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The first report on the oribatid mites (Acari: Oribatida) in tundra of the Chunatundra Mountains on the Kola Peninsula, Russia

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Original research

ABSTRACT

The aim of this research was to obtain initial data on the fauna and abundance of the oribatid mites from the main types of the mountain tundra habitats of the Chunatundra Mountains. Four plots, including two lichen tundra plots, one dwarf shrub tundra plot and one sphagnum bog in the belt of mountain tundra were investigated. Multidimensional scaling and discriminant function analysis were used to identify trends in the fauna and abundance of oribatid species through the explored plots. A total of 70 species and one subspecies from 37 genera and 24 families were found during the course of this investigation. Nine species, one subspecies, one genus and one family of oribatid mites have been added to the fauna of the Kola Peninsula. The families Brachychthoniidae, Oppiidae and Suctobelbidae are the most diverse in the discovered local fauna. According to literature data, the first two families are characteristic of the low tundra communities, the third family is more common for the boreal zone. The discovered oribatid fauna is similar to the fauna of other tundra sites of the Kola Peninsula studied previously and is significantly different to the local oribatid mite faunae of the Scandinavian Peninsula. The abundance of the adult oribatid mites reached 39 080 ind./m^2 in the lichen tundra and 56 200 ind./m^2 in the dwarf shrub tundra. The minimum abundance of oribatid mites, 18 640 ind./m^2 was found in the sphagnum bog. Differences in the oribatid mite complexes of lichen tundra, dwarf shrub tundra and the sphagnum bog were found. The species *Carabodes labyrinthicus*, *Nothrus borussicus*, *Sellnickochthonius immaculatus*, *Mycobates sarekensis,* and *Tectocepheus velatus* were associated with the lichen tundra habitats. *Nanhermannia sellnicki*, *Chamobates borealis* and a few species of *Oppiella* and *Suctobelbella* were associated with the dwarf shrub tundra. *Mucronothrus nasalis*, *Limnozetes ciliatus*, *Platynothrus peltifer*, *Trimalaconothrus foveolatus*, *Limnozetes* cf. *rugosus,* and *Trimalaconothrus maior* are most characteristic of the sphagnum bog. The family Suctobelbidae was represented by a large number of species, while the families Ceratozetidae and Camisiidae were much less diverse. The low diversity of Ceratozetidae, a high diversity of Suctobelbidae and relatively high abundance of oribatid mites in the explored tundra habitats may be explained by an ambivalent nature of the oribatid community, which combines boreal and arctic features due to marine climate. Also, this result may be a feature of a local mountain tundra which is surrounded by the underlying belts of the mountain forests that are a source of the increasingly diversity of species.

Keywords mountain tundra; lichen tundra; dwarf shrub tundra; wet tundra; sphagnum bog; community structure; fauna of the tundra

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Introduction

During previous investigations of the tundra communities on the Kola Peninsula, a high number of oribatid mite species was found. Until now, 89 species from 47 genera and 27 families were known for the mountain tundra of the Kola Peninsula (Liskovaya 2011; Zenkova and Melekhina 2014; Leonov and Rakhleeva 2015; Leonov *et al.* 2015; Leonov and Rakhleeva 2020). However, compared to more investigated regions, the known number of oribatid species in the mountain tundra of the Kola Peninsula is still far from expected. In the Scandinavian Peninsula, 145 species, 69 genera, and 42 families of oribatid mites were found in the alpine and arctic/alpine habitats (Heggen 2010), 123 oribatid species belonging to 39 families were found in the treeless habitats of Taimyr Peninsula (Makarova 2015), and 151 species, 83 genera, 46 families were found in the western North American Low Arctic (Behan-Pelletier 1999). In addition, the known fauna of the oribatid mites in the mountain tundra habitats of the Kola Peninsula comprises significantly fewer species than the fauna of oribatid mites in plain tundra on the Kola Peninsula, which includes140 species belonging to 73 genera and 39 families (Krivolutsky 1966; Liskovaya 2011; Leonov and Rakhleeva 2015). Tundra is a diverse complex of communities that includes different types of habitats, development of which depends on many environmental factors — temperature, character of snow cover, etc. (Chernov and Matveyeva 1997; Körner 2003; Nagy and Grabherr 2009). Even minimal changes in the plant communities in tundra may lead to extremely great changes in the oribatid mite communities (Minor *et al.* 2016a; Seniczak and Plichta 1978; Seniczak *et al.* 2014). Thus, the investigation of the different types of tundra habitats is important for a better understanding of the structure and complexity of the tundra biome.

The aims of this research were to obtain data on the fauna and abundance of the oribatid mites from the main types of the mountain tundra habitats of the Chunatundra Mountains and to compare explored habitats with each other and with the literature data.

Materials and methods

Study area

The Chunatundra Mountains are located in the central part of the Kola Peninsula, west of the Khibiny Mountains (Figure 1). The average annual air temperature is -1 °C. The region belongs to the area with a predominance of precipitation over evaporation. In the mountains, precipitation amounts 600–800 mm per year and exceeds 1 000 mm at the peaks of the largest mountains. 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 crooked birch 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 (represented by small shrubs and lichens) occupies the tops of the mountains and plateaus (Stanyukovich 1973).

