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Vladislav D. Leonov, Anna A. Rakhleeva. The first report on oribatid mites in tundra belts of the Lovozersky Mountains on the Kola Peninsula, Russia. *Acarologia*, 2020, 60 (2), pp.301-316. 10.24349/acarologia/20204369 . hal-02543765

HAL Id: hal-02543765

<https://hal.science/hal-02543765>

Submitted on 15 Apr 2020

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Previous volumes (2010-2018): 250 € / year (4 issues)

Acarologia, CBGP, CS 30016, 34988 MONTFERRIER-sur-LEZ Cedex, France

ISSN 0044-586X (print), ISSN 2107-7207 (electronic)

The digitalization of Acarologia papers prior to 2000 was supported by Agropolis Fondation under the reference ID 1500-024 through the « Investissements d'avenir » programme (Labex Agro: ANR-10-LABX-0001-01)



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

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Original research

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./m². In the dwarf shrub tundra, this value is over three times higher — up to 81,160 ind./m², which is comparable with the oribatid mite abundance of forest habitats. The minimum values were discovered in wetted tundra (6,200 ind./m²). 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 *Platynothonrus peltifer* prevailed in wetted tundra as compared to automorphic tundra habitats. 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.

Received 16 September 2019

Accepted 08 April 2020

Published 15 April 2020

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Academic editor

Baumann, Julia

DOI

10.24349/acarologia/20204369

ISSN 0044-586X (print)

ISSN 2107-7207 (electronic)

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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 (Zenkova and Melekhina 2014; Leonov and Rakhleeva 2015; Leonov *et al.* 2015; Leonov 2017). In two other large mountain massifs of

How to cite this article Leonov V. D. and Rakhleeva A. A. (2020), The first report on oribatid mites in tundra belts of the Lovozersky Mountains on the Kola Peninsula, Russia. *Acarologia* 60(2): 301-316; DOI 10.24349/acarologia/20204369

the Kola Peninsula (the Chunutundra 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 Rakhleeva 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 Kuamdespakh 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; $67^{\circ}51.118' \text{ N}$, $34^{\circ}53.623' \text{ E}$). 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*, *Pleurozium schreberi*, *Juncus trifidus*, and *Carex* sp. Grasses (single sedges and bumps of *Juncus trifidus*) grow mainly among lichen thalluses. *Cetrariella delisei* dominates among lichens. *Cladonia stellaris* is numerous. *Pleurozium 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).

