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The first report on oribatid mites in tundra belts of the Lovozersky Mountains on the Kola Peninsula, Russia

Vladislav D. Leonov, Anna A. Rakhleeva

ABSTRACT

The fauna of oribatid mites (Acari, Oribatida) in the mountain tundra on the Kola Peninsula (Russia) is still poorly studied. The main aim of this research is to obtain initial data on the fauna and abundance of oribatid mites of the Lovozersky Mountains. We investigated five plots, including three lichen tundra plots, one dwarf shrub tundra plot and one wetted tundra plot in one of the largest mountain massifs of the Kola Peninsula — the Lovozersky Mountains. Multidimensional scaling and discriminant function analysis were used to identify some trends in the fauna and abundance of species on the explored plots. The abundance of oribatid mites in the lichen tundra reached 23,680 ind./m$^2$. In the dwarf shrub tundra, this value is over three times higher — up to 81,160 ind./m$^2$, which is comparable with the oribatid mite abundance of forest habitats. The minimum values were discovered in wetted tundra (6,200 ind./m$^2$). A total of 71 species, 38 genera, and 24 families of oribatid mites were found during the course of this study. Eight species of Oribatida have been added to the fauna of the Kola Peninsula. A significant difference was observed in the structure of oribatid faunas of the explored habitats. The occurrence in samples and relative abundance of Mycobates sarekensis, Oribatula amblyptera, Tectocepheus velatus and Carabodes labyrinthicus increased in lichen tundra compared to dwarf shrub tundra. Species of Suctobelbidae and Oppiidae were higher in occurrence and relative abundance in dwarf shrub tundra compared to lichen tundra. The occurrence and relative abundance of Trimalaconothrus angulatus, T. maior and Platynothrus peltifer prevailed in wetted tundra as compared to dwarf shrub tundra. The family Suctobelbidae was represented by a large number of species, while the family Ceratozetidae showed a small number of species in the discovered fauna. According to the literature, these features of the fauna are unusual for tundra. A low diversity of Ceratozetidae, a high diversity of Suctobelbidae and high abundance of oribatid mites in dwarf shrub tundra may be explained by the ambivalent nature of the oribatid community in the explored region, which combines boreal and arctic features due to marine climate.

Keywords  Acari; Oribatida; mountain tundra habitats; lichen tundra; dwarf shrub tundra; wetted tundra; community structure; fauna of the tundra; Suctobelbidae; Ceratozetidae

Introduction

The oribatid mite communities in mountain tundra habitats of the Kola Peninsula remain poorly studied. They have been studied only in the Khibiny Mountains, where 50 species, 34 genera, and 23 families of oribatid mites have been found (Zenkov et al. 2014; Leonov and Rakhleeva 2015; Leonov et al. 2015; Leonov 2017). In two other large mountain massifs of...
the Kola Peninsula (the Chunatundra and the Lovozersky Mountains), oribatid mites have not been studied to date. The oribatid mite fauna of the plain tundra on the Kola Peninsula is better investigated, with 140 species known, belonging to 73 genera and 39 families (Krivolutsky 1966; Liskovaya 2011; Leonov and Rakheeva 2015; Leonov 2017).

In the Scandinavian Peninsula, a total of 145 species, 69 genera, and 42 families of oribatid mites have been found only in the alpine habitats (Heggen 2010). Meanwhile, 151 species of oribatid mites are known to inhabit the western North American Low Arctic (Behan-Pelletier 1999a). Based on the aforementioned data, a considerable species richness is expected to be found in the mountain tundra habitats of the Kola Peninsula.

An important aspect of the tundra community research is the study of oribatid mites in different types of tundra, which include lichen tundra, dwarf shrub tundra and wetted tundra conditions. Due to differences in the vegetation of these tundra types, differences in the environmental conditions for oribatid mites exist. Thus, we can expect a major difference in the fauna and abundance of oribatid mites in these habitats.

The aims of this research are to obtain initial data on the fauna and abundance of oribatid mites of the Lovozersky Mountains and to compare them between the explored tundra habitats and with the literature data.

**Materials and methods**

**Study area**

The Lovozersky Mountains are located in the central part of the Kola Peninsula, east of the Khibiny Mountains (Figure 1). The average annual air temperature there is approximately -1 °C. The region belongs to an area with a predominance of precipitation over evaporation. In areas with complex terrain, precipitation amounts to 600–800 mm. Precipitation exceeds 1 000 mm at the peaks of the largest mountain ranges. The climate type is subarctic marine (Agarkova et al. 2008).

In the mountains of the Kola Peninsula the following vegetation zones are present: the spruce-pine-birch belt occupies areas up to 250–480 m a.s.l.; above this, the belt of birch crooked forest spreads over several tens of meters; the belt of dwarf shrubs extends up to 600–700 m a.s.l.; the alpine lichen tundra belt occurs up to 850–900 m a.s.l.; and the belt of sparse vegetation covers the tops of the mountains and plateaus (Stanyukovich 1973).

**Study sites**

The research was conducted in the Seydyavvr State Nature Reserve (Figure 1). Five mountain tundra plots on a south-facing slope were explored in the northern part of the Lovozersky Mountains. The plots formed an altitude transect from the plateau between the Kuamdespahk and Kuivchorr Mountains to Lake Seydozero along the Suolui River. The following coordinates and altitudes of the plots were obtained using a GPS/GLONASS Garmin eTrex 30 receiver:

