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Oribatid mite communities (Acari: Oribatida) in different habitats of the Polistovsky Nature Reserve (Pskov Region, Russia)

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Abstract. The fauna and community structure of oribatid mites (Acari: Oribatida) in the Pskov Region of Russia is not yet comprehensively studied. Until now not much attention has been paid to soil communities of bogs and open landscapes of this area. The aim of this study was to compare the community composition of oribatid mites in different habitats in the environs of the Polistovsky National Nature Reserve (Pskov Region, Russia). We found 56 oribatid species in this area during our sampling campaign in 2010. Of these 16 have not been recorded in the Pskov Region before. Forest habitats were the richest in species within the examined territory. The highest faunistic similarity of oribatid communities was found between raised bogs and transition bogs. The mite faunistic composition in these two types of habitats was in turn quite similar to that in spruce forests. At the same time secondary habitats such as meadows hosted fewer oribatid species and were faunsitically distinct from the other habitats. Analysis of the rank abundance distribution of oribatid species indicated a disturbed state of oribatid communities in meadows even after their abandonment 20–25 years ago. The abundance of all oribatid ecomorphs besides surface-dwelling mites was similar and not significantly different across habitats. We assume that the relatively high number of previously unrecorded oribatid species for the Pskov Region in the research area is related to the considerable age of landscapes in the Polistovsko–Lovatskaya peat bog system and immigration of oribatid mites with transiting birds. More detailed comparative study of the oribatid fauna and community structure in the Polistovsky Reserve is needed to discover driving forces of the revealed community structure and diversity.

Key words: oribatid mites, Pskov Region, Polistovsky Nature Reserve, soil animals, ecological structure.

INTRODUCTION

Oribatid mites (Acari: Oribatida) are widely spread across all soil types in the world (Krantz & Walter, 2009). They play an important role in organic matter decomposition in soil and form a considerable part of soil biodiversity. This group is often used as a model during soil ecological and bioindication research (Krivolutsky, 1995).

The fauna and community structure of oribatid mites in the Pskov Region in the North-West of Russia is still not comprehensively studied (Zaitsev, 2001). Over the past few decades 205 oribatid species were found in this region. Predominantly watershed habitats were studied before (Krivolutsky, 1995). Boggy and meadow habitats have received much less attention so far (Karppinen & Krivolutsky, 1982). At the same time peat bog ecosystems can host most interesting from the faunistic point of view species (Druk, 1982). Research performed in some peat bogs of Lithuania as well as in the Republic of Karelia and the Nizhniy Novgorod Region in Russia showed that oribatid mite communities in such habitats are quite peculiar from both ecological and faunistic points of view (Eitminavichute, 1972; Laskova, 1983; Sidorchuk, 2008).

The aim of this study was to compare oribatid mite community composition in different habitats in the environs of the Polistovsky National Nature Reserve (Pskov Region, Russia).

MATERIAL AND METHODS

Soil and litter samples were collected on the territory of core and buffer zones of the Polistovsky Nature Reserve in June 2010 with a soil corer. The geographical coordinates and vegetation type were assessed simultaneously. Samples were taken in 23 localities in six major biotopes defined by their position in the relief, drainage, and vegetation: raised peat bogs, transition bogs, secondary aspen–birch forests, spruce forests, upland meadows, and bottomland meadows (Table 1). Spruce forests with a fraction of aspen and birch are the closest to the natural southern taiga primary vegetation of this ecoregion (Olson et al., 2001). Meadows were quite actively grazed and mown on the territory of the modern reserve and its buffer zone until the middle of the 1990s, but later they were abandoned because of the decreasing human population in the area. Since the 1990s anthropogenic stress in the reserve and its environs has in general considerably decreased due to the overall economic collapse in North-Western Russia and the foundation of the reserve in 1994. This resulted in an active recovery of natural vegetation, disappearance of meadows, and an increase of forest cover (Manakov et al., 2010).