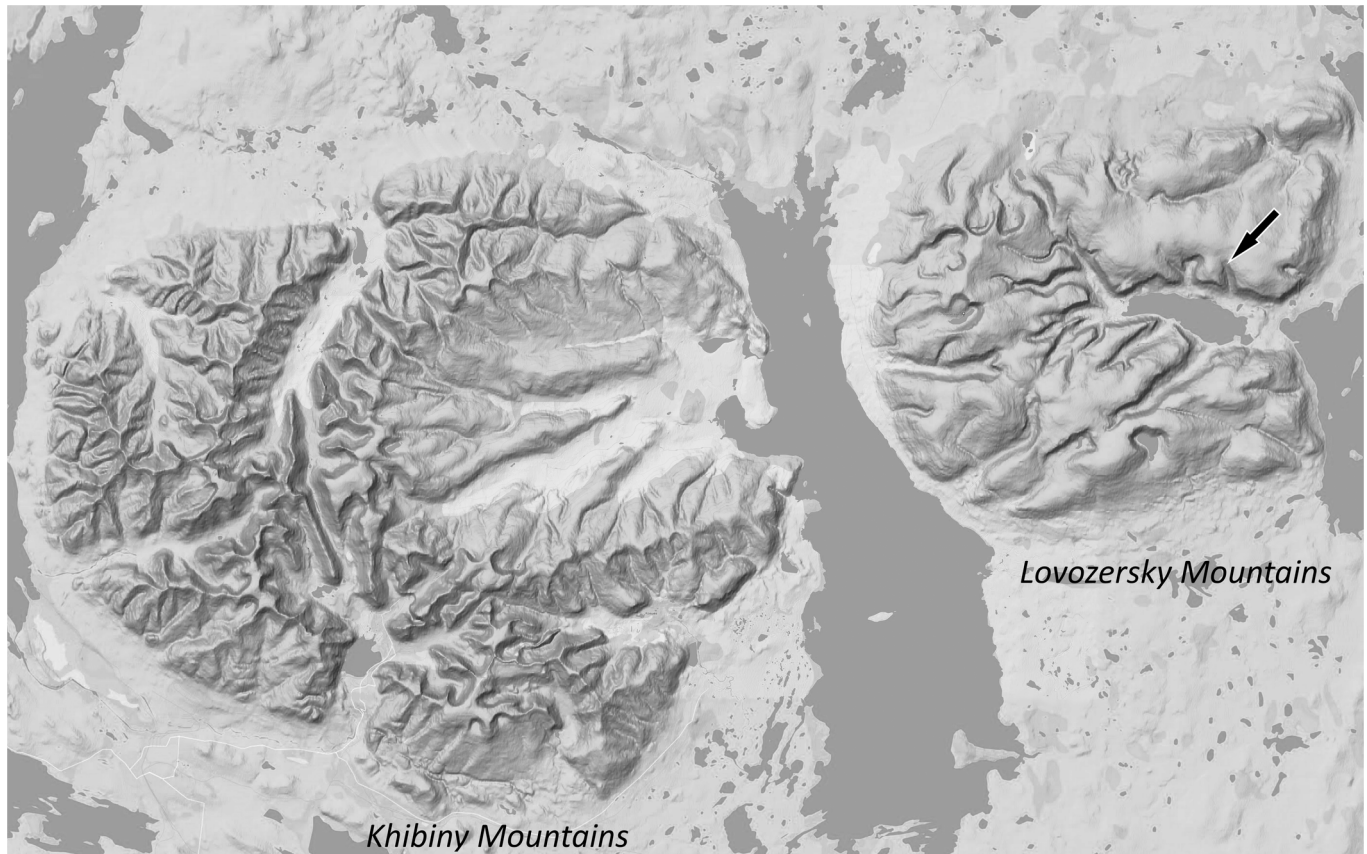


Figure 1 The location of the study plots in the Lovozersky Mountains (indicated by the arrow).

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*, *Phyllodoce caerulea*, *Vaccinium vitis-idaea*, *Cladonia stellaris*, *Cetrariella 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*, *Gymnomitrium concinatum*, *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