Study sites

Three tundra plots and one sphagnum bog within the belt of the mountain tundra were studied. The coordinates and altitudes of the explored habitats were obtained using a GPS/GLONASS receiver Garmin eTrex 30.

1. Lichen tundra plot at an altitude of 638 m a.s.l. (ChT-LT-638; 67°41.015′ N, 32°32.579′ E) is located on the flat plateau of the mountain. Vegetation covers about 50% and is developed on the rocks and in the cavities between them. *Flavocetraria nivalis* dominates in vegetation cover. *Cetraria islandica* is numerous. *Empetrum hermaphroditum, Vaccinium vitis-idaea*, *Arctostaphylos uva-ursi* grow within lichen thalluses and do not exceed lichens in height. There are clumps of *Juncus trifidus* and single representatives of *Carex* sp. The soil (hereinafter, the

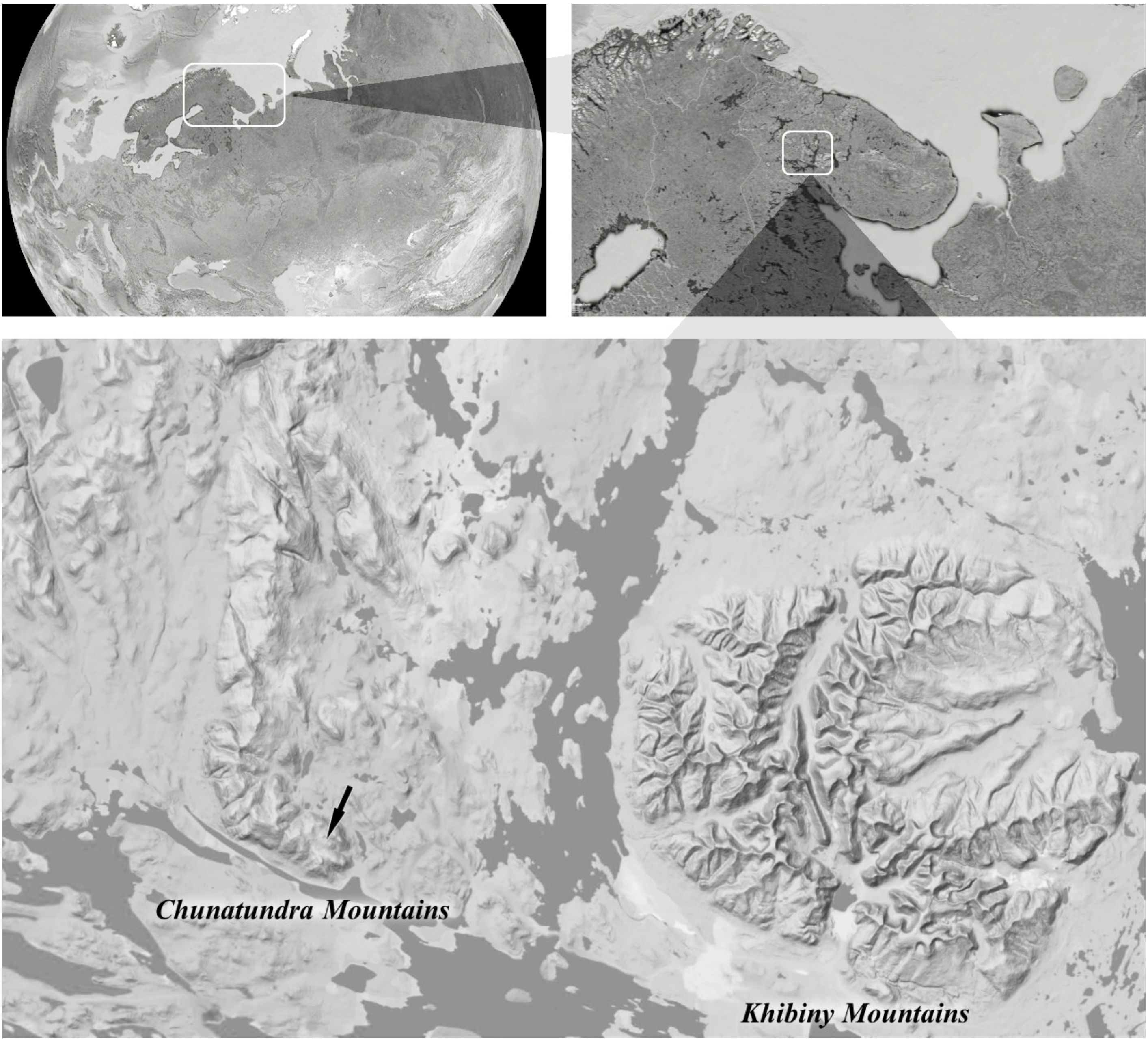

Figure 1 The location of the study area in the Chunatundra Mountains (indicated by the arrow). The map was made using the images from the Google Earth software.

names of the soils are given using WRB (IUSS Working Group WRB 2015)) is Entic Podzol (Skeletic).