Each intact sample included litter and moss and the top 5 cm of the humus layer collected on an area of 100 cm^2. In the raised peat bogs samples were taken in moss down to a depth of 15 cm. The collected substrate was transported to the lab in cool boxes at the temperature of 5–10 °C. Extraction was performed in the Laboratory for Soil Ecological Functions, IEE RAS (Moscow), using Tullgren extractors. A mixture of alcohol, water, and glycerol in the proportion of 90 : 9 : 1, respectively, was used as a conservation liquid (Ghilarov, 1975). All oribatid mites including juvenile individuals except those from the Oppiidae, Suctobelbidae, and Phthiracaridae families were identified to the species level. Only three juvenile individuals of the families mentioned above were met in our samples and they were excluded from further analysis. Allocation to higher taxa and attributing scientific names was done using the system provided in the Fauna Europaea database (www.faunaeur.org (accessed 10.10.2013)). Division of oribatid mite species into different ecomorphs (surface-, litter-, soil-, water-dwelling, and non-specialized) was done following the classification of Krivolutsky (1995).

Table 1. Distribution of sampling locations in the environs of the Polistovsky Nature Reserve across six defined habitats and their geographical coordinates

No.	Latitude, °N	Longitude, °E	Habitat	Location
1	57°05.959′	30°22.892′	Transition bog	Reserve core
2	57°10.259′	30°38.424′	Transition bog	Buffer zone
3	57°05.901′	30°22.855′	Transition bog	Buffer zone
4	57°10.455′	30°38.709′	Raised peat bog	Buffer zone
5	57°06.252′	30°23.398′	Raised peat bog	Reserve core
6	57°21.183′	30°48.748′	Upland meadow	Reserve core
7	57°26.504′	30°40.804′	Bottomland meadow	Buffer zone
8	57°03.494′	30°39.090′	Raised peat bog	Reserve core
9	57°03.424′	30°37.766′	Bottomland meadow	Buffer zone
10	57°22.150′	30°45.743′	Upland meadow	Buffer zone
11	57°06.190′	30°23.443′	Raised peat bog	Buffer zone
12	57°06.118′	30°25.838′	Spruce forest	Reserve core
13	57°03.416′	30°37.119′	Bottomland meadow	Buffer zone
14	57°30.993′	30°45.580′	Secondary forest	Buffer zone
15	57°06.108′	30°23.268′	Spruce forest	Buffer zone
16	57°10.513′	30°38.823′	Spruce forest	Buffer zone
17	57°03.421′	30°38.505′	Secondary forest	Buffer zone
18	57°03.000′	30°38.000′	Spruce forest	Buffer zone
19	57°09.840′	30°37.209′	Secondary forest	Buffer zone
20	57°03.410′	30°38.775′	Secondary forest	Buffer zone
21	57°22.024′	30°46.757′	Secondary forest	Buffer zone
22	57°04.905′	30°42.092′	Upland meadow	Buffer zone
23	57°06.112′	30°23.347′	Spruce forest	Buffer zone

The faunistic similarity of oribatid communities in different habitats was estimated by means of cluster analysis (Bray–Curtis similarity index, complete-link clustering). Cluster analysis and rank distribution model analysis of species dominance in oribatid communities were performed using BioDiversity Pro 2.0 software (McAleece et al., 1997). Significance of differences between means of species richness and abundance of oribatid communities in different habitats was tested using 1-way ANOVA for untransformed data. If ANOVA returned significant results, differences between means were tested using Unequal N HSD pairwise tests. Statistical analysis was done using STATISTICA 7 software (StatSoft, 2007).