1. Grass-moss-lichen tundra plot: altitude of 740 m a.s.l. (plot GMLT-740; 67°51.118’ N, 34°53.623’ E). Vegetation cover is closed. The main plant and lichen species are Salix sp., Dryas octopetala, Empetrum hermaphroditum, Phyllodoce caerulea, Cetrariella delisei, Cladonia stellaris, Sphaerophorus globosus, Pleuroziun schreberi, Juncus tristis, and Carex sp. Grasses (single sedges and bumps of Juncus tristis) grow mainly among lichen thalluses. Cetrariella delisei dominates among lichens. Cladonia stellaris is numerous. Pleuroziun schreberi is a dominant species among mosses. The proportion of mosses in the vegetation is small compared to lichens. The Marchantiophytas occupy areas with no other vegetation. The dwarf shrub layer is not developed: shrubs take the form of trailing among the lichen thalluses. Some shrubs exhibit cushion growth forms. The soil type is Leptosol (hereafter, soil names are given using the World Reference Base for Soil Resources, WRB, IUSS Working Group WRB 2015).
2. Lichen tundra plot: altitude of 740 m a.s.l. (plot LT-740; 67°51.118’ N, 34°53.623’ E). Vegetation cover is closed. The main plant and lichen species are *Salix* sp., *Betula nana*, *Vaccinium vitis-idaea*, *Flavocetraria nivalis*, *Cladonia stellaris*, *Sphaerophorus globosus*, *Pleurozium schreberi*, and *Carex* sp. *Flavocetraria nivalis* forms a dense, closed lichen cover with the inclusion of *Pleurozium schreberi*. *Salix* sp. and *Betula nana* are not exceeded in height by the lichen thalluses and do not develop a shrub cover. Sparse grasses are represented by sedge species. The soil type is Leptosol.

3. Grass-lichen tundra plot: altitude of 721 m a.s.l. (plot GLT-721; 67°51.020’ N, 34°53.547’ E). This plot is vegetated by *Carex* spp., *Salix* sp., *Salix cf. polaris*, *Phyllocladus caerulea*, *Vaccinium vitis-idaea*, *Cladonia stellaris*, *Cetraria delisei*. Vegetation cover is a mosaic represented by evenly distributed grasses (cereals, sedges), mosses, and lichens. Dwarf shrubs do not exceed the height of the lichen. The soil type is Entic Podzol.

4. Wetted tundra plot: altitude of 702 m a.s.l. (plot WT-702; 67°50.950’ N, 34°53.595’ E). This is a heavily wetted site of the mountain tundra which is fed by underground watercourses discharged to the surface and continuing their way open down the slope (the spring of the Suolui River). The vegetation cover is a dense, closed cover of Bryophyta and Marchantiophyta (without *Sphagnum* mosses) with some dicotyledonous and monocotyledonous plants developed. It is dominated by *Dicranum* sp., *Sarmentypnum sarmentosum*, *Gymnomitrion concinnatum*, *Carex* sp., *Bartsia alpina*, and *Ranunculus acris*. The shrub layer is represented by *Salix* sp.

5. Dwarf shrub tundra plot: altitude of 428 m a.s.l. (plot DST-428; 67°50.300’ N, 34°53.913’ E). Vegetation cover is closed. The main plant and lichen species are *Betula nana*, *Salix* sp., *Juniperus communis*, *Vaccinium myrtillus*, *V. uliginosum*, *Cetraria islandica*, and *Leonov V. D. and Rakhleeva A. A. (2020), Acarologia 60(2): 301-316; DOI 10.24349/acarologia/20204369*
Pleurozium schreberi. Closed shrub cover is not developed. Betula nana and Salix sp. are represented by detached plants that are much higher than the dwarf shrubs. Vaccinium myrtillus and V. uliginosum with rare horsetails, small grasses and herbs developed a distinct and closed vegetation layer. The soil cover is represented by mosses and lichens with a dominance of Pleurozium schreberi and Cetraria islandica. The soil is Entic Podzol.

Sampling and sample processing

In each studied habitat 10 samples were taken with a corer (25 cm²) up to 10 cm depth (included topsoil, litter and soil-cover vegetation — mosses, lichen and dwarf shrub parts) between Jul. 30, 2014 and Aug. 1, 2014. The samples were placed in multilayer paper bags and transported to Moscow (moving time — three days) to carry out further processing. Microarthropods were extracted using a Tullgren funnel in the laboratory without additional heating for 10 days (Potapov and Kuznetsova 2011).

Mite identification

Adult oribatid mites were identified to the species level using the identification keys (Gilyarov 1975; Weigmann 2006; Bayartogtokh 2010; Niedbała 2011). We used additional literature on the systematics of oribatid mites, descriptions and redescriptions of species, keys to individual genera and families of mites, regional keys, and keys for individual groups (Shaldybina 1972; Norton 1977; Behan-Pelletier 1985; Behan-Pelletier 1986; Woas 1986; Pavlichenko 1994; Chinone 2003; Miko and Mourek 2008; Miko 2010; Miko et al. 2011; Mourek et al. 2011; Beck et al. 2014; Niedbała 2014). We checked juveniles to identify fauna more completely, but we did not use information about juveniles in further analyzes because of impossibility to identify most of them to species level. The valid species status and synonymy are based on the nomenclature of Weigmann (2006).

Data analysis

Mean values, standard deviations, and standard errors were calculated using Microsoft Office Excel 2010. The oribatid communities in the explored plots were compared using multidimensional scaling and discriminant functional analysis according to Tiunov and Scheu (2000, 2005). Based on the presence of species in individual samples and relative abundance in them, the similarity matrices between samples were calculated using the Jaccard and Bray-Curtis similarity measures (Bray and Curtis 1957; Krebs 1999; Magurran 2003). The similarity matrices were analyzed using multidimensional scaling. The minimum number of meaningful dimensions was evaluated by comparing actual stress values with the theoretical exponential function of stress. A 3D solution for both Jaccard and Bray-Curtis matrices showed the best results. The coordinates of the samples in 3D space were used for discriminant function analysis. Two significant discriminant functions (canonical Roots) were obtained. To interpret the extracted canonical Roots in terms of both occurrence in samples and abundance of oribatid species, Spearman rank correlations were calculated between the canonical scores of canonical Roots and both presence/absence and relative abundance of oribatid species in individual samples. Calculations were made in PAST 3.26b (Hammer et al. 2001) and Statistica 6.0 (StatSoft, Tulsa).

