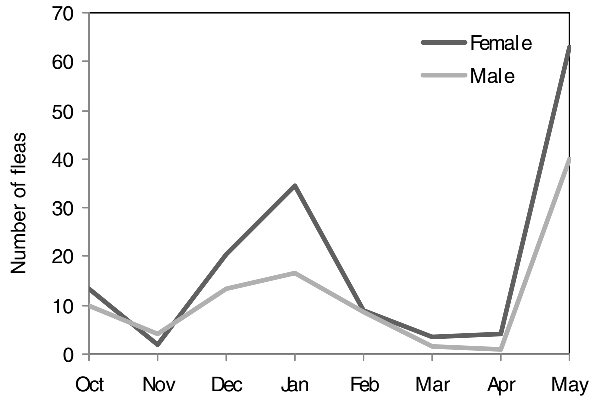

Fig. 5. Seasonal changes in the abundance of fleas in nests of *Mus spicilegus.*

individuals. *Ctenophthalmus assimilis* was highly predominant (87%), *Nosopsyllus fasciatus* was dominant (7.8%), *Ctenophthalmus agyrtes* and *Ctenophthalmus solutus* were subdominant (1.7–2.5%), *Hystrichopsylla orientalis* and *Ceratophyllus hirundinis* were only subrecedent (0.2–0.8%). There were two abundance peaks for fleas – January and May. Males reflected the population fluctuations of females, but the number of females was slightly higher than that of males over the entire study period, except November (Fig. 5).

Discussion

Mašán & Stanko (2005) found 27,097 individuals belonging to 56 mesostigmatic mite species in 14 examined nests of *M. spicilegus* from sites of South-East Slovakia. When compared with their results, we have found the same 7 species of parasitic mites and also showed very similar levels of nest infestation intensity. However, we recorded in our material a 2.1 times higher dominance of *L. algericus.* According to the cited authors, high relative abundance of hair ectoparasites (58.8%), particularly *L. algericus* (57%) in the nests of *M. spicilegus* (in contrast to nest mite fauna of other rodent species of Central Europe) is typical. The species composition of the other ecological groups of mites is very similar, but we have not recorded some nidicoles (*Cyrtolaelaps mucronatus* G. et R. Canestrini, 1881 and *Euryparasitus emarginatus* Koch, 1839). Further differences were observed in species diversity, or dominance in groups of edaphic and coprophilic mite species (Mašán & Stanko 2005 and present paper).

In Vojvodina, Mikeš (1966) studied ectoparasites of *M. spicilegus* infesting the host and its nests. Based on a material from 45 nests, the author identified 1,638 individuals belonging to 17 species of mesostigmatic mites. The composition of parasitic mites was similar to the present study, but the recorded species showed different values of dominance. Among all identified species, *Eulaelaps stabularis* and *Laelaps algericus* were highly dominant, whereas *Androlalelaps fahrenholzi* was recedent. In this study, *A. fahreholzi* was eudominant and *E. stabularis* was only recedent.

Popescu et al. (1974) examined 370 individuals of *M. spicilegus* from Romania and recorded 14 species of mesostigmatic mites and 6 species of fleas.

The high abundance of the parasitic mite *L. algericus* in nests of the mound-building mouse is typical. In comparison with the nest mite fauna of other small mammals, the proportion of obligatory specific parasites in nests of the mound-building mouse is significantly higher. We assume that the high occurrence of hair parasites in the nests of *M. spicilegus* may be related with their specific ecology.