2. Lichen tundra plot at an altitude of 466 m a.s.l. (ChT-LT-466; 67°39.662′ N, 32°35.720′ E). A closed cover of *Flavocetraria nivalis* is developed with rare patches of *Cetraria islandica* and *Alectoria ochroleuca*. Dwarf shrubs *Vaccinium vitis-idaea*, *Phyllodoce caerulea*, *Empetrum hermaphroditum* and shrub *Betula nana* grow only within lichen thalluses and do not exceed them in height. *Betula nana* occurs sporadically and sometimes formed thick pillow-like thickets. Representatives of *Festuca ovina* are rare. The soil is Entic Podzol.

3. Dwarf shrub tundra plot at an altitude of 419 m a.s.l. (ChT-DST-419; 67°39.725′ N, 32°36.050′ E). The dwarf shrub cover is extremely dense and forms a multi-layer system. *Betula*

nana and *Salix lapponum* dominate in the upper layer, *Vaccinium myrtillus* grows under them. The lower layer is represented by mosses and lichens penetrated by *Empetrum hermaphroditum*. The vegetation of this habitat includes lichens (*Cetraria islandica*, *Cladonia gracilis*), mosses (*Pleurozium schreberi*), grasses (*Festuca ovina*, *Cornus suecica*), dwarf shrubs (*Vaccinium myrtillus*, *Phyllodoce caerulea*, *Empetrum hermaphroditum*), shrubs (*Betula nana*, *Salix lapponum*) and single, small and crooked representatives of *Betula* sp. Soil is Histic Entic Gleyic Podzol.

4. Sphagnum bog at an altitude of 417 m a.s.l. (ChT-SB-417; 67°39.567′ N, 32°36.370′ E). The bog is developed within the tundra belt on a flattened side of the mountain range. The dominant vegetation is represented by a typical wetland species — *Sphagnum* sp. and *Eriophorum* sp. Also, mosses (*Pleurozium schreberi*, *Polytrichum* sp.), grasses (*Carex* sp., *Bartsia alpine*), dwarf shrubs (*Vaccinium myrtillus*, *Empetrum hermaphroditum*, *Rubus chamaemorus*) and shrubs (*Ledum palustre*, *Salix* sp.) grow in this habitat.

Sampling and sample processing

In each studied habitat, 10 samples were taken with a corer (25 cm^2) up to 10 cm depth (included topsoil, litter and soil-cover vegetation — mosses, lichen and dwarf shrub parts) between July 24 and July 26, 2015. The samples were placed in multilayer paper bags which were put in the cardboard boxes with cells for each sample. The samples were delivered to Moscow in three days for further processing. Microarthropods were extracted using Tullgren funnels in the laboratory without additional heating for 10 days (Potapov and Kuznetsova 2011).

Identification of mites

Adult oribatid mites were identified to the species level using the identification keys of Ghilarov (1975), Weigmann (2006) and Bayartogtokh (2010). Ptyctimous oribatid mites were identified using Niedbała (2011). Juveniles were checked, but information about the juveniles was not used in the statistical procedures. 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. Permutational MANOVA (PerMANOVA) was performed to establish a significant difference between the oribatid mite communities of the studied habitats (Anderson 2001). SIMPER procedure (similarity percentages) was used for determining which species contribute to the dissimilarity between the investigated habitats (Clarke 1993). Bray-Curtis similarity measure and the relative abundance (%) of species in samples were used for the PerMANOVA and SIMPER tests. Calculations were made in PAST 3.26b (Hammer *et al.* 2001).

The oribatid communities in the explored habitats were compared using multidimensional scaling and the discriminant functional analysis according to Tiunov and Scheu (2000). Based on arcsine transformed values of species relative abundance in samples, the similarity matrix was calculated using the Bray-Curtis similarity measure. The similarity matrix was 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 3-dimensions solution showed the best result. The coordinates of the samples in the 3-dimensions space were used for discriminant function analysis. Two significant discriminant functions (canonical roots) were obtained. To interpret the extracted canonical roots in terms of changes in the relative abundance of oribatid species Spearman rank correlations were calculated between the canonical scores of canonical roots and relative abundance of species in the individual samples. These calculations were made using Statistica 6.0 (StatSoft, Tulsa).

Results

A total of 3 776 specimens of adult oribatid mites were collected and identified to species level, and 2 052 specimens of juveniles were identified to family level. Seventy species and one subspecies belonging to 37 genera and 24 families were found in the explored habitats (Table 1). Compared to the previous studies, 9 species and one subspecies of oribatid mites were found on the Kola Peninsula for the first time: *Brachychthonius impressus*, *Neobrachychthonius marginatus magnus*, *Sellnickochthonius furcatus*, *Atropacarus* cf. *genavensis*, *Trimalaconothrus foveolatus*, *Kunstidamaeus* cf. *diversipilis*, *Suctobelbella similis*, *Hydrozetes lacustris*, *Ceratozetes parvulus*, and family Mucronothridae, represented by *Mucronothrus nasalis* (Liskovaya 2011; Zenkova and Melekhina 2014; Leonov and Rakhleeva 2015; Leonov *et al.* 2015; Leonov and Rakhleeva 2020).