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 redescrptions 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					
<i>Palaeacarus kamenskii</i> (Zachvatkin, 1945)	0	0	0	0	480
Brachychthoniidae Thor, 1934					
<i>Eobrachychthonius latior</i> (Berlese, 1910)	0	520	0	40	200
<i>Liochthonius brevis</i> (Michael, 1888)	0	0	0	0	280
<i>Liochthonius lapponicus</i> (Tragardh, 1910)	120	920	200	0	1120
<i>Liochthonius muscorum</i> Forsslund, 1964	200	0	0	0	0
<i>Liochthonius neglectus</i> Moritz, 1976	0	80	0	0	160
<i>Liochthonius perfusorius</i> Moritz, 1976*	0	0	0	40	0
<i>Liochthonius perelegans</i> Moritz, 1976*	0	0	40	0	0
<i>Liochthonius sellnicki</i> (Thor, 1930)	0	200	0	360	1320
<i>Liochthonius</i> cf. <i>sellnicki</i> (Thor, 1930)	0	0	0	0	40
<i>Neobrachychthonius marginatus</i> (Forsslund, 1942)	40	0	0	0	0
<i>Sellnickochthonius immaculatus</i> (Forsslund, 1942)*	160	0	40	0	520
Eulohmanniidae Grandjean, 1931					
<i>Eulohmannia ribagai</i> (Berlese, 1910)	0	0	0	0	480
Phthiracaridae Perty, 1841					
<i>Phthiracarus clavatus</i> Parry, 1979	0	0	0	0	200
<i>Phthiracarus</i> cf. <i>membranifer</i> Parry, 1979*	0	0	0	0	40
<i>Phthiracarus opacus</i> Niedbala, 1986	0	0	0	0	160
Malaconothridae Berlese, 1916					
<i>Trimalaconothrus angulatus</i> Willmann, 1931*	0	0	0	360	0
<i>Trimalaconothrus maior</i> (Berlese, 1910)	0	0	0	240	0
Nothridae Berlese, 1896					
<i>Nothrus borussicus</i> Sellnick, 1929	840	40	1400	400	160
Camisiidae Oudemans, 1900					
<i>Camisia biurus</i> (C.L. Koch, 1839)	0	0	0	0	40
<i>Camisia solhoeyi</i> Colloff, 1993	40	0	0	120	0
<i>Neonothrus humicolus</i> Forsslund, 1955	0	0	0	0	320
<i>Heminothrus longisetosus</i> Willmann, 1925	0	1440	120	0	2000
<i>Platynothrus peltifer</i> (C.L. Koch, 1839)	0	0	0	880	40
Nanhermanniidae Sellnick, 1928					
<i>Nanhermannia sellnicki</i> Forsslund, 1958	0	0	0	0	4920
Damaeidae Berlese, 1896					
<i>Belba compta</i> (Kulczynski, 1902)	0	0	0	0	840
<i>Kunstidamaeus nidicola</i> (Willmann, 1936)	0	0	0	40	200
<i>Porobelba spinosa</i> (Sellnick, 1920)	400	0	0	0	720
Eremaeidae Oudemans, 1900					
<i>Eueremaus silvestris</i> (Forsslund, 1956)	0	0	0	0	720
Peloppiidae Balogh, 1943					
<i>Ceratoppia sphaerica</i> (L. Koch, 1879)	0	80	0	0	0
Carabodidae C.L. Koch, 1837					
<i>Carabodes areolatus</i> Berlese, 1916	0	0	0	0	760
<i>Carabodes labyrinthicus</i> (Michael, 1879)	6200	2760	0	0	160
Tectocephidae Grandjean, 1954					
<i>Tectocephus velatus</i> (Michael, 1880)	6520	6160	5520	640	4800
Quadroppiidae Balogh, 1983					
<i>Quadroppia quadricarinata</i> (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					
<i>Dissorhina ornata</i> (Oudemans, 1900)	0	0	0	0	200
<i>Oppiella</i> sp.3	0	0	0	160	0
<i>Oppiella</i> sp.5	0	0	0	0	40
<i>Oppiella acuminata</i> (Strenzke, 1951)	0	440	0	0	4240
<i>Oppiella maritima</i> (Willmann, 1929)	0	0	0	0	440
<i>Oppiella neerlandica</i> (Oudemans, 1900)	0	0	0	40	7600
<i>Oppiella nova</i> (Oudemans, 1902)	0	120	0	0	5000
<i>Oppiella splendens</i> (C.L. Koch, 1841)	0	0	0	0	5240
<i>Oppiella subpectinata</i> (Oudemans, 1900)	0	0	0	0	120
<i>Oppiella uncarinata</i> (Paoli, 1908)	0	0	0	0	480
Suctobelbidae Jacot, 1938					
<i>Suctobelba trigona</i> (Michael, 1888)	440	160	0	80	320
<i>Suctobelbella</i> sp.1	0	0	0	0	3440
<i>Suctobelbella</i> sp.2	0	0	0	0	520
<i>Suctobelbella acutidens</i> (Forsslund, 1941)	40	280	680	120	5880
<i>Suctobelbella</i> cf. <i>arcana</i> (Moritz, 1970)	0	0	0	0	4800
<i>Suctobelbella falcata</i> (Forsslund, 1941)	0	0	0	0	600
<i>Suctobelbella longirostris</i> (Forsslund, 1941)	0	40	0	0	1280
<i>Suctobelbella</i> cf. <i>prominens</i> (Moritz, 1966)*	0	0	0	0	480
<i>Suctobelbella sarekensis</i> (Forsslund, 1941)	40	0	0	0	840
<i>Suctobelbella</i> cf. <i>sarekensis</i>	0	0	0	0	4400
<i>Suctobelbella subtrigona</i> (Oudemans, 1900)	0	0	0	0	1000
Licneremaeidae Grandjean, 1931					
<i>Licneremaeus licnophorus</i> (Michael, 1882)	0	80	80	0	0
Phenopelopidae Petrunkevich, 1955					
<i>Eupelops torulosus</i> (C. L. Koch, 1840)	0	0	0	0	520
Achipteriidae Thor, 1929					
<i>Parachipteria punctata</i> (Nicolet, 1855)	0	0	0	0	160
Ceratozetidae Jacot, 1925					
<i>Ceratozetes thienemanni</i> Willmann, 1943	0	0	0	0	2040
<i>Diapterobates humeralis</i> (Hermann, 1804)	0	0	0	0	80
<i>Edwardzetes edwardsi</i> (Nicolet, 1855)	0	0	0	80	0
<i>Melanozetes mollicomus</i> (C. L. Koch, 1839)	0	0	0	120	40
Chamobatidae (Thor, 1938)					
<i>Chamobates borealis</i> (Tragardh, 1902)	7640	0	6120	2000	6480
Mycobatidae Grandjean, 1954					
<i>Mycobates sarekensis</i> (Tragardh, 1910)*	240	800	0	0	0
<i>Mycobates tridactylus</i> Willmann, 1929	0	160	0	0	0
Schelorbitidae Grandjean, 1933					
<i>Liebstadia similis</i> (Michael, 1888)	40	0	40	40	200
<i>Hemileius initialis</i> (Berlese, 1908)	40	40	40	160	1640
Oribatulidae Thor, 1929					
<i>Oribatula amblyptera</i> Berlese, 1916*	360	120	240	280	0
<i>Oribatula tibialis</i> (Nicolet, 1855)	0	80	0	0	80
<i>Oribatula pannonica</i> Willmann, 1949	0	0	0	0	40
Number of species	18	21	12	20	56
Average abundance (ind./m ²)	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. *prominens*, *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