RESULTS

In total 1567 oribatid mite individuals were extracted from the collected samples. They belonged to 56 species from 37 families. Sixteen species have not been found before on the territory of the Pskov Region. The taxonomic status of four species needs further clarification. These species are *Metabelba* sp., *Pyroppia* sp., *Parakalumna* sp., and *Zetorchestidae* sp. (Table 2). The number of species was considerably differing between habitats (Table 2). The highest total oribatid species

Table 2. Average abundance (±SE) and species richness of oribatid mites in six main habitat types studied in the environs of the Polistovsky Nature Reserve. Different letters next to the values of average abundance and number of species per sample in various habitats show groups that are significantly different from each other according to the results of the Unequal N HSD test

	Raised peat bog	Transition bog	Secondary forest	Spruce forest	Upland meadow	Bottomland meadow
Number of replicates, *n*	4	3	5	5	3	3
Total abundance, ind. m^{-2}	7250±3205[a]	7067±3380[a]	7920±2774[a]	7960±1350[a]	5733±3514[a]	3300±2954[a]
Average number of species per sample	8±2[ab]	9±2[ab]	9±2[ab]	14±2[a]	6±2[ab]	3±2[b]
Total number of species	16	20	26	39	15	8
Number of 'unique' species*	0	2	4	13	1	1
Achipteria coleoptrata (Linnaeus, 1758)	–	100±100	200±137	500±559	700±700	–
Belba corynopus (Hermann, 1804)**	–	–	40±45	–	–	–
Camisia lapponica (Trägårdh, 1910)	–	–	–	20±22	–	–
Carabodes coriaceus Koch, 1835**	–	–	–	60±45	–	–
C. marginatus (Michael, 1884)**	–	–	20±22	40±45	–	–
C. ornatus Štorkán, 1925**	–	–	–	120±108	–	–
Cepheus cepheiformis (Nicolet, 1855)	–	–	120±134	260±217	–	–
Ceratoppia bipilis (Hermann, 1804)	–	–	–	200±224	33±33	–
Ceratozetes gracilis (Michael, 1884)	–	–	–	60±67	–	–
C. minimus Sellnick, 1928**	–	–	–	160±179	–	–
Chamobates cuspidatus (Michael, 1884)	175±136	367±367	120±134	780±349	33±33	–
Conchogneta willmanni (Dyrdowska, 1929)**	–	–	–	940±561	–	–
Eupelops acromios (Hermann, 1804)	50±58	–	–	40±45	67±67	–
Euzetes globulus (Nicolet, 1855)	–	–	60±67	40±45	–	–
Fuscozetes pseudosetosus Shaldybina, 1975**	–	–	–	180±124	–	–
Galumna obvia (Berlese, 1914)	125±144	100±100	–	280±238	–	–
Heminothrus thori (Berlese, 1904)	–	–	–	80±89	–	–
Hermanniella dolosa Grandjean, 1931	–	–	60±67	160±45	–	–
Hoplophthiracarus illinoisensis (Ewing, 1909)	675±456	1100±700	–	140±76	–	–
Hypochthonius rufulus Koch, 1835	50±58	100±100	20±22	–	–	–
Lauroppia falcata (Paoli, 1908)	–	–	20±22	–	–	–
Malaconothrus monodactylus (Michael, 1888)	525±321	33±33	–	–	–	–
Medioppia hygrophila (Mahunka, 1987)**	1425±1459	33±33	–	–	–	–
Metabelba sp.***	–	–	–	20±22	–	–
Microtritia minima (Berlese, 1904)**	–	–	–	–	–	867±867