The Engelmann classification (Engelmann 1978) was used to describe the classes of oribatid mite dominance: eudominants (40–100%), dominants (12.5–39.9%), subdominants (4–12.4%), recedents (1.3–3.9%) and subrecedents (less than 1.3%) of mean abundance in the investigated habitats.
Table 1 Abundance (ind./m²) of oribatid mites in mountain tundra of the Lovozersky Mountains: grass-moss-lichen tundra plot (GMLT-740), lichen tundra plot (LT-7400), grass-lichen tundra plot (GLT-721), wetted tundra plot (WT-702), and dwarf shrubs tundra plot (DST-428).

| Taxa | GMLT-740 | LT-740 | GLT-721 | WT-702 | DST-428 |
|------|----------|--------|---------|--------|---------|
| Palaeacaridae Grandjean, 1932 | | | | | |
| Palaeacarus kamenskii (Zachvatkin, 1945) | 0 | 0 | 0 | 0 | 480 |
| Brachychthoniidae Thor, 1934 | | | | | |
| Eobrachychthonius latior (Berlese, 1910) | 0 | 520 | 0 | 40 | 200 |
| Liocithonius brevis (Michael, 1888) | 0 | 0 | 0 | 0 | 280 |
| Liocithonius laponicus (Tragardh, 1910) | 120 | 920 | 200 | 0 | 1120 |
| Liocithonius muscorum Forsslund, 1964 | 200 | 0 | 0 | 0 | 0 |
| Liocithonius neglectus Moritz, 1976 | 0 | 80 | 0 | 0 | 160 |
| Liocithonius perfusorius Moritz, 1976* | 0 | 0 | 0 | 40 | 0 |
| Liocithonius perelegans Moritz, 1976* | 0 | 0 | 40 | 0 | 0 |
| Liocithonius sellnicki (Thor, 1930) | 0 | 200 | 0 | 360 | 1320 |
| Liocithonius cf. sellnicki (Thor, 1930) | 0 | 0 | 0 | 0 | 40 |
| Neobrachychthonius marginatus (Forsslund, 1942) | 40 | 0 | 0 | 0 | 0 |
| Sellnickochthonius immaculatus (Forsslund, 1942)* | 160 | 0 | 40 | 0 | 520 |
| Eulohmanniidae Grandjean, 1931 | | | | | |
| Eulohmannia ribagai (Berlese, 1910) | 0 | 0 | 0 | 0 | 480 |
| Phthiracaridae Perty, 1841 | | | | | |
| Phtiracarus clavatus Parry, 1979 | 0 | 0 | 0 | 0 | 200 |
| Phtiracarus cf. membranifer Parry, 1979* | 0 | 0 | 0 | 0 | 40 |
| Phtiracarus opacus Niedbala, 1986 | 0 | 0 | 0 | 0 | 160 |
| Malacronothridae Berlese, 1916 | | | | | |
| Trimalaconothrus angulatus Willmann, 1931* | 0 | 0 | 0 | 360 | 0 |
| Trimalaconothrus maior (Berlese, 1910) | 0 | 0 | 0 | 240 | 0 |
| Nothridae Berlese, 1896 | | | | | |
| Notthus borussicus Sellnick, 1929 | 840 | 40 | 1400 | 400 | 160 |
| Camisiidae Oudemans, 1900 | | | | | |
| Camisia biurus (C.L. Koch, 1839) | 0 | 0 | 0 | 0 | 40 |
| Camisia solhoeyi Colloff, 1993 | 40 | 0 | 0 | 120 | 0 |
| Neohermannia humicolus Forsslund, 1955 | 0 | 0 | 0 | 0 | 320 |
| Heminothrus longisetosus Willmann, 1925 | 0 | 1440 | 120 | 0 | 2000 |
| Platynothrus peltifer (C.L. Koch, 1839) | 0 | 0 | 880 | 40 | 0 |
| Nanhermanniidae Sellnick, 1928 | | | | | |
| Nanhermannia sellnicki Forslund, 1958 | 0 | 0 | 0 | 0 | 4920 |
| Damaeidae Berlese, 1896 | | | | | |
| Belba compa (Kulczynski, 1902) | 0 | 0 | 0 | 0 | 840 |
| Kunstidamaeus nidicola (Willmann, 1936) | 0 | 0 | 0 | 40 | 200 |
| Porobolba spinosa (Sellnick, 1920) | 400 | 0 | 0 | 0 | 720 |
| Eremaeidae Oudemans, 1900 | | | | | |
| Eueremaus silvestris (Forslund, 1956) | 0 | 0 | 0 | 0 | 720 |
| Peloppiidae Balogh, 1943 | | | | | |
| Ceratoppia sphaerica (L. Koch, 1879) | 0 | 80 | 0 | 0 | 0 |
| Carabodidae C.L. Koch, 1837 | | | | | |
| Carabodes areolatus Berlese, 1916 | 0 | 0 | 0 | 0 | 760 |
| Carabodes lapparinus (Michael, 1879) | 6200 | 2760 | 0 | 0 | 160 |
| Tectocepheidae Grandjean, 1954 | | | | | |
| Tectocephhus velatus (Michael, 1880) | 6520 | 6160 | 5520 | 640 | 4800 |
| Quadroppiidae Balogh, 1983 | | | | | |
| Quadroppia quadricarinata (Michael, 1885) | 320 | 160 | 0 | 0 | 2280 |

The sign "*" marks species first encountered on the Kola Peninsula.
*Camisia cf. invenusta*, found in the amount of 1 individual in the instar of tritonymph, is absent in the table.
### Table 1 Continued.

