



# Arctic, Antarctic, and Alpine Research

An Interdisciplinary Journal

ISSN: 1523-0430 (Print) 1938-4246 (Online) Journal homepage: <https://www.tandfonline.com/loi/uaar20>

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To cite this article: Stanisław Seniczak, Anna Seniczak, Dariusz J. Gwiazdowicz & Stephen J. Coulson (2014) Community Structure of Oribatid and Gamasid Mites (Acari) in Moss-Grass Tundra in Svalbard (Spitsbergen, Norway), *Arctic, Antarctic, and Alpine Research*, 46:3, 591-599, DOI: [10.1657/1938-4246-46.3.591](https://doi.org/10.1657/1938-4246-46.3.591)

To link to this article: <https://doi.org/10.1657/1938-4246-46.3.591>



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Published online: 05 Jan 2018.



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# Community structure of oribatid and gamasid mites (Acari) in moss-grass tundra in Svalbard (Spitsbergen, Norway)

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## Abstract

The mite fauna of patches of High Arctic moss-grass tundra of Svalbard in Petuniabukta, Billefjord (moss, grasses, *Salix polaris*, bare soil), and adjacent to Vestpynten, Adventfjord (moss, moss mixed with grasses, *Cassiope tetragona*, *S. polaris*), were investigated. Our aim was to describe the mite fauna of this tundra with particular focus on the stage structure that is rarely investigated. We observed that the oribatid mites were distinctly more abundant and richer in species (22) than the gamasid mites (7) and their density and diversity varied between vegetation and location. Species diversity of Oribatida and Gamasida and the Shannon  $H'$  index of mite communities were low, and *Liochthonius sellnicki* or *Tectocephus velatus* dominated the Oribatida and *Oppiella translamellata* and *Diapterobates notatus* were relatively abundant, while the Gamasida were dominated by *Arctoseius multidentatus*, with *Zercon forsslundi* and *Z. solenites* relatively abundant. The juvenile densities of the Oribatida were usually greater than adults. *Eniochthonius minutissimus* and *Metabelba* sp. are new records for Svalbard.

DOI: <http://dx.doi.org/10.1657/1938-4246-46.3.591>

## Introduction

The High Arctic archipelago of Svalbard has a quite diverse invertebrate community and is among the best known for any region of the Arctic (Hodkinson, 2013). Bayartogtokh et al. (2011) presented 81 species of oribatid mites for the archipelago, while Coulson et al. (2014) gave 29 species of gamasid mites. However, considerable taxonomic confusion has accumulated during the 150-year history of mite research in Svalbard (Ávila-Jiménez et al., 2011; Bayartogtokh et al., 2011; Coulson et al., 2014), during which microscopic techniques and the taxonomy of these small arthropods has progressed greatly. Ávila-Jiménez et al. (2011) considered critically the total list of 27 species then recorded from Svalbard archipelago and, based on an assessment of fresh soil samples collected between 2007 and 2009 from throughout Svalbard and from recent publications, they reduced this list to 22 species, since increased by subsequent material from new field collections to 29 (Coulson et al., 2014, and references therein). A similar problem concerns the oribatid mites. It is unknown what level of taxonomic identification was used for many records of these mites, so potential synonyms exist, and since the original material has often been lost, this group is also in need of further investigation from fresh sampling. Moreover, ecological studies in Svalbard are generally lacking, except for Seniczak and Plichta (1978) and Coulson et al. (2003), who described the oribatid mites from their own microhabitats. The lists of species presented by other authors give only general information on the presence of species, including accidental ones that can be easily transported from quite distant habitats by birds (Lebedeva and Krivolutskiy, 2003; Lebedeva and Lebedev, 2008; Coulson et al., 2009).

The ecology of oribatid mites in polar ecosystems such as Svalbard is important to study as these systems are unique and created by characteristic environmental conditions, mainly low

annual temperature and precipitation, short summer, and a long, dark winter. The soil is frozen for the greater part of the year and therefore is still in an early stage of development, offering plants only a thin, nutrient-poor organic soil layer. Therefore, the tundra flora is composed of robust species, such as lichens, moss, grasses, and herbs (Jónsdóttir, 2005), which grow and develop in a short summer when the upper soil horizon is thawed and the soil fauna is active, decomposing the soil organic matter and releasing nutrients for plant growth. Some tree species also occur on the Svalbard tundra, but because of the High Arctic environment they are small with a prostrate growth form. Moreover, the extreme Arctic environment delays the succession of plants, and the community composition develops slowly, resembling the initial stages of plant succession near the glacier forelands observed in moderate climates. Finally, this tundra ecosystem is composed of clearly differentiated habitats, often at small scales of a few meters (Jónsdóttir, 2005), enabling clearly distinguishable soil mite communities to be readily identified (Gwiazdowicz and Coulson, 2011).