The families Brachychthoniidae, Suctobelbidae, and Oppiidae were the most diverse in the discovered local fauna. Eighteen species and one subspecies of Brachychthoniidae (26.8% of the total fauna), 9 species of Suctobelbidae (12.7% of the total fauna), and 7 species of Oppiidae (11.3% of the total fauna) were found (Table 1). The lichen and dwarf shrub tundra differed considerably in the fauna of the oribatid mites. The explored sphagnum bog was characterized by a specific fauna of oribatid mites. *Mucronothrus nasalis*, which was found there, is one of the most adapted species of oribatid mites to aquatic habitats (Behan-Pelletier and Eamer 2007). In this investigation, species of sphagnum bog was an important component of biodiversity: 13 species of the discovered local fauna (18%) were found only in this habitat.

Among tundra habitats, the abundance of oribatid mites was lower in the lichen tundra and increased in the dwarf shrub tundra. The sphagnum bog was characterized by the lowest abundance among all explored biotopes. Adult oribatid mites were more numerous than juveniles in the tundra habitats in this investigation (Table 1). In contrast, in the sphagnum bog, juvenile oribatid mites were more numerous than adults through the high abundance of both Malaconothridae and Mucronothridae instars (Table 2).

According to the PerMANOVA test, differences observed between assemblages of oribatid mites of all explored habitats were statistically significant (Figure 2). Based on the results of SIMPER test, they were due to the different composition of complexes of dominant species: the five most numerous species determined more than 50% of the cumulative difference between oribatid mite assemblages of the explored habitats.

In the lichen tundra, *Carabodes labyrinthicus*, *Tectocepheus velatus,* and *Sellnickochthonius furcatus* dominated. The relative abundance of these species and also *Nothrus borussicus*, *Mycobates sarekensis* and six species of the family Brachychthoniidae significantly decreased from the lichen tundra to the dwarf shrub tundra (Table 3). Small-size species of the families Suctobelbidae and Oppiidae dominated in the dwarf shrub tundra. They decreased in the relative abundance from the dwarf shrub tundra to the lichen tundra, as well as species *Nanhermannia sellnicki*, *Chamobates borealis*, *Eobrachychthonius latior*, *Hemileius initialis* (and some other species). A specific complex of dominant species was found in the sphagnum bog, represented by species of wet habitats: *Mucronothrus nasalis*, *Limnozetes ciliatus*, *Platynothrus peltifer*, *Trimalaconothrus maior,* and *Limnozetes* cf. *rugosus*. The relative abundance of these oribatid species increased significantly with the highest values of the Spearman rank correlation from the tundra habitats to the sphagnum bog. Along with this, species which were the most characteristic of the lichen and dwarf shrub tundra significantly decreased in the relative abundance (Table 3).

Discussion

The discovered local oribatid mite fauna of the Chunatundra Mountains is characterized by a high diversity of the families Brachychthoniidae, Suctobelbidae, and Oppiidae (Table 1). The families Brachychthoniidae and Oppiidae often are the most diverse in the tundra communities

Table 1 Fauna and average abundance (ind./m^2) of the adult oribatid mites and average abundance of the juvenile oribatid mites in the explored habitats of the Chunatundra Mountains: lichen tundra plots (ChT-LT-638, ChT-LT-466), dwarf shrubs tundra plot (ChT-DST-419) and sphagnum bog (ChT-SB-417).