| Taxa                                      | GMLT-740 | LT-740 | GLT-721 | WT-702 | DST-428 |
|-------------------------------------------|----------|--------|---------|--------|---------|
| Oppiidae Grandjean, 1951                  |          |        |         |        |         |
| Dissorhina ornata (Oudemans, 1900)        | 0        | 0      | 0       | 0      | 200     |
| Oppiella sp.3                             | 0        | 0      | 0       | 160    | 0       |
| Oppiella sp.5                             | 0        | 0      | 0       | 0      | 40      |
| Oppiella acuminata (Strenzke, 1951)       | 0        | 440    | 0       | 0      | 4240    |
| Oppiella maritima (Willmann, 1929)        | 0        | 0      | 0       | 0      | 440     |
| Oppiella neerlandica (Oudemans, 1900)     | 0        | 0      | 0       | 40     | 7600    |
| Oppiella nova (Oudemans, 1902)            | 0        | 120    | 0       | 0      | 5000    |
| Oppiella splendens (C.L. Koch, 1841)      | 0        | 0      | 0       | 0      | 5240    |
| Oppiella subpectinata (Oudemans, 1900)    | 0        | 0      | 0       | 0      | 120     |
| Oppiella unicarinata (Paoli, 1908)        | 0        | 0      | 0       | 0      | 480     |
| **Suctobelbidae Jacot, 1938**             |          |        |         |        |         |
| Suctobelba trigona (Michael, 1888)        | 440      | 160    | 0       | 80     | 320     |
| Suctobelbella sp.1                         | 0        | 0      | 0       | 0      | 3440    |
| Suctobelbella sp.2                         | 0        | 0      | 0       | 0      | 520     |
| Suctobelbella acutidens (Forsslund, 1941) | 40       | 280    | 680     | 120    | 5880    |
| Suctobelbella cf. arcana (Moritz, 1970)   | 0        | 0      | 0       | 0      | 4800    |
| Suctobelbella falcata (Forsslund, 1941)   | 0        | 0      | 0       | 0      | 600     |
| Suctobelbella longirostris (Forsslund, 1941) | 0    | 40     | 0       | 0      | 1280    |
| Suctobelbella cf. prominens (Moritz, 1966)* | 0      | 0      | 0       | 0      | 480     |
| Suctobelbella sarekensis (Forsslund, 1941) | 40  | 0      | 0       | 0      | 840     |
| Suctobelbella cf. sarekensis              | 0        | 0      | 0       | 0      | 4400    |
| Suctobelbella subtrigona (Oudemans, 1900) | 0        | 0      | 0       | 0      | 1000    |
| **Licneremaeidae Grandjean, 1931**        |          |        |         |        |         |
| Licneremaecus licnophorus (Michael, 1882) | 0        | 80     | 80      | 0      | 0       |
|  |          |        |         |        |         |
| Phenopelopidae Petrunkevich, 1955         |          |        |         |        |         |
| Eupelops torulosus (C. L. Koch, 1840)     | 0        | 0      | 0       | 0      | 520     |
|  |          |        |         |        |         |
| Achipteridae Thor, 1929                   |          |        |         |        |         |
| Parachipteria punctata (Nicolet ,1855)     | 0        | 0      | 0       | 0      | 160     |
|  |          |        |         |        |         |
| Ceratozetidae Jacot, 1925                 |          |        |         |        |         |
| Ceratozetes thienemanni Willmann, 1943    | 0        | 0      | 0       | 0      | 2040    |
| Diapterobates humeralis (Herrman, 1804)   | 0        | 0      | 0       | 0      | 80      |
| Edwardzetes edwardsi (Nicolet, 1855)      | 0        | 0      | 0       | 0      | 80      |
| Melanocetes mollicomus (C. L. Koch, 1839) | 0        | 0      | 0       | 120    | 40      |
|  |          |        |         |        |         |
| Chamobatidae (Thor, 1938)                 |          |        |         |        |         |
| Chamobates borealis (Tragardh, 1902)      | 7640     | 0      | 6120    | 2000   | 6480    |
|  |          |        |         |        |         |
| Mycobatidae Grandjean, 1954               |          |        |         |        |         |
| Mycobates sarekensis (Tragardh, 1910)*    | 240      | 800    | 0       | 0      | 0       |
| Mycobates tridactylus Willmann, 1929      | 0        | 160    | 0       | 0      | 0       |
|  |          |        |         |        |         |
| Scheloribatidae Grandjean, 1933           |          |        |         |        |         |
| Leibstadtia similis (Michael, 1888)       | 40       | 0      | 40      | 40     | 200     |
| Hemileius initialis (Berlese, 1908)       | 40       | 40     | 40      | 160    | 1640    |
|  |          |        |         |        |         |
| Oribatulidae Thor, 1929                   |          |        |         |        |         |
| Oribatula amblyptera Berlese, 1916*       | 360      | 120    | 240     | 280    | 0       |
| Oribatula thibialis (Nicolet, 1855)       | 0        | 80     | 0       | 0      | 80      |
| Oribatula pannonica Willmann, 1949        | 0        | 0      | 0       | 0      | 40      |
|  |          |        |         |        |         |
| **Number of species**                     | 18       | 21     | 12      | 20     | 56      |
| Average abundance (ind./m²)               | 23680    | 14680  | 14520   | 6200   | 81160   |
| Standard deviation                       | 14521    | 12887  | 9222    | 10051  | 24332   |
| Standard error                           | 4592     | 4075   | 2916    | 3178   | 7695    |

*The sign "*" marks species first encountered on the Kola Peninsula.

*Camisia cf. invenusta*, found in the amount of 1 individual in the instar of tritonymph, is absent in the table.
Results

A total of 5,535 specimens of adult oribatid mites were collected and identified. Overall, 71 species, 38 genera, and 24 families of oribatid mites were found in the Lovozersky Mountains (Table 1). As a result, the known oribatid mite fauna of the Kola Peninsula has increased by eight species (Liochthonius perfusorius, L. perelegans, Sellnickochthonius immaculatus, Phthiracarus cf. membranifer, Trimalaconothrus angulatus, Suctobelbella cf. promemens, Mycobates sarekensis, Oribatula amblyptera) compared to previous studies (Liskovaya 2011; Zenkova et al. 2011; Zenkova and Melekhina 2014; Leonov and Rakhleeva 2015; Leonov et al. 2015). One specimen of Camisia cf. invenusta in the tritonymph stage was found in plot GMLT-740, though adults of this species were not found.

Three oribatid families — Brachychthoniidae, Oppiidae, and Suctobelbidae — were most abundant in species. Each of these was represented by 11 species, which comprised 15.3% of the total discovered fauna. Camisiidae (5 species) and Ceratozetidae (4 species) contributed 6.9% and 5.6% to the local fauna, respectively.

The explored lichen and dwarf shrub tundra differed considerably in the composition and structure of oribatid mite community. Species of the family Brachychthoniidae constituted the majority of the lichen tundra fauna (8 species, 26.7% of the fauna). The family Suctobelbidae — second in the number of species in lichen tundra — had four species (13.3% of the fauna). All the remaining families included only one or two species. In the dwarf shrub tundra, the family Suctobelbidae had the largest representation (11 species, 19.6% of the fauna). The family Oppiidae exhibited the second-highest number of species (9 species, 16.1% of the fauna), while the family Brachychthoniidae included seven species (12.5% of the fauna).