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Table 2. *Continued*

	Raised peat bog	Transition bog	Secondary forest	Spruce forest	Upland meadow	Bottomland meadow
Minunthozetes semirufus (Koch, 1841)**	–	–	3520 ± 2412	–	133 ± 133	–
Nanhermannia dorsalis (Banks, 1896)**	525 ± 276	2333 ± 2333	–	160 ± 179	–	–
N. nana (Nicolet, 1855)	–	–	–	140 ± 110	–	–
Nothrus anauniensis Canestrini et Fanzago, 1876**	225 ± 223	267 ± 145	–	80 ± 55	–	33 ± 33
N. palustris Koch, 1839	–	–	140 ± 110	40 ± 45	–	–
Oppiella nova (Oudemans, 1902)	700 ± 808	900 ± 379	60 ± 67	220 ± 114	33 ± 33	100 ± 100
Oribatella calcarata (Koch, 1835)	–	–	–	20 ± 22	–	–
Oribatula tibialis (Nicolet, 1855)	–	–	80 ± 55	100 ± 112	–	–
Parakaluma sp.***	–	–	600 ± 326	20 ± 22	267 ± 133	500 ± 500
Paratritia baloghi Moritz, 1966**	–	–	–	20 ± 22	–	–
Pergalumna nervosa (Berlese, 1914)	50 ± 58	–	80 ± 65	–	33 ± 33	–
Phthiracarus globosus (C. L. Koch, 1841)	–	33 ± 33	320 ± 331	140 ± 84	233 ± 233	267 ± 267
P. laevigatus (C. L. Koch, 1841)**	–	–	100 ± 50	180 ± 152	–	–
Platynothrus peltifer (Koch, 1839)	–	33 ± 33	1380 ± 476	–	2467 ± 2367	–
Protoribates pannonicus Willmann, 1951**	–	–	20 ± 22	–	–	–
Punctoribates punctum (C. L. Koch, 1839)	–	–	120 ± 134	640 ± 503	–	–
Pyroppia sp.***	–	–	–	100 ± 112	–	–
Rhinoppia media (Mihelčič, 1956)	–	–	60 ± 67	–	–	–
Rhysotritia duplicata (Grandjean, 1953)	50 ± 58	–	20 ± 22	140 ± 130	–	133 ± 133
Scheloribates laevigatus (C. L. Koch, 1836)	375 ± 207	467 ± 260	260 ± 140	700 ± 411	633 ± 410	1367 ± 1126
S. latipes (C. L. Koch, 1844)	–	–	–	–	67 ± 67	–
Steganacarus carinatus (C. L. Koch, 1841)	–	–	–	940 ± 435	–	–
S. striculus (C. L. Koch, 1836)	150 ± 100	400 ± 400	420 ± 268	160 ± 179	300 ± 300	–
Suctobelbella palustris (Forsslund, 1953)	–	100 ± 100	40 ± 45	20 ± 22	–	–
Tectocepheus velatus (Michael, 1880)	1900 ± 1428	500 ± 306	40 ± 45	–	233 ± 186	33 ± 33
Trhypochthonius tectorum (Berlese, 1896)	250 ± 191	100 ± 58	–	–	–	–
Trichoribates trimaculatus (C. L. Koch, 1836)	–	33 ± 33	–	20 ± 22	–	–
Trimalaconothrus foveolatus Willmann, 1931	–	–	–	–	500 ± 500	–
Xenillus tegeocranus (Hermann, 1804)	–	–	–	40 ± 45	–	–
Zetomimus furcatus (Pearce et Warburton, 1905)**	–	33 ± 33	–	–	–	–
Zetorchestidae sp.***	–	33 ± 33	–	–	–	–

* – species found within one habitat type;
** – not met before in the Pskov Region (according to Krivolutsky, 1995 and Zaitsev, 2001);
*** – the taxonomic status of these species requires further examination.

richness was found in spruce and secondary forests. In both raised peatbogs and transition bogs the oribatid species richness was lower. Even fewer species were recorded in meadows (Table 2). The average species richness was significantly higher in the spruce forests than in bottomland meadows (ANOVA; $F = 5.64$, $p < 0.01$).

The distribution of the number of 'unique' species (species found only within one habitat type during our study) was quite peculiar. The greatest number of such species, 13, was present in spruce forests (Table 2). In secondary forests four unique species were found. Transition bogs hosted two such species. One unique oribatid species was found both in bottomland and upland meadows. No unique species were met in raised peat bogs. Mites with low occurrence (met only in two habitat types in our study) mainly inhabited forests (eight species) and peat bogs (three species). Forest habitats hosted 12 out of the 16 new oribatid species found in the Pskov Region (Table 2). Among them were for example *Medioppia hygrophila*, *Nanhermannia dorsalis*, and *Zetomimus furcatus*.

The highest abundance of oribatid mites was recorded in spruce forests (Table 2). Meadows were characterized with the lowest oribatid mite densities. The oribatid mite abundance in raised peat bogs was similar to that in forests. However, the oribatid abundances did not differ significantly between habitats (ANOVA; $p > 0.05$) due to the high spatial variability of data and low replication (Table 2).