Taxa	ChT-LT-638	ChT-LT-466	ChT-DST-419	ChT-SB-417
Brachychthoniidae Thor, 1934				
Brachychthonius impressus Moritz, 1976*	40	0	0	0
Eobrachychthonius latior (Berlese, 1910)	80	0	1640	0
Liochthonius sp.	0	200	0	0
Liochthonius sp. 1	160	0	0	0
Liochthonius sp. 2	40	0	0	0
Liochthonius brevis (Michael, 1888)	0	80	80	0
Liochthonius clavatus (Forsslund, 1942)	120	40	0	0
Liochthonius lapponicus (Tragardh, 1910)	600	1000	0	0
Liochthonius muscorum Forsslund, 1964	0	0	0	720
Liochthonius neglectus Moritz, 1976	400	80	0	240
Liochthonius perfusorius Moritz, 1976	0	0	80	0
Liochthonius sellnicki (Thor, 1930)	120	80	80	0
Liochthonius cf. *simplex* (Forsslund, 1942)	80	0	0	0
Neobrachychthonius marginatus (Forsslund, 1942)	320	600	0	0
Neobrachychthonius marginatus magnus Moritz, 1976*	80	0	0	0
Sellnickochthonius sp.	280	0	0	0
Sellnickochthonius furcatus (Weis-Fogh, 1948)*	2240	9040	120	0
Sellnickochthonius immaculatus (Forsslund, 1942)	1800	1120	40	40
Sellnickochthonius zelawaiensis (Sellnick, 1928)	280	0	240	0
Eulohmanniidae Grandjean, 1931				
Eulohmannia ribagai (Berlese, 1910)	40	40	1200	0
Phthiracaridae Perty, 1841				
Atropacarus cf. *genavensis* Mahunka, 1993*	0	0	0	280
Malaconothridae Berlese, 1916				
Malaconothrus monodactylus (Michael, 1888)	0	0	0	80
Trimalaconothrus foveolatus Willmann, 1931*	0	0	0	760
Trimalaconothrus maior (Berlese, 1910)	0	0	0	1080
Mucronothridae Kunst, 1972*				
Mucronothrus nasalis (Willmann, 1929)*	0	0	0	6360
Nothridae Berlese, 1896				
Nothrus borussicus Sellnick, 1929	560	0	0	200
Camisiidae Oudemans, 1900				
Camisia biurus (C.L. Koch, 1839)	120	120	120	0
Neonothrus humicolus Forsslund, 1955	0	1440	640	0
Heminothrus longisetosus Willmann, 1925	440	0	0	0
Platynothrus peltifer (C.L. Koch, 1839)	0	0	760	1760
Nanhermanniidae Sellnick, 1928				
Nanhermannia cf. *coronata* Berlese, 1913	0	0	0	160
Nanhermannia sellnicki Forsslund, 1958	0	240	4360	0
Damaeidae Berlese, 1896				
Kunstidamaeus cf. *diversipilis* (Willmann, 1951)*	0	40	0	0
Kunstidamaeus nidicola (Willmann, 1936)	640	0	0	0
Porobelba spinosa (Sellnick, 1920)	120	240	320	0
Eremaeidae Oudemans, 1900				
Eueremaeus silvestris (Forsslund, 1956)	320	0	80	0
Liacaridae Sellnick, 1928				
Adoristes ovatus (C.L. Koch, 1839)	0	0	440	0
Carabodidae C.L. Koch, 1837				
Carabodes areolatus Berlese, 1916	0	0	80	0
Carabodes labyrinthicus (Michael, 1879)	15800	2120	160	0
Carabodes marginatus (Michael, 1884)	0	0	320	0
Tectocepheidae Grandjean, 1954				
Tectocepheus velatus (Michael, 1880)	7040	12720	2520	80

The sign “*” marks new taxa for the Kola Peninsula

Table 1 Continued.

Taxa	ChT-LT-638	ChT-LT-466	ChT-DST-419	ChT-SB-417
Quadroppiidae Balogh, 1983				
Quadroppia quadricarinata (Michael, 1885)	520	0	0	0
Oppiidae Grandjean, 1951				
Dissorhina ornata (Oudemans, 1900)	120	0	200	40
Oppiella acuminata (Strenzke, 1951)	80	0	160	0
Oppiella cf. *keilbachi* (Moritz, 1969)	0	120	0	0
Oppiella neerlandica (Oudemans, 1900)	0	0	5920	0
Oppiella nova (Oudemans, 1902)	40	4400	10320	200
Oppiella subpectinata (Oudemans, 1900)	2920	640	120	0
Oppiella unicarinata (Paoli, 1908)	0	0	9080	0
Suctobelbidae Jacot, 1938				
Suctobelbella sp.	0	640	0	0
Suctobelbella sp. 1	0	0	80	0
Suctobelbella sp. 5	0	0	2400	0
Suctobelbella acutidens (Forsslund, 1941)	480	1360	6200	0
Suctobelbella cf. *arcana* Moritz, 1970	240	0	1760	0
Suctobelbella longirostris (Forsslund, 1941)	0	0	120	0
Suctobelbella cf. *sarekensis* (Forsslund, 1941)	240	0	960	0
Suctobelbella similis (Forsslund, 1941)*	0	0	280	0
Suctobelbella subcornigera (Forsslund, 1941)	40	0	0	0
Hydrozetidae Grandjean, 1954				
Hydrozetes lacustris (Michael, 1882)*	0	0	0	40
Limnozetidae Grandjean, 1954				
Limnozetes cf. *rugosus* (Sellnick, 1923)	0	0	0	960
Limnozetes ciliatus (Schrank, 1803)	0	0	0	4520
Phenopelopidae Petrunkevich, 1955				
Eupelops sp.	200	0	160	0
Ceratozetidae Jacot, 1925				
Ceratozetes thienemanni Willmann, 1943	480	0	560	0
Ceratozetes parvulus Sellnick, 1922*	0	0	0	800
Diapterobates humeralis (Hermann, 1804)	0	0	360	0
Melanozetes mollicomus (C. L. Koch, 1839)	0	0	0	120
Chamobatidae (Thor, 1938)				
Chamobates borealis (Tragardh, 1902)	0	2600	2840	0
Mycobatidae Grandjean, 1954				
Mycobates sarekensis (Tragardh, 1910)	1160	0	0	0
Scheloribatidae Grandjean, 1933				
Scheloribates laevigatus (C. L. Koch, 1835)	0	0	0	40
Hemileius initialis (Berlese, 1908)	0	80	920	160
Oribatulidae Thor, 1929				
Oribatula tibialis (Nicolet, 1855)	0	40	480	0
Number of species	36	25	38	21
Average abundance of the adult oribatida, ind./m^2	38240	39080	56200	18640
Standard deviation for the adult oribatida	10330	20721	44807	7538
Standard error for the adult oribatida, ind./m^2	3267	6553	14169	2384
Proportion of the adults in the total abundance	79%	69%	70%	38%
Average abundance of the juvenile oribatida, ind./m^2	10280	17680	24120	30000
Standard deviation for the juvenile oribatida	3272	11272	12697	14074
Standard error for the juvenile oribatida, ind./m^2	1091	3757	4232	4691
Proportion of the juveniles in the total abundance	21%	31%	30%	62%
Average abundance of the total oribatida, ind./m^2	48520	56760	80320	48640