The wetted tundra plot was characterized by ordinary fauna that is similar in composition to the fauna of the lichen tundra plots. The Brachychthoniidae remained the most abundant in species (3 species, 15% of the fauna), while the Oppiidae that is typically well represented in

| Species | GMLT-740 | LT-740 | GLT-721 | WT-702 | DST-428 |
|---------|----------|--------|--------|--------|---------|
| Tectocepheus velatus | 27.5 | 42 | 38 | 10.4 | 5.9 |
| Chamobates borealis | 32.3 | | 42.1 | | 32.5 |
| Carabodes labyrinthicus | 26.2 | 18.8 | | | 0.2 |
| Platynothrus peltifer | | | 14.3 | | |
| Liochthonius laponicus | 0.5 | 6.3 | 1.4 | | 1.4 |
| Heminothrus longisetosus | | 9.8 | 0.8 | | 2.5 |
| Mycobates sarekensis | 1 | 5.4 | | | |
| Nothrus borussicus | 3.5 | 0.3 | 9.6 | 6.5 | 0.2 |
| Liochthonius sellnicki | 1.4 | | 5.8 | | 1.6 |
| Trimalaconothrus angulatus | | | | 5.8 | |
| Nanhermannia sellnickii | | | | | 6.1 |
| Oppiella acuminata | 3 | | | | 5.2 |
| Oppiella neerlandica | | | 0.6 | | 9.4 |
| Oppiella nova | 0.8 | | | | 6.2 |
| Oppiella splendens | | | | | 6.5 |
| Suctobelbella acutidens | 0.2 | 1.9 | 4.7 | 1.9 | 7.2 |
| Suctobelbella arcana | | | | 5.9 | |
| Suctobelbella sarekensis | | | | | 5.4 |
Tundra communities included only two species (6.7% of the fauna) — *Oppiella acuminata* and *O. nova*.

The abundance of oribatid mites increased from lichen to dwarf shrub tundra. The lowest oribatid abundance was observed in the wetted tundra plot (Table 1).

Substantial differences were observed in the dominance structure of oribatid mite communities across the studied habitats (Table 2). Lichen tundra was characterized by a small number of dominant species with high levels of dominance in the explored plots. No dominant species were discovered in the dwarf shrub tundra, but 10 subdominant species were noted in this habitat. A specific complex of dominant species was observed in the wetted tundra plot. The strong dominance of *T. angulatus* and *P. peltifer* displays a specific type of oribatid dominance structure that is typical for wetlands. Notably, *P. peltifer* was not observed in the dominant complexes of the other explored tundra habitats and reached high values of dominance only in wetted tundra.

There was a significant difference in the structure of oribatid faunas of the explored habitats (Figure 2). Changes in environmental conditions for oribatid mites from lichen tundra to dwarf shrub tundra (canonical Root 1) led to a statistically significant decrease in the occurrence of *M. sarekensis*, *O. amblyptera*, *T. velatus*, *C. labyrinthicus* in the studied plots. The occurrence of many species, especially of the families Oppiidae and Suctobelbidae, increased. Species of these families had the highest Spearman R correlation values with canonical Root 1 (Table 3).

### Table 3 Spearman rank correlations between the occurrence of species in individual samples in the explored plots and canonical Roots (only species with significant correlation, p <0.05; for correlation with Root 1 all species with negative Spearman R and species with the positive Spearman R>0.5 are given).

| Species                  | Spearman R | p-value | Species                  | Spearman R | p-value |
|--------------------------|------------|---------|--------------------------|------------|---------|
| *Mycobates sarekensis*   | -0.53      | 0.0001  | *Trimalaconothrus angulatus* | -0.41      | 0.0035  |
| *Oribatula amblyptera*   | -0.43      | 0.0024  | *Chamobates borealis*     | -0.41      | 0.0040  |
| *Tectocephus velatus*    | -0.37      | 0.0103  | *Platynothrus peltifer*   | -0.41      | 0.0042  |
| *Carabodes labyrinthicus*| -0.33      | 0.0237  | *Trimalaconothrus maior*  | -0.33      | 0.0215  |
| *Suctobelbella cl. prominens* | 0.52 | 0.0002  | *Oppiella acuminata*      | 0.30       | 0.0353  |
| *Ceratocetes thienemanni*| 0.52       | 0.0002  | *Tectocephus velatus*     | 0.32       | 0.0285  |
| *Belba compta*           | 0.52       | 0.0001  | *Nanhermannia sellnicki*  | 0.33       | 0.0238  |
| *Eulohmannia ribagai*    | 0.54       | 0.0001  | *Suctobelbella sp.1*      | 0.33       | 0.0238  |
| *Suctobelbella sarekensis*| 0.55      | 0.0001  | *Suctobelbella arcana*    | 0.33       | 0.0238  |
| *Quadroppia quadricarinata* | 0.58 | 0       | *Liochthonius neglectus*  | 0.34       | 0.0194  |
| *Oppiella nova*          | 0.62       | 0       | *Suctobelbella longirostris* | 0.39      | 0.0059  |
| *Liochthonius sellnicki* | 0.62       | 0       | *Oppiella nova*           | 0.44       | 0.0015  |
| *Oppiella splendens*     | 0.67       | 0       | *Suctobelbella acutidens* | 0.57       | 0       |
| *Suctobelbella cl. sarekensis* | 0.67 | 0       | *Liochthonius lapponicus* | 0.60       | 0       |
| *Suctobelbella longirostris* | 0.69 | 0       | *Heminothrus longisetosus* | 0.62       | 0       |
| *Hemileius initialis*    | 0.69       | 0       |                         |            |         |
| *Nanhermannia sellnicki* | 0.70       | 0       |                         |            |         |
| *Suctobelbella sp.1*     | 0.70       | 0       |                         |            |         |
| *Suctobelbella cl. arcana* | 0.70 | 0       |                         |            |         |
| *Oppiella neerlandica*   | 0.72       | 0       |                         |            |         |
The occurrence of typical wetland oribatid species — *T. angulatus*, *T. maior* and *P. peltifer* (Behan-Pelletier and Eamer 2007) — decreased significantly from the wetted tundra plot to automorphic tundra habitats (canonical Root 2). The occurrence of species belonging to the families Suctobelbidae, Oppiidae and Brachychthoniidae significantly increased. The occurrence of *H. longisetosus* had the highest positive correlation with Root 2 (Table 3).