We compared the structure of mite communities from subterraneous nests of *M. spicilegus* with those from nests of other small mammals with similar nidobilogy. Mašán et al. (1994) found 2,078 individuals of 58 mesostigmatic mites species in nests of the common mole *Talpa europaea* from Slovakia. Species richness in the present study is poorer, but the composition of mite species and the presence of ecological groups are very similar. However, we registered some differences between relative and cumulative abundance of individual ecological groups of mites. Mašán et al. (1994) recorded that nidicolous species were the most abundant (36.52% of individuals), whereas in our study they were only little represented (3.3%). In contrast, we observed a 2.3 times higher abundance of individuals in the parasitic group than in the nest of common mole. Kocianová & Kožuch (1988) investigated 45 winter nests of *T. europaea* from Western Slovakia. They recorded only 19 species of mites. The facultative parasite *H. nidi* was most abundant and obligatory parasites were little represented. In Sweden, Lundqvist (1974) collected 31 species of gamasid mites from 51 nests of common mole. When compared with his results, the composition of parasitic and nidicolous species in the present study was similar, but hair ectoparasites 14.7 times more abundant. By contrast, we did not observe the parasitic mite *Myonyssus gigas* (Oudemans, 1912; syn. *Myonyssus rossicus* Bregetova, 1956) in nests of *M. spicilegus* and we did not find any edaphic species (e.g., species from genera *Hypoaspis, Macrocheles*, *Parasitus* and *Veigaia*).

The analysis of mesostigmatic mites fauna in the nests of several species of small mammals was made by Mrciak et al. (1966). In the nests of *Microtus arvalis*, they found 37 species; the composition of parasitic and nidicolous species was very similar to the composition of these ecological groups in mound-building mouse nests.

Fleas are obligatory haematophagous parasites strongly associated with nests of their hosts where they find favourable conditions for their reproduction and development. Mašán & Stanko (2005) obtained 169 fleas of 6 species in nests of *M. spicilegus*; *C. assimilis* was most abundant (79.88%). Similarly, we observed a high predominance of *C. assimilis* (87.01%), but we did not record the species *Megabothris turbidus* (Rothschild, 1909). On the other hand, we found the species *Ceratophyllus hirundinis*, which was not reported in the previous study, and we recorded a 2.5 times higher average number of fleas per one nest. High abundance of *C. assimilis* was observed in nests of many rodents (Kocianová & Kožuch 1988; Němec 2006). Mikeš (1966) reported only three flea species from nests of the mound-building mouse and their abundance was very low (11 individuals from all nests). He did not record some of the species reported here, namely *Ctenophthalmus agyrtes*, *C. solutus*, *Hystrichopsylla orientalis* and *Nosopsyllus fasciatus*. In contrast, *Stenoponia tripectinata* (Tiraboshi, 1902) and *Leptopsylla segnis* (Schőnherr, 1816) were not present in our material from eastern Slovakia. *Stenoponia tripectinata* is a Mediterranean species the adults of which occur only during cold months (Krasnov et al. 2002). There is only one recently published record on *S. tripectinata* from Slovakia; the species was found in nests of *M. spicilegus* only from two sites of the Hronská pahorkatina hilly country – Gbelce and Malá Mužla (Stanko & Várfalvyová 2010). In general, the high number of fleas in the nests of small mammals is typical. For example, Němec (2006) described the flea fauna in nests of *T. europaea* and *M. arvalis* from the western part of the Czech Republic: 15 species were found in nests of *T. europaea* (the mean number of fleas per one nest was 43) and 12 species from common vole nests, the mean number of fleas per nest was also very high (54 individuals). According to Mašán & Stanko (2005), the low abundance of fleas in nests or on the body of *M. spicilegus* may be influenced by the grooming behaviour, which was observed in mammals living in communities. Among other benefits, grooming removes parasites. Unlike moles and voles, the mound-building mouse lives in association with several individuals in mounds during winter (Muntyanu 1990).

In the context of seasonal changes of the composition of nest mite fauna, parasitic mites were the most abundant group, reaching a population peak in December. Edaphic mites generally reflected the population fluctuations of parasites, but never attained any great proportion (Fig. 1). The increase of the abundance of parasitic, nidicolous and edaphic mites and fleas in May is probably associated with the breeding season of the mound-building mouse. Several authors suggest that in early spring, mice leave their winter nests and disperse (Orsini et al. 1983). However, we observed that some parental pairs probably stay in winter nests and start breeding in mounds (unpubl. data). High abundance of parasitic mites and fleas in late autumn and early winter is probably a reflection of the higher mammal densities in the nests. During winter, due to mortality, especially of older mice, and the dispersion of the mouse population in spring, the number of inhabitants is declining in nests, which results in a significant decrease of the populations of parasitic mites in the nests.

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