The sign “*” marks new taxa for the Kola Peninsula

(Ananieva *et al.* 1973, 1979; Thomas and MacLean Jr 1988; Grishina *et al.* 1998; Behan-Pelletier 1999, Makarova 2015) and polar deserts (McAlpine 1965; Bulavintsev and Babenko 1983; Makarova 2002). Families Ceratozetidae and Camisiidae, which are an important component of the faunae in the tundra communities (Thomas and MacLean Jr 1988; Sidorchuk 2009; Heggen 2010; Coulson *et al.* 2014; Makarova 2015), had low diversity in the present study: only four species of families Ceratozetidae and Camisiidae (each of them comprises by 5.6% of the fauna) were found. These families are most diverse in the East European tundra (Melekhina 2020).

Despite the relatively geographical closeness and some similarities in the natural conditions, the oribatid mite fauna of the Chunatundra Mountains differs from the local oribatid faunae of alpine and arctic/alpine habitats of the South, North-West and North-East Scandinavian Peninsula (Heggen 2010). In these local faunae, Camisiidae, Damaeidae, Ceratozetidae and Oppiidae are the most diverse. The families Achipteriidae and Ceratoppiidae, well represented in the alpine and arctic/alpine habitats in the Scandinavian Peninsula (Heggen 2010), were not found in this investigation.

Like in the Lovozersky Mountains (Leonov and Rakhleeva 2020), a large number of species of the family Suctobelbidae was found in the local fauna of the Chunatundra Mountains. In contrast to Chunatundra Mountains, the family Suctobelbidae has low diversity in the local faunae of the Scandinavian Peninsula (Heggen 2010). A high diversity of the family Suctobelbidae is not common for plain tundra (Makarova 2015; Melekhina and Zinovyeva 2012; MacLean *et al.* 1978; Thomas and MacLean Jr 1988) and mountain tundra (Sidorchuk 2009), in contrast to the taiga zone (Krivolutsky *et al.* 1999; Laskova 2001; Melekhina 2004). The occurrence of Suctobelbidae might be typical for communities of mountain tundra that are surrounded by mountain forests, which may be a source of the increasing diversity of the

Table 2 Average abundance (ind./m^2) of juvenile oribatid mites in the explored habitats of the Chunatundra Mountains: lichen tundra plots (ChT-LT-638, ChT-LT-466), dwarf shrubs tundra plot (ChT-DST-419), and sphagnum bog (ChT-SB-417).

Taxa	ChT-LT-638	ChT-LT-466	ChT-DST-419	ChT-SB-417
Camisiidae Oudemans, 1900	720	3760	4280	4680
Carabodidae C.L. Koch, 1837	80	680	0	0
Ceratozetidae Jacot, 1925	0	120	1560	240
Chamobatidae (Thor, 1938)	0	2320	3800	0
Damaeidae Berlese, 1896	680	360	400	0
Eremaeidae Oudemans, 1900	400	0	720	0
Eulohmanniidae Grandjean, 1931	80	0	1680	0
Hydrozetidae Grandjean, 1954	0	0	0	360
Limnozetidae Grandjean, 1954	0	0	0	400
Malaconothridae Berlese, 1916	0	0	0	6720
Mucronothridae Kunst, 1972	0	0	0	16520
Nanhermanniidae Sellnick, 1928	0	0	5080	1080
Nothridae Berlese, 1896	3840	0	440	0
Oribatulidae Thor, 1929	0	0	1960	0
Phenopelopidae Petrunkevich, 1955	40	40	40	0
Scheloribatidae Grandjean, 1933	0	240	3200	0
Tectocepheidae Grandjean, 1954	4440	10160	960	0
Average abundance for the juvenile oribatida, ind./m^2	10280	17680	24120	30000
Standard deviation for the juvenile oribatida	3272	11272	12697	14074
Standard error for the juvenile oribatida, ind./m^2	1091	3757	4232	4691