Results similar to those described above for fauna were obtained using the relative abundance of species in the studied biotopes (Figure 3). From lichen tundra to dwarf shrub tundra (canonical Root 1) the proportion of species *T. velatus*, *O. amblyptera*, *C. labyrinthicus*, *M. sarekensis* decreased significantly (Table 4). There was a statistical increase of relative abundance of many species, especially those of the family Suctobelbidae, with the highest values of Spearman R (Table 4). These results are similar to the results obtained exclusively through the analysis of the fauna in the explored habitats (Table 3). But in the case of fauna, just one species, *O. neerlandica*, had the highest positive correlation with dwarf shrub tundra condition. In the case of relative abundance, *O. neerlandica*, *N. sellnicki*, *Suctobelbella* sp.1 and *Suctobelbella arcana* demonstrated the highest positive correlation of relative abundance with changes in conditions from lichen tundra to dwarf shrub tundra. The relative abundance of typical wetland oribatid species decreased from the wetted tundra plot to automorphic tundra habitats (Table 4).

**Discussion**

Based on the analyses carried out above, we can distinguish species complexes specific for different types of tundra. *T. velatus*, *O. amblyptera*, *C. labyrinthicus*, *M. sarekensis* are more...
typical for the lichen tundra in this research. Species of the *Mycobates* and *Oribatula* are known from previous studies as characteristic for saxicolous mosses above the upper forest line. Species of the *Mycobates* and *Carabodes* genera are closely connected with lichens (Materna 2000). *M. sarekensis* was most common in both higher alpine zones and glacier-forelands in alpine Fennoscandia. *T. velatus* was related to glacier-forelands (Heggen 2010). *T. velatus* is a species which thrives in the most severe or disturbed conditions (Zyromska-Rudzka 1977; Kevan et al. 1995; Skubała 1997). *Tectocepheus velatus* was found as a dominant species (Tikhonov 2003; Sidorchuk 2009) or most occurring species (Thomas and MacLean Jr 1988) in tundra habitats.

The species of Suctobelbidae and Oppiidae were most common and abundant in dwarf shrub tundra of the Lovozersky Mountains and appeared in the complex of dominant species only in this habitat (Table 2). In the Central Alps, species of these families were most common in a mountain forest habitat than above tree-line (Fischer and Schatz 2013). *Oppiella splendens*, *O. neerlandica*, *O. nova* and *Suctobelbella subtrigona* were limited in altitudinal distribution by low-alpine and sub-alpine belts in the alpine Fennoscandia (Heggen 2010). The Suctobelbidae and Oppiidae species were characteristic for saxicolous mosses below the upper forest-line in the Krokonoš Mountains, Czech Republic (Materna 2000).

According to the law of relative constancy (Walter 1970), wetted tundra should be the most severe habitat in the tundra conditions. It is unexpected to see such strong correlation of relative

| Species                        | Spearman R | p-value | Species                        | Spearman R | p-value |
|--------------------------------|------------|---------|--------------------------------|------------|---------|
| *Tectocepheus velatus*         | -0.62      | 0       | *Chamobates borealis*          | -0.67      | 0       |
| *Oribatula amblyptera*         | -0.47      | 0.0008  | *Platynothrus peltifer*        | -0.43      | 0.0026  |
| *Carabodes labyrinthicus*      | -0.40      | 0.0052  | *Trimalaconothrus angulatus*   | -0.41      | 0.0035  |
| *Mycobates sarekensis*         | -0.39      | 0.0068  | *Trimalaconothrus maior*       | -0.33      | 0.0213  |
| *Suctobelbella subtrigona*     | 0.50       | 0.0003  | *Mycobates tridactylus*        | 0.29       | 0.0427  |
| *Suctobelbella cf. prominens*  | 0.51       | 0.0002  | *Oppiella nova*                | 0.32       | 0.0265  |
| *Quadroppia quadricarinata*    | 0.51       | 0.0002  | *Suctobelbella acutidens*      | 0.34       | 0.0191  |
| *Belba compta*                 | 0.52       | 0.0002  | *Liochthonius neglectus*       | 0.34       | 0.0170  |
| *Ceratozetes thienemanni*      | 0.53       | 0.0001  | *Mycobates sarekensis*         | 0.38       | 0.0073  |
| *Eulohmannia ribagai*          | 0.53       | 0.0001  | *Tectocepheus velatus*         | 0.47       | 0.0009  |
| *Suctobelbella sarekensis*     | 0.55       | 0       | *Liochthonius lapponicus*       | 0.56       | 0       |
| *Hemileius initialis*          | 0.61       | 0       | *Heminothrus longisetosus*     | 0.63       | 0       |
| *Suctobelbella cf. sarekensis* | 0.65       | 0       |                                 |            |         |
| *Oppiella nova*                | 0.66       | 0       |                                 |            |         |
| *Oppiella splendens*           | 0.67       | 0       |                                 |            |         |
| *Suctobelbella longirostris*   | 0.69       | 0       |                                 |            |         |
| *Oppiella neerlandica*         | 0.70       | 0       |                                 |            |         |
| *Nanhermannia sellnicki*       | 0.70       | 0       |                                 |            |         |
| *Suctobelbella sp.1*           | 0.70       | 0       |                                 |            |         |
| *Suctobelbella arcana*         | 0.70       | 0       |                                 |            |         |
abundance of *Ch. borealis* with wet environment (Table 4). Probably, this is one of few species of oribatid mites that are tolerant to wet conditions in the tundra. The relative abundance of species Suctobelbidae, Oppiidae and Brachychthoniidae increased significantly from the wetted tundra to automorphic tundra habitats. *H. longisetosus* demonstrates the avoidance of wetting under the tundra conditions (Table 3, 4). In alpine Fennoscandia, *H. longisetosus* was limited by altitude in its distribution (Heggen 2010).