Results of cluster analysis of faunistic similarity of oribatid communities between six habitats suggest that there is a certain grouping of semi-primary biotopes such as peat bogs and spruce forests, and secondary ones (secondary forests and meadows) (Fig. 1). However, because of the small number of samples the similarity level between all biotopes remained quite low (at the level of ca 20–50%).

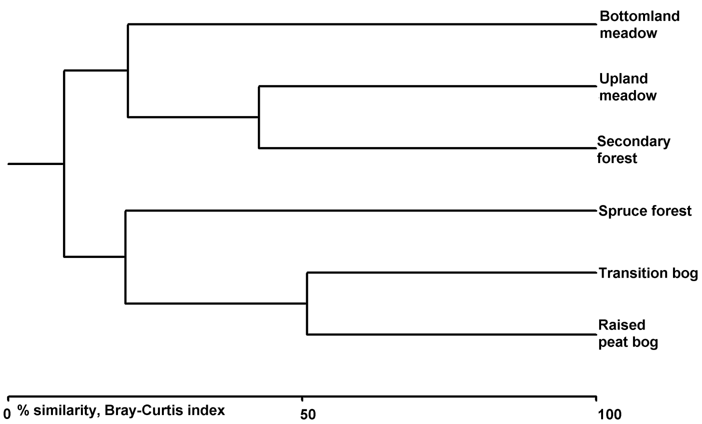

Fig. 1. Results of cluster analysis of the species composition of oribatid mite communities in six habitat types in the environs of the Polistovsky Nature Reserve. Bray–Curtis index is used as a similarity measure, complete link clustering method was applied.

Rank distribution analysis of oribatid species abundance in six habitats showed that mite communities in spruce forests and raised peat bogs corresponded best with the log-series distribution model (Fig. 2). The abundance distribution of oribatid communities in the other habitats considerably deviated from the log-series model. For example, the mite community in transition bogs clearly deviated from this model in a stochastic way (Fig. 2). In both types of meadows the number of rare species (comprising <5% of the total abundance) was very low along with the extremely low overall species richness. In secondary forests the number of rare species was on the contrary quite high. At the same time there were only a few abundant species. Such distribution patterns are closer to the log-normal model of abundance distribution.

The abundance of different oribatid mite ecomorphs in pre-defined habitat types is shown in Fig. 3. The density of surface-dwelling oribatids was significantly higher in spruce forests than in bogs and bottomland meadows (ANOVA; $F = 2.94$,