Table 2 Dominant species of studied habitats, % (values in bold are for eudominants, in bold italics are dominants, italics are subdominants).

Species	GMLT-740	LT-740	GLT-721	WT-702	DST-428
<i>Tectocepheus velatus</i>	27.5	42	38	10.4	5.9
<i>Chamobates borealis</i>	32.3		42.1	32.5	8
<i>Carabodes labyrinthicus</i>	26.2	18.8			0.2
<i>Platynothrus peltifer</i>				14.3	
<i>Liochthonius lapponicus</i>	0.5	6.3	1.4		1.4
<i>Heminothrus longisetosus</i>		9.8	0.8		2.5
<i>Mycobates sarekensis</i>	1	5.4			
<i>Nothrus borussicus</i>	3.5	0.3	9.6	6.5	0.2
<i>Liochthonius sellnicki</i>		1.4		5.8	1.6
<i>Trimalaconothrus angulatus</i>				5.8	
<i>Nanhermannia sellnicki</i>					6.1
<i>Oppiella acuminata</i>		3			5.2
<i>Oppiella neerlandica</i>				0.6	9.4
<i>Oppiella nova</i>		0.8			6.2
<i>Oppiella splendens</i>					6.5
<i>Suctobelbella acutidens</i>	0.2	1.9	4.7	1.9	7.2
<i>Suctobelbella arcana</i>					5.9
<i>Suctobelbella sarekensis</i>					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).