In tundra mite communities, the saprophagous oribatid mites usually dominate and their densities depend highly on the spatial distribution of plants and the thickness of organic matter (Seniczak and Plichta, 1978; Coulson et al., 2003). As most plant species are distributed patchily, the mites also form aggregations, often displaying a relationship between plant and oribatid mite species. As with the flora, the oribatid mites of the tundra are composed mainly of pioneer and ubiquitous species that are well adapted to the polar climate. The gamasid mites of Svalbard are less known (Ávila-Jiménez et al., 2011), being often omitted from studies involving other soil taxa, mainly due to the difficulties of working with this group (e.g., Hodkinson et al., 2003, 2004). Therefore, we hypothesize that the plant patches of moss-grass tundra of Svalbard regulate the density, species number, dominance, and

stage structure of both oribatid and gamasid mites. Our aim is to describe the oribatid and gamasid mites for moss-grass High Arctic tundra, with particular focus on the stage structure of these mites that is rarely investigated in ecological studies due to the taxonomic challenges.

## Study Areas, Material, and Methods

This study was conducted at two locations in central Spitsbergen: Petuniabukta (Billefjord, N78°42', E16°40') and Vestpynten close to the Svalbard airport at Vestpynten (N 78°15', E15°25'), located about 60 km from Petuniabukta (Fig. 1). Both represent poorly developed sandy soils with moss-grass vegetation. In Petuniabukta, the greatest mean monthly air temperature in 2001–2003 was in July and August (+8.1 °C), and the lowest in January to March (–17.8 °C) (Rachlewicz and Styszyńska, 2007). At Vestpynten, the warmest monthly mean temperature was in July–August (+7.5 °C) and lowest in January–March (–18.1 °C) (Norwegian Meteorological Institute, 2012). Mean annual precipitation in this region is about 200 mm (Rachlewicz, 2003).

Material was collected between 23 July and 7 August 2007 from various vegetation types: Petuniabukta—(1) moss, (2) grasses, (3) *Salix polaris*, and (4) bare soil (without higher plants and poor in organic matter); Vestpynten—(5) moss, (6) moss mixed with grasses, (7) *Cassiope tetragona*, and (8) *S. polaris*. Between one to seven samples of plants and litter (vegetation types 1–3 and 5–8) or bare soil (4), 1 dm<sup>2</sup> in area and 5 cm deep in plant vegetation or 5 cm deep in bare soil, were taken (Table 1). Replication was partly limited by the strict environmental laws pertaining to Svalbard, which restricted the number of samples due to a slow regeneration time of the High Arctic tundra. Only one sample was taken from small patches of *S. polaris* and *C. tetragona* because of the need to limit disturbance to the vulnerable tundra environment.

Mites were extracted from the soil samples in Tullgren funnels in Svalbard, preserved in 70% ethanol, and identified to species, or genus, including all life stages. Names of oribatid