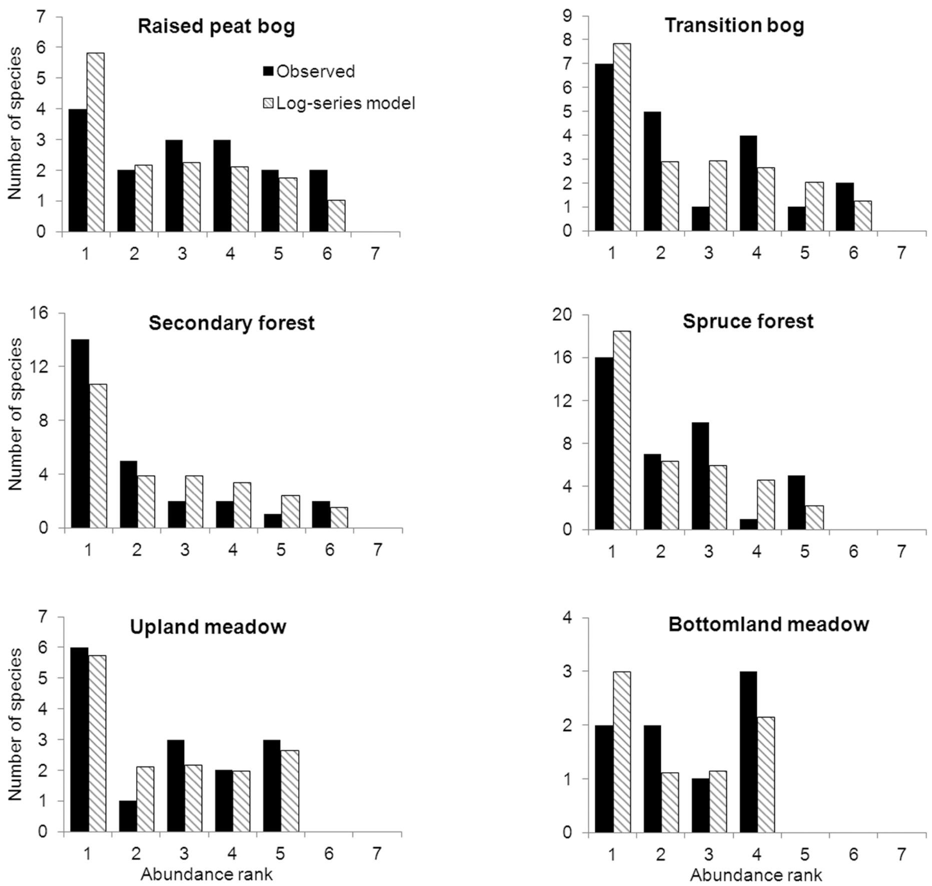

Fig. 2. Rank distribution of oribatid species abundance in six habitat types in the environs of the Polistovsky Nature Reserve and its comparison with the log-series model distribution. Abundance classes are defined on the basis of $\log_2$.

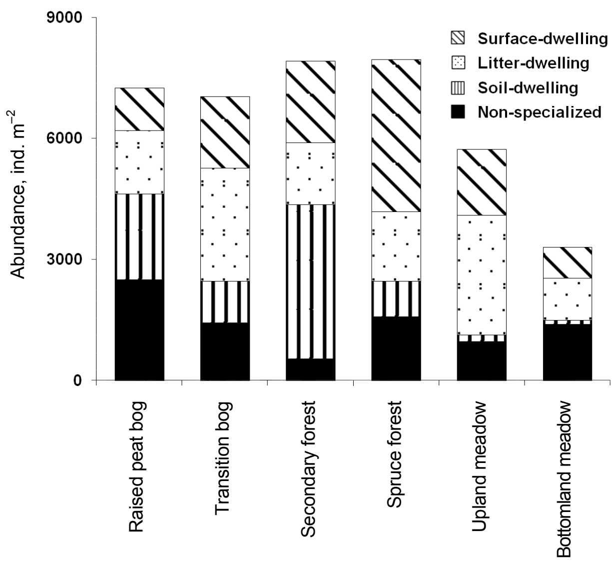

Fig. 3. Abundance of different oribatid mite ecomorphs in six habitat types in the environs of the Polistovsky Nature Reserve. Abundance of water-dwelling mites was extremely low and could not be depicted at the given scale.

$p < 0.05$). The abundance of mites from other ecomorphs was not significantly different between habitats (ANOVA; $F = 0.29$, 1.19, 0.82, and 1.47 for litter-dwelling, soil-dwelling, non-specialized, and water-dwelling oribatids, respectively; $p > 0.1$ in all cases).

DISCUSSION

Over one-fourth of the entire known oribatid species in the Pskov Region were detected in our study despite the low sampling effort. This indicates quite high subregional biodiversity of the acarofauna in the environs of the Polistovsky Nature Reserve (Zaitsev, 2001), which can be related to the considerable geological age of the Polistovsko-Lovatskaya peat bog system, which started to form after the Valdai glaciate retreat (Svendsen et al., 2004; Zaitsev et al., 2013). Moreover, the bogs protected in the Polistovsky Nature Reserve serve as an important transit stop for many migratory bird species, which are known to transport soil mites in their plumage (Krivolutsky & Lebedeva, 2004; Lebedeva, 2012). Presence in the peat bogs of oribatid species with basically West-European or Central-European distribution (*M. hygrophila*, *N. dorsalis*, and *Z. furcatus*) that have been rarely met in Russia before (Zaitsev, 2001) highlights the importance of these extrazonal habitats in the formation of the overall regional soil invertebrate diversity in North-Western Russia (Weigmann, 2006). However, in total peat bogs host fewer unique species than one could expect (Sidorchuk, 2008).