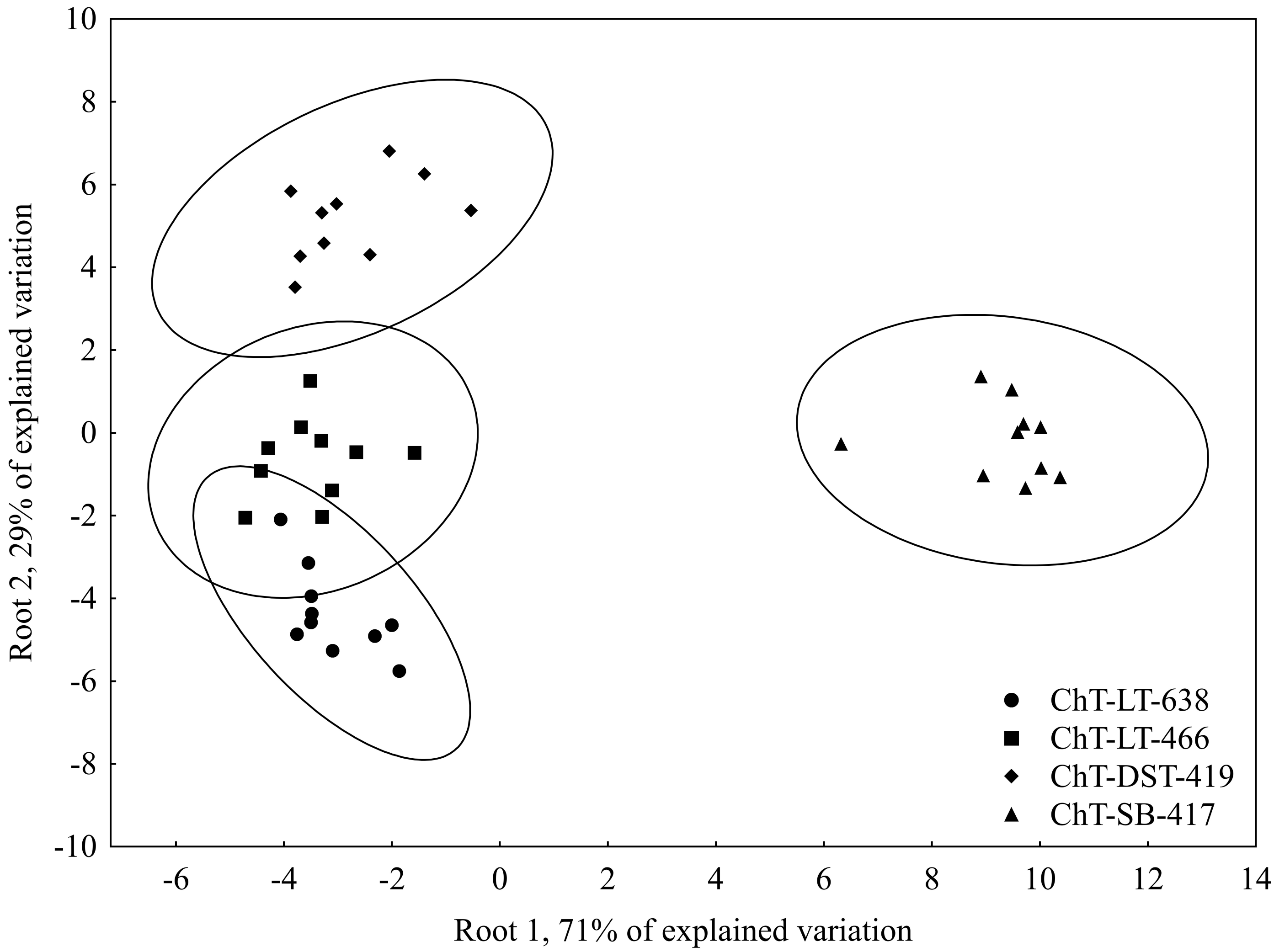

Figure 2 Discriminant (canonical) function analysis of the relative abundances of oribatid mites in the explored habitats. Dots are single samples. The analysis was based on the Bray—Curtis similarity matrix. Both canonical roots were significant. Ellipses show a 95% prediction interval.

oribatid mites and particularly the family Suctobelbidae. It could also be a specific feature of the oribatid mite fauna of the Kola Peninsula which is developed under the relative mildness conditions of the oceanic type of climate. The mild conditions may lead to the relative species richness of the local faunae of oribatid mites on the Kola Peninsula.

The abundance of oribatid mites in the explored habitats (Table 1) corresponds to the values described for tundra communities in previous investigations (Thomas and MacLean Jr 1988; Melekhina and Zinovyeva 2012; Leonov and Rakhleeva 2020). In the sphagnum bog, the abundance of oribatid mites is comparatively high for such severe environmental conditions compared to some other wetland habitats located in a temperate climate (Zaitsev 2013; Lehmitz 2014; Minor *et al.* 2016b). Discovered values of the total (adult+juvenile) oribatid mite abundance are comparable with that in the mires of western Norway (Seniczak *et al.* 2010; Seniczak *et al.* 2019b; Solhøy 1979) but these values are lower than the density of the oribatid mites in the bogs of Poland (Seniczak *et al.* 2019a).

Like in the previously investigated plain and mountain tundra of the Kola Peninsula (Leonov and Rakhleeva 2015; Leonov *et al.* 2015; Leonov and Rakhleeva 2020), lichen and dwarf shrub tundra differ significantly in the composition of oribatid mite community. *Carabodes* *labyrinthicus*, *Nothrus borussicus*, *Sellnickochthonius immaculatus*, *Mycobates sarekensis,* and *Tectocepheus velatus* are more typical for the lichen tundra. Species of *Mycobates* are known as characteristic of saxicolous mosses above the upper forest line and species of *Mycobates* and *Carabodes* are closely related to the lichens (Materna 2000). *Mycobates sarekensis* occurs in both higher alpine zones and glacier-forelands in alpine habitats of the Scandinavian Peninsula (Heggen 2010).