The discovered oribatid mite fauna of the Lovozersky Mountains is typical for the oribatid mite fauna of the European North of Russia if we consider this region as a complex of boreal and tundra habitats (Melekhina 2011). There were some similarities and differences between the oribatid fauna in the explored tundra plots and other tundra and polar desert regions (Table 5).

The families Brachychthoniidae, Oppiidae, and Ceratozetidae are usually the most diverse groups in the known tundra faunas (Table 5). It is known that the Ceratozetidae species, especially large ones, predominate in fauna or abundance in the local faunas of oribatid mites in tundra and polar deserts (Hammer 1954; Ananieva *et al.* 1979; Kalyakin *et al.* 1998; Behan-Pelletier 1999b; Makarova 2002; Krivolutsky *et al.* 2003; Ryabinin 2009). However, no species of this family were found in any studied lichen tundra plots, though 15 species of the family Ceratozetidae were noted in the plain lichen tundra of the Kola Peninsula and six species in the lichen tundra of Mount Vudyavrchhor, three of which (*Diapterobates humeralis, Fuscozetes* sp. and *T. cf. trimaculatus*) have a large body size (Leonov *et al.* 2015). Low diversity of Ceratozetidae is not typical for tundra (Table 5).

The discovered high diversity of the family Suctobelbidae in the fauna is not common for the previously explored tundra. In the typical tundra of the Chaunskaya Bay (Chukotka),
the family Suctobelbidae was represented by only one species, *Suctobelbella* sp. (MacLean et al. 1978). Only three species of the family Suctobelbidae (*S. acutidens*, *S. sarekensis*, *S. setosoclavata*) and two species of the family Oppiidae (*O. nova*, *O. translamellata*) have been found at the latitudinal transect in Northern Alaska (21 habitats were investigated) (Thomas and MacLean Jr 1988). Despite the high diversity of Oribatida in Greenland Island, only 4 species of the family Suctobelbidae have been found (Makarova 2015). A high diversity of the family Suctobelbidae was found in boreal forests of Karelia (Laskova 2001) and in the mountain tundra of the Polar Urals (Sidorchuk 2009). The increasing role of the family Suctobelbidae is shown not only when comparing the total explored fauna of the Lovozersky Mountains with the faunas of other large regions, but also in the explored dwarf shrub tundra versus the lichen tundra (Tables 1, 2). This means that the high occurrence of the family Suctobelbidae and its high proportion in abundance may be an indicator of milder environmental conditions in arctic/subarctic habitats. This may be typical for a local mountain tundra which is surrounded by the underlying belts of the mountain forests being a source of the increasingly diverse family Suctobelbidae. But the last hypothesis seems to be confirmed only in the Polar Urals (Sidorchuk 2009).

Species found in wetted tundra enriched the species diversity of oribatid mites in the explored region. *Liochthonius perfusorius*, *T. angulatus*, *T. maior*, *Oppiella* sp.3, *E. edwardsi* species were added to the fauna of automorphic tundra habitats. However, this did not exclusively occur due to wetland species. Only *T. angulatus* and *T. maior* can be strictly considered as wetland species (Behan-Pelletier and Eamer 2007).

There was a similarity in oribatid abundance between the lichen tundra in the Lovozersky

| Regions for comparison and reference | Brachychthoniidae | Camisiidae | Oppiidae | Suctobelbidae | Ceratozetidae | Other diverse families |
|------------------------------------|------------------|------------|----------|---------------|---------------|-----------------------|
| Lovozersky Mountains (this investigation) | 15.3% | 6.9% | 15.3% | 15.3% | 5.6% |
| Alaska (Thomas and MacLean Jr 1988) | 9.0% | 4.5% | 9.0% | 4.5% | 26.9% |
| Greenland (Makarova 2015) | 12.7% | 9.1% | 9.1% | 3.6% | 10.9% |
| Iceland (Gjelstrup, Solhøy, 1994) | 9.6% | 8.4% | 9.0% | 4.8% | 10.8% |
| North-West Scandinavia (Heggen 2010) | 6.6% | 9.5% | 6.6% | 4.4% | 8.8% |
| North-East Scandinavia (Heggen 2010) | 2.5% | 12.3% | 11.1% | 4.9% | 9.9% |
| Spitzbergen (Coulsen et al 2014) | 14.9% | 13.8% | 9.2% | 3.4% | 9.2% |
| Karelia, Russia (Laskova 2001) | 7.7% | 5.8% | 6.3% | 6.7% | 6.7% |
| Dalmiye Zeleivs (Kola Peninsula, Russia) (Leonov 2017) | 9.3% | 5.0% | 8.6% | 4.3% | 7.9% |
| NAO, Russia (Makarova, personal communication) | 14.3% | 10.4% | 9.5% | 3.8% | 16.2% |
| Polar Ural, Russia (Sidorchuk 2009) | 4.7% | 7.8% | 10.9% | 7.8% | 10.9% |
| Yamal Peninsula, Russia (Tikhonov 2003) | 20.6% | 7.9% | 12.7% | 3.2% | 11.1% |
| Bely Island (Kara Sea Russia) (Makarova et al. 2015) | - | - | 20.0% | - | 20.0% |
| West Sayan Mountains (Tyva Republic, Russia) (Tikhonov 2003) | 2.2% | 6.5% | 10.9% | 4.3% | 13.0% |
| Alash Plateau (Tyva Republic, Russia) (Tikhonov 2003) | 14.9% | 7.5% | 6.0% | 6.0% | 7.5% |
| Putorana Plateau, Russia (Tikhonov 2003) | 16.0% | 12.0% | 4.0% | - | 12.0% |
| Severnaya Zemlya Archipelago, Russia (Makarova 2002) | 30.0% | - | 30.0% | - | 40.0% |
| Chaun Bay, Northern Chukotka, Russia (MacLean et al. 1978) | 4.3% | 4.3% | 8.7% | 2.2% | 17.4% |
| Taimyr Peninsula (Western Coast) (Grishina et al. 1998) | 20.5% | 5.0% | 18.0% | 2.6% | 15.4% |
| West Sayan Mountains (Tyva Republic, Russia) (Tikhonov 2003) | 2.2% | 6.5% | 10.9% | 4.3% | 13.0% |
| Alash Plateau (Tyva Republic, Russia) (Tikhonov 2003) | 14.9% | 7.5% | 6.0% | 6.0% | 7.5% |
| Putorana Plateau, Russia (Tikhonov 2003) | 16.0% | 12.0% | 4.0% | - | 12.0% |
| Severnaya Zemlya Archipelago, Russia (Makarova 2002) | 30.0% | - | 30.0% | - | 40.0% |
| Chaun Bay, Northern Chukotka, Russia (MacLean et al. 1978) | 4.3% | 4.3% | 8.7% | 2.2% | 17.4% |
| Taimyr Peninsula (Western Coast) (Grishina et al. 1998) | 20.5% | 5.0% | 18.0% | 2.6% | 15.4% |
Mountains and those known from the literature for mountain and plain lichen tundra (Table 6). The densities of oribatid mites in the studied lichen tundra were similar to previously recorded values for the Khibiny Mountains (Vudyavrchor Mountain). However, oribatid densities were considerably lower than noted for the plain lichen tundra of the Kola Peninsula (Leonov and Rakhleeva 2015). The recorded abundance in the dwarf shrub tundra of the Lovozersky Mountains does not look typical for most tundra communities, although similar high abundance was noted in previous studies of the mountain tundra of the Pai-Khoi Ridge, Putorana Plateau, and plain tundra of Alaska (Thomas and MacLean Jr 1988; Tikhonov 2003; Melekhina and Zinovyeva 2012). Oribatid abundance in the dwarf shrub tundra was close to that of the plain dwarf shrub tundra of the Kola Peninsula (Leonov and Rakhleeva 2015).