The low level of faunistic similarity between semi-primary (spruce forests and bogs) and secondary habitats (secondary forests and meadows) can be explained by the absence of hygrophilous species (e.g. *M. hygrophila*) and mites belonging to surface- and litter-dwelling ecomorphs (*Galumna obvia*, *Hoplophthiracarus illinoisensis*, *Nanhermannia dorsalis*, and some others). In addition, this may be due to the given sampling effort and higher levels of anthropogenic impacts in the secondary biotopes in the past (Schon et al., 2012). As a result of this, one can also observe quite contrasting species richness between relatively undisturbed forests and peat bogs on the one hand and recently actively exploited meadows on the other (Chachaj & Seniczak, 2005; Manakov et al., 2010). The last reason can at least partially explain quite low levels of oribatid abundance discovered during our sampling campaign. Even in spruce forests, where we found the highest density of oribatid mites, their abundance was approximately 10–15% of the average values known from the literature for this vegetation type (Krivolutsky, 1995). The mite abundance in peat bogs, on the contrary, was comparable to the lowest values known from the literature (e.g. Sidorchuk, 2008). Peat bogs were obviously the least disturbed ecosystems on the study area, and thus oribatid abundance on their territory has remained at the natural levels (Manakov et al., 2010). Considerable faunistic and community structure differences between spruce and secondary forests prove the importance of age because meadows or arable lands were abandoned in explaining the variance of oribatid species richness and composition (Zaitsev et al., 2006).

Correspondence of rank abundance distribution of oribatid mite species in spruce forests and peat bogs with the log-series model indicates that soil microarthropod community ecology in these habitats is determined by a limited number of environmental factors (Magurran, 2004). Defining these driving forces will be the task for the nearest future. The low proportion of rare species in meadows indicates the ongoing process of acarofauna recovery in these habitats (Magurran, 2004). Oribatid communities in secondary forests characterized by a large number of rare species demonstrate more advanced stages of soil ecosystem recovery than meadows. A mixture of species found predominantly in meadows and in spruce forests was observed in secondary forests.

The lack of significant differences between the abundance of oribatid community ecomorphs in different habitats in the environs of the Polistovsky Nature Reserve results mainly from high variance of data, but it could also be a sign of the same origin of oribatid communities and similar macroecological situation on the studied territory (Zaitsev et al., 2013). The only exception was the abundance of surface-dwelling mites. Its relatively high value in spruce forests indicates the most optimal hydrothermal conditions in these least disturbed and relatively drained biotopes (Krivolutsky et al., 1995).

In conclusion we can state that despite the strict conservation status of the Polistovsky Nature Reserve and negligible anthropogenic loads over the past 20–25 years, oribatid mite communities in secondary vegetation types such as meadows and secondary forests still demonstrated low abundance and species richness. The overall ecological structure of oribatid mite communities across all habitats in the area is quite similar, which is not typical of communities liberated from anthropogenic stress. This could be tested in the future by performing additional sampling. Possibly this is related to the ongoing mite fauna enrichment process by migratory birds and high initial buffering capacity of soils in the Polistovsky Nature Reserve (Lindo et al., 2012). More detailed comparative study of the oribatid fauna and community structure in the Polistovsky Nature Reserve is needed to detect the driving forces of both the revealed community similarity and variance.

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REFERENCES

Chachaj, B. & Seniczak, S. 2005. The influence of sheep, cattle and horse grazing on soil mites (Acari) of lowland meadows. *Folia Biologica-Krakow*, **53**, 127–132.

Druk, A. Ya. 1982. Oribatid mites of some bog types in Moscow region. In *Soil Invertebrates of Moscow Region* (Ghilarov, M. S., ed.), pp. 72–77. Nauka Publishers, Moscow (in Russian).