Correlation with Root 1			Correlation with Root 2		
Species	Spearman R	p-value	Species	Spearman R	p-value
<i>Mycobates sarekensis</i>	-0.53	0.0001	<i>Trimalaconothrus angulatus</i>	-0.41	0.0035
<i>Oribatula amblyptera</i>	-0.43	0.0024	<i>Chamobates borealis</i>	-0.41	0.0040
<i>Tectocepheus velatus</i>	-0.37	0.0103	<i>Platynocheilus peltifer</i>	-0.41	0.0042
<i>Carabodes labyrinthicus</i>	-0.33	0.0237	<i>Trimalaconothrus maior</i>	-0.33	0.0215
<i>Suctobelbella</i> cf. <i>prominens</i>	0.52	0.0002	<i>Oppiella acuminata</i>	0.30	0.0353
<i>Ceratozetes thienemanni</i>	0.52	0.0002	<i>Tectocepheus velatus</i>	0.32	0.0285
<i>Belba compta</i>	0.52	0.0001	<i>Nanhermannia sellnicki</i>	0.33	0.0238
<i>Eulohmannia ribagai</i>	0.54	0.0001	<i>Suctobelbella</i> sp.1	0.33	0.0238
<i>Suctobelbella sarekensis</i>	0.55	0.0001	<i>Suctobelbella arcana</i>	0.33	0.0238
<i>Quadroppia quadricarinata</i>	0.58	0	<i>Liochthonius neglectus</i>	0.34	0.0194
<i>Oppiella nova</i>	0.62	0	<i>Suctobelbella longirostris</i>	0.39	0.0059
<i>Liochthonius sellnicki</i>	0.62	0	<i>Oppiella nova</i>	0.44	0.0015
<i>Oppiella splendens</i>	0.67	0	<i>Suctobelbella acutidens</i>	0.57	0
<i>Suctobelbella</i> cf. <i>sarekensis</i>	0.67	0	<i>Liochthonius lapponicus</i>	0.60	0
<i>Suctobelbella longirostris</i>	0.69	0	<i>Heminothrus longisetosus</i>	0.62	0
<i>Hemileius initialis</i>	0.69	0			
<i>Nanhermannia sellnicki</i>	0.70	0			
<i>Suctobelbella</i> sp.1	0.70	0			
<i>Suctobelbella</i> cf. <i>arcana</i>	0.70	0			
<i>Oppiella neerlandica</i>	0.72	0			

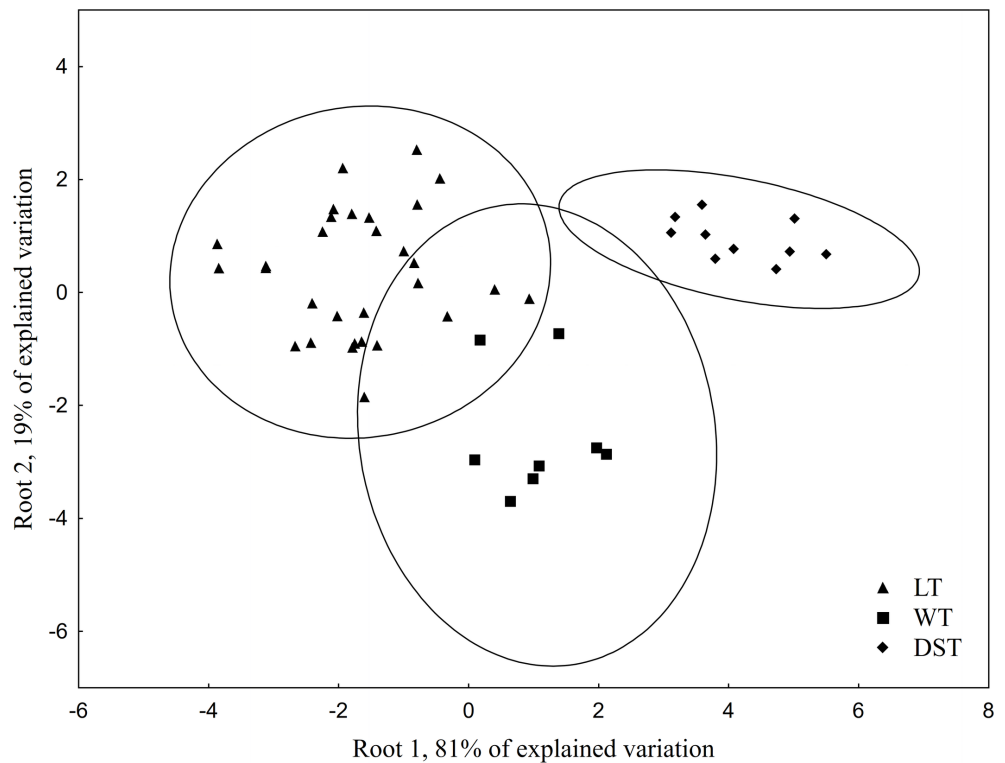


Figure 2 Discriminant (canonical) function analysis of faunas of oribatid mites discovered in the explored habitats. Dots are single samples, “LT” means lichen tundra, “WT” means wetted tundra, “DST” means dwarf shrub tundra. The analysis was based on the Jaccard similarity matrix for single samples. Both canonical Roots were significant. Ellipses are normal type of Statistica 6 software ellipses.