In this investigation, species of *Carabodes* have different preferences to environmental conditions. *Carabodes labyrinthicus* is strongly associated with the lichen tundra, whereas two other species of *Carabodes* are found only in the dwarf shrub tundra, where *C. labyrinthicus* decreases significantly in the abundance. This trend was observed in the previous investigations of the oribatid mites in the Lovozersky Mountains, Khibiny Mountains and in the plain tundra of the Kola Peninsula (Leonov and Rakhleeva 2015; Leonov *et al.* 2015; Leonov and Rakhleeva 2020). *Carabodes labyrinthicus* was found as a permafrost indicator in sub-Arctic palsa mires (Markkula 2014; Markkula *et al.* 2018).

Species of the Suctobelbidae and Oppiidae are most abundant in dwarf shrub tundra. A similar pattern was observed in the previous investigations of the oribatid mites in the mountain and plain tundra of the Kola Peninsula (Leonov and Rakhleeva 2015; Leonov *et*

Table 3 Spearman rank correlations of the relative abundance of oribatid mite species in the individual samples with the canonical roots (species with significant correlation only, p <0.05).

Correlation with Root 2			Correlation with Root 1		
Species	Spearman R	p-value	Species	Spearman R	p-value
Nanhermannia sellnicki	0.76	0.0000	*Mucronothrus nasalis*	0.75	0.0000
Oppiella neerlandica	0.64	0.0000	*Limnozetes ciliatus*	0.72	0.0000
Suctobelbella sp. 5	0.62	0.0000	*Platynothrus peltifer*	0.60	0.0000
Chamobates borealis	0.62	0.0000	*Trimalaconothrus foveolatus*	0.48	0.0016
Eobrachychthonius latior	0.60	0.0000	*Limnozetes* cf. *rugosus*	0.46	0.0027
Hemileius initialis	0.59	0.0001	*Trimalaconothrus maior*	0.43	0.0055
Suctobelbella acutidens	0.54	0.0003	*Liochthonius muscorum*	0.42	0.0077
Eulohmannia ribagai	0.45	0.0035	*Atropacarus* cf. *genavensis*	0.36	0.0241
Carabodes marginatus	0.42	0.0076	*Neobrachychthonius marginatus*	-0.32	0.0445
Suctobelbella similis	0.41	0.0081	*Liochthonius lapponicus*	-0.35	0.0257
Oppiella unicarinata	0.41	0.0086	*Sellnickochthonius furcatus*	-0.37	0.0171
Neonothrus humicolus	0.39	0.0117	*Neonothrus humicolus*	-0.45	0.0037
Diapterobates humeralis	0.38	0.0143	*Chamobates borealis*	-0.47	0.0022
Oppiella nova	0.38	0.0143	*Suctobelbella acutidens*	-0.54	0.0003
Oribatula tibialis	0.38	0.0149	*Tectocepheus velatus*	-0.67	0.0000
Adoristes ovatus	0.36	0.0231	*Carabodes labyrinthicus*	-0.68	0.0000
Liochthonius perfusorius	0.32	0.0454			
Neobrachychthonius marginatus magnus	-0.33	0.0392			
Liochthonius sp. 1	-0.34	0.0337			
Sellnickochthonius furcatus	-0.36	0.0234			
Liochthonius clavatus	-0.38	0.0155			
Liochthonius neglectus	-0.39	0.0127			
Quadroppia quadricarinata	-0.40	0.0116			
Liochthonius lapponicus	-0.40	0.0113			
Kunstidamaeus nidicola	-0.45	0.0036			
Tectocepheus velatus	-0.45	0.0034			
Mycobates sarekensis	-0.59	0.0001			
Sellnickochthonius immaculatus	-0.62	0.0000			
Nothrus borussicus	-0.62	0.0000			
Carabodes labyrinthicus	-0.67	0.0000			

al. 2015; Leonov and Rakhleeva 2020). Species of these families were more common in a mountain forest habitat than above tree-line in the Central Alps (Fischer and Schatz 2013). The Suctobelbidae and Oppiidae species were characteristic for saxicolous mosses below the upper forest-line in the Krokonoše Mountains in Czech Republic (Materna 2000).

The distribution of *Nanhermannia sellnicki* is similar to the results obtained in previous investigations of the tundra communities on the Kola Peninsula (Leonov and Rakhleeva 2015; Leonov *et al.* 2015; Leonov and Rakhleeva 2020). However, this species may show changing ecological preferences in different environmental conditions. *Nanhermannia sellnicki* was the most abundant species in the bogs of the western part of Norway, where the climate is mild and temperate with an average annual temperature of 6.8 °C (Seniczak *et al.* 2019b). *Chamobates borealis,* which was strongly associated with the wet conditions in the Lovozersky Mountains (Leonov and Rakhleeva 2020) and was found as a permafrost indicator in sub-Arctic palsa mires (Markkula 2014; Markkula *et al.* 2018), is significantly correlated with the tundra conditions and with dwarf shrub tundra in this research. This difference might be caused by different climate conditions of the comparing regions. The ecological preferences of these species require further refinement.

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