Eitminavichute, I. S. 1972. *Pedobiological Characteristics of Typical Bogs in the Lithuanian SSR*. Mintis Publishers, Vilnius (in Russian).

Ghilarov, M. S. 1975. *Methods of Soil-Zoological Research*. Nauka Publishers, Moscow (in Russian).

Karppinen, E. & Krivolutsky, D. A. 1982. List of oribatid mites (Acarina, Oribatei) of northern palaearctic region. I. Europe. *Acta Entomologica Fennica*, **41**, 1–32.

Krantz, G. W. & Walter, D. E. 2009. *A Manual on Acarology*. Texas Technical University Press, Lubbock.

Krivolutsky, D. A. (ed.) 1995. *Oribatid Mites*. Nauka Publishers, Moscow (in Russian).

Krivolutsky, D. A. & Lebedeva, N. V. 2004. Oribatid mites (Oribatei, Acariformes) in bird feathers: non-Passerines. *Acta Zoologica Lituanica*, **14**, 26–47.

Laskova, L. M. 1983. Oribatid mites (Oribatei) in bog soils of Karelia. In *Abstracts of All-Union Colloquium on Soil Zoology* (Ghilarov, M. S., ed.), p. 206. Vilnius (in Russian).

Lebedeva, N. V. 2012. Oribatid mites transported by birds to polar islands. A review. *Berichte zur Polar- und Meerforschung*, **640**, 152–161.

Lindo, Z., Whiteley, J., & Gonzalez, A. 2012. Traits explain community disassembly and trophic contraction following experimental environmental change. *Global Change Biology*, **18**, 2448–2457.

Magurran, A. E. 2004. *Measuring Biological Diversity*. Princeton University Press, Princeton.

Manakov, G. G., Evdokimov, S. I., & Grigor′eva, N. V. 2010. *Western Border Area of Russia: Geographic Aspects of Formation and Development of Pskov Region*. ANO Logos Publishers, Pskov (in Russian).

McAleece, N., Gage, J. D. G., Lambshead, P. J. D., & Paterson, G. L. J. 1997. *BioDiversity Professional statistics analysis software*. http://www.sams.ac.uk/peter-lamont/biodiversity-pro (accessed 10.10.2013).

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., et al. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. *Bioscience*, **51**, 933–938.

Schon, N. L., Mackay, A. D., & Minor, M. A. 2012. Vulnerability of soil invertebrate communities to the influences of livestock in three grasslands. *Applied Soil Ecology*, **53**, 98–107.

Sidorchuk, E. A. 2008. Oribatid mites (Acari, Oribatei) of three fens in the northern part of European Russia. *Zoologichesky Zhurnal*, **87**, 626–631 (in Russian).

StatSoft, Inc. 2007. *STATISTICA (data analysis software system), version 7*. Tulsa, USA. www.statsoft.com (accessed 10.10.2013).

Svendsen, J. I., Alexanderson, H., Astakhov, V. I., Demidov, I., Dowdeswell, J. A., Funder, S., et al. 2004. Late Quaternary ice sheet history of northern Eurasia. *Quaternary Science Reviews*, **23**, 1229–1271.

Weigmann, G. 2006. *Hornmilben (Oribatida)*. Die Tierwelt Deutschlands. Vol. 76. Goecke & Evers, Keltern.

Zaitsev, A. S. 2001. Geography of oribatid mite distribution in Russia. *Vestnik Moskovskogo Universiteta, serija 5, geographicheskaya*, **6**, 34–37 (in Russian).

Zaitsev, A. S., Wolters, V., Waldhardt, R., & Dauber, J. 2006. Long-term succession of oribatid mites after conversion of croplands to grasslands. *Applied Soil Ecology*, **33**, 230–239.

Zaitsev, A. S., van Straalen, N. M., & Berg, M. P. 2013. Landscape geological age explains large scale spatial trends in oribatid mite diversity. *Landscape Ecology*, **28**, 285–296.