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; Skubala 1997). *Tectocephus 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 Krokonoše 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

Table 4 Spearman rank correlations between the relative abundance of species in individual samples in 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).

Correlation with Root 1			Correlation with Root 2		
Species	Spearman R	p-value	Species	Spearman R	p-value
<i>Tectocephus velatus</i>	-0.62	0	<i>Chamobates borealis</i>	-0.67	0
<i>Oribatula amblyptera</i>	-0.47	0.0008	<i>Platynothrus peltifer</i>	-0.43	0.0026
<i>Carabodes labyrinthicus</i>	-0.40	0.0052	<i>Trimalaconothrus angulatus</i>	-0.41	0.0035
<i>Mycobates sarekensis</i>	-0.39	0.0068	<i>Trimalaconothrus maior</i>	-0.33	0.0213
<i>Suctobelbella subtrigona</i>	0.50	0.0003	<i>Mycobates tridactylus</i>	0.29	0.0427
<i>Suctobelbella cf. prominens</i>	0.51	0.0002	<i>Oppiella nova</i>	0.32	0.0265
<i>Quadroppia quadricarinata</i>	0.51	0.0002	<i>Suctobelbella acutidens</i>	0.34	0.0191
<i>Belba compta</i>	0.52	0.0002	<i>Liochthonius neglectus</i>	0.34	0.0170
<i>Ceratozetes thienemanni</i>	0.53	0.0001	<i>Mycobates sarekensis</i>	0.38	0.0073
<i>Eulohmannia ribagai</i>	0.53	0.0001	<i>Tectocephus velatus</i>	0.47	0.0009
<i>Suctobelbella sarekensis</i>	0.55	0	<i>Liochthonius lapponicus</i>	0.56	0
<i>Hemileius initialis</i>	0.61	0	<i>Heminothrus longisetosus</i>	0.63	0
<i>Suctobelbella cf. sarekensis</i>	0.65	0			
<i>Oppiella nova</i>	0.66	0			
<i>Oppiella splendens</i>	0.67	0			
<i>Suctobelbella longirostris</i>	0.69	0			
<i>Oppiella neerlandica</i>	0.70	0			
<i>Nanhermannia sellnicki</i>	0.70	0			
<i>Suctobelbella sp.1</i>	0.70	0			
<i>Suctobelbella arcana</i>	0.70	0			