The abundance of oribatid mites in the dwarf shrub tundra was similar to that of forest communities (Table 6). Dwarf shrubs and cushion plants significantly modify the conditions under them (Seniczak and Plichta 1978; Seniczak et al. 2014) and provide to the oribatid mites with thicker litter that is more structurally diverse and has a richer feed base, which may mitigate the effect of severe environmental conditions (Minor et al. 2016a). The observed patterns of fauna (low diversity of the family Ceratozetidae and high diversity of the family Suctobelbidae) and high abundance in dwarf shrub tundra may be explained by the ambivalent nature of the oribatid community in the explored region, which combines boreal and arctic

| Region for comparison | Habitats | Abundance of oribaida in compared regions, ind./m² | Reference |
|----------------------|----------|--------------------------------------------------|-----------|
| **Tundra habitats**  |          |                                                  |           |
| Kola Peninsula       | Lichen tundra GMLT-740 | 23680 | This investigation |
|                      | Lichen tundra LT-740 | 14680 |                                      |
|                      | Lichen tundra GLT-721 | 14520 |                                      |
|                      | Dwarf shrub tundra DST-428 | 81160 |                                      |
| Alaska               | Plain tundra | 3720 — 61880 | Thomas and MacLean Jr 1988 |
| Hornsund, Western Spitsbergen | Moss-lichen tundra | 21260 | Seniczak and Plichta 1978 |
| Vudyavrchor Mountain, Kola Peninsula, Russia | Mountain lichen tundra | 10200 — 16720 | Leonov and Rakhleeva 2015 |
|                      | Mountain shrubs tundra | 24240 |                                      |
| Dalniye Zelentsy, Kola Peninsula, Russia | Plain tundra | 1000 — 25000 | Krivolutsky 1966 |
| Dalniye Zelentsy Kola Peninsula | Plain lichen tundra | 53480 — 61680 | Leonov and Rakhleeva 2015 |
|                      | Plain shrubs tundra | 92800 |                                      |
| Yugorsky peninsula   | Mountain tundra | 15000 — 43840 | Melekhina and Zinovyeva 2012 |
|                      | Plain tundra | 8500 — 38920 |                                      |
| Yamal Peninsula      | Plain tundra | 4000 — 33520 | Tikhonov 2003 |
| West Sayan Mountains (Tyva Republic, Russia) | Mountain tundra | 2030 — 3290 | Tikhonov 2003 |
| Alash Plateau (Tyva Republic, Russia) | Mountain tundra | 3380 — 8730 | Tikhonov 2003 |
| Putorana Plateau     | Mountain tundra | 30840 — 47320 | Tikhonov 2003 |
| Western Taimyr, Russia | Plain tundra | 4444 | Chernov et al. 1971 |
| Maria Pronchshetseva Bay, Taymyr Peninsula, Russia | Plain tundra | 400 — 18100 | Ananieva et al.1979 |
| **Forest habitats**  |          |                                                  |           |
| Ryashkov island, White Sea, Russia | Pine forest | 120400 | Byzova et al. 1986 |
| Ryashkov island, White Sea, Russia | Spruce forest | 95600 | Byzova et al. 1986 |
| Vudyavrchor Mountain, Kola Peninsula, Russia | Spruce-birch forest | 106880 | Leonov et al. 2015 |
| Arkhangelsk region, Russia | Spruce forest | 141800 | Own unpublished data |
features. The fauna of the explored region is likely to be boreal in its genesis (reduced boreal
due to the severity of conditions in the mountain tundra). Moreover, relative mildness of the
Kola Peninsula climate due to oceanicity may lead to relative species richness (in comparison
with zonal tundra).

The oribatid mite abundance in wetted tundra was considerably lower than in other plots of
the Lovozersky Mountains (Table 1). It corresponds to that of oligotrophic bog habitats known
from the literature (Weigmann, 1991; Zaitsev 2013; Minor et al. 2016b).

Despite the existence of some knowledge gaps regarding oribatid mite communities in the
subarctic mountains and tundra regions, the fragmentation of the existing research, and the
heterogeneity of data in the literature, some trends in the characteristic features of oribatid
communities in the plain and mountain tundra have emerged. Oribatid communities in the
tundra habitats of the Lovozersky Mountains are similar to other tundra regions in the high
diversity of the families Brachychthoniidae and Oppiidae in the total fauna and abundances of
oribatid mites in the explored lichen tundra are typical for other tundra regions. A high diversity
of the family Suctobelbidae in the fauna, a small number of large thick-shelled oribatid mite
species of the family Ceratozetidae, their low abundance, and the high abundance of oribatid
mites in the dwarf shrub tundra are the features which distinguish the tundra habitats in our
investigation from typical tundra environments elsewhere.

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