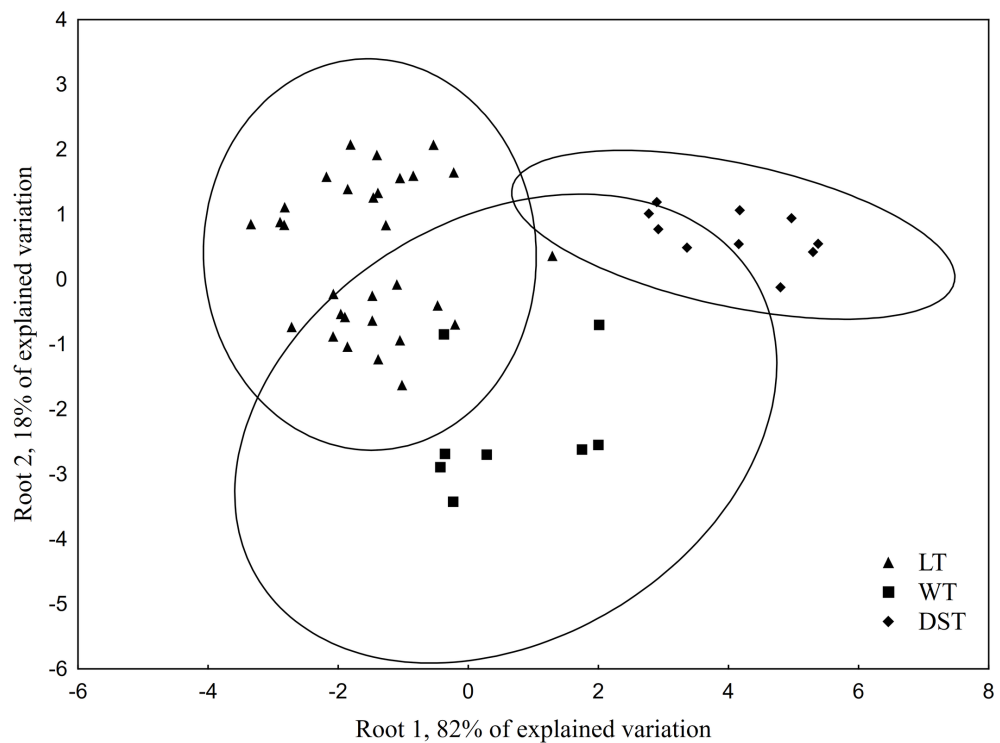


Figure 3 Discriminant (canonical) function analysis of relative abundance of oribatid mites in explored habitats. Dots are single samples, “LT” means lichen tundra, “WT” means wetted tundra, “DST” means dwarf shrub tundra. The analysis was based on the Bray–Curtis similarity matrix of relative abundance of species for single samples. Both canonical Roots were significant. Ellipses are normal type of Statistica 6 software ellipses.

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 Vuduyavrchorr, 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

Table 5 Comparison of the most diverse families in faunas of plain and mountain tundra of different regions in contrast with the fauna of oribatid mites of the Lovozersky Mountains.

Regions for comparison and reference	Diversity of the key families of Oribatida in tundra regions					
	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%	Damaeidae 8.8%
North-East Scandinavia (Heggen 2010)	2.5%	12.3%	11.1%	4.9%	9.9%	Phthiracaridae 6.2% Damaeidae 4.9% Carabodidae 4.9%
Spitzbergen (Coulson 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%	
Dalniye Zelentsy (Kola Peninsula, Russia) (Leonov 2017)	9.3%	5.0%	8.6%	4.3%	7.9%	Damaeidae 6.4% Phthiracaridae 5.0%
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%	Damaeidae 7.8%
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%	Crotoniidae 20% Ceratoppiidae 20%
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%	Nothridae 4%
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%	Peloppiidae 13.0%
Taimyr Peninsula (Western Coast) (Grishina et al. 1998)	20.5%	5.0%	18.0%	2.6%	15.4%	Peloppiidae 10.3% Tegoribatidae 10.3%

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 (Vudyavrchorr 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

Table 6 Comparison of oribatid mite abundance in the explored tundra plots of the Lovozersky Mountains and other regions.

Region for comparison	Habitats	Abundance of oribaida in compared regions, ind./m ²	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
Vudyavrchorr 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 <i>et al.</i> 1971
Maria Pronchshtseva Bay, Taymyr Peninsula, Russia	Plain tundra	400 — 18100	Ananieva <i>et al.</i> 1979
Forest habitats			
Ryashkov island, White Sea, Russia	Pine forest	120400	Byzova <i>et al.</i> 1986
Ryashkov island, White Sea, Russia	Spruce forest	95600	Byzova <i>et al.</i> 1986
Vudyavrchorr Mountain, Kola Peninsula, Russia	Spruce-birch forest	106880	Leonov <i>et al.</i> 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.

Acknowledgments

The authors are very grateful to O.L. Makarova and A.B. Babenko (A.N. Severtsov Institute of Ecology and Evolution RAS) for consultations and discussions regarding the results. The authors would like to thank E.A. Sidorchuk (PIN RAS) for her help and advice in the identification of oribatid mites. The authors thank A.V. Tiunov, Corresponding Member of the RAS (A.N. Severtsov Institute of Ecology and Evolution RAS), for advice in part of statistical processing of the data.

The authors thank the following participants of the expedition during which the material was collected: M.S. Bizin and K.O. Prokopyeva, graduates of the Faculty of Soil Science of the Lomonosov Moscow State University, as well as the staff of the Seydyavvr State Nature Reserve of Regional Significance for their assistance in conducting the expedition.

The authors are very grateful to the reviewers whose advice and remarks helped to improve the manuscript.

This research was supported by the Russian Foundation for Basic Research (Project No. 14-04-31754).

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