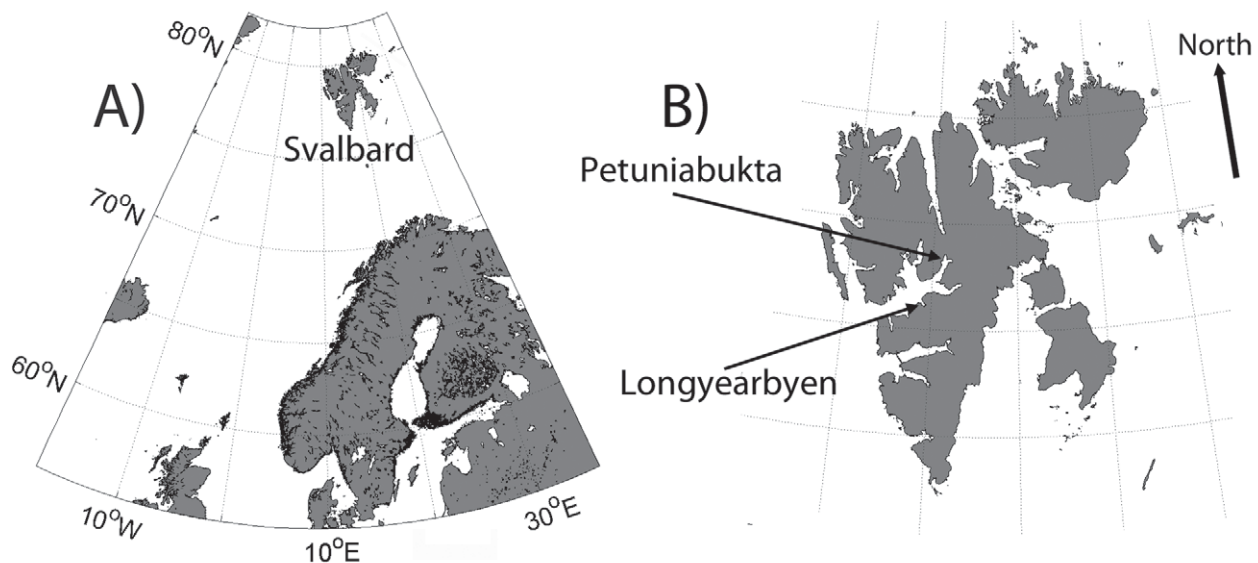
species follow Subías (2004) and partly Weigmann (2006). The juveniles of Oribatida include larvae, protonymphs, deutonymphs, and tritonymphs, which were all identified separately using diagnostic characteristics given by Seniczak (1980, 1991) and Seniczak and Seniczak (2010a, 2012a) as well as undescribed material from existing collections. In total, 11,052 oribatid mites and 265 gamasid mites were collected, and the density presented as individuals m<sup>-2</sup>. The populations of oribatid and gamasid species were characterized by the density (*A*) and dominance (*D*) indices (Odum, 1982), while the communities were described by total abundance and species number and compared by Shannon *H'* index and Pielou and Hurlbert evenness (Beisel et al., 2003). Further statistical analysis was precluded by the lack of necessary replication. We used the classes of dominance after Seniczak (1978), including superdominants (*D* > 40), which are typical of extreme microhabitats.

Stage structure is given for all species for which the juvenile stages are known, except for the Oppiidae and Suctobelbidae, which have soft juveniles that are poorly extracted from soil samples and which would distort the observed stage structure (Seniczak, 1978). Investigation of the stage structure of the small oribatid mite, *Liochthonius sellnicki* (Thor, 1930) was possible because it was the only member of Brachychthoniidae in moss-grass tundra. All material identified is deposited at the University of Technology and Life Sciences, Bydgoszcz, Poland (Oribatida), or University of Life Sciences, Poznań, Poland (Gamasida), and is available for future comparisons.

## Results

### DENSITY OF ORIBATIDA AND GAMASIDA, SPECIES NUMBER OF MITES, AND SHANNON AND EVENNESS INDICES

The Oribatida achieved the highest density in moss mixed with grasses at Vestpynten; their density was relatively high in patches of *Cassiope tetragona* and *Salix polaris* in Petuniabukta but was low in moss, grasses, and bare soil (Table 1, Fig. 2). Generally, Vestpynten was inhabited by more abundant mites than



**FIGURE 1.** Investigated regions of Svalbard (Spitsbergen). (A) Location of Svalbard in the Arctic Ocean; (B) locations of the town of Longyearbyen (close to Vestpynten) and Petuniabukta.

TABLE 1

Habitat (number of samples), mean density (thousand individuals  $m^{-2}$ ), species number ( $S$ ) of Oribatida and Gamasida, Shannon  $H'$  index and Pielou and Hurlbert evenness of communities of these mites in chosen microhabitats of moss-grass tundra in Svalbard.

| Habitat (samples)             | Oribatida |       |       |     | Gamasida |     |     |     |       | Oribatida + Gamasida |      |              |                |
|-------------------------------|-----------|-------|-------|-----|----------|-----|-----|-----|-------|----------------------|------|--------------|----------------|
|                               | Ad        | Juv   | Tot   | $S$ | Ad       | Juv | Tot | $S$ | Tot   | $S$                  | $H'$ | $E_{Pielou}$ | $E_{Hurlbert}$ |
| Petuniabukta                  |           |       |       |     |          |     |     |     |       |                      |      |              |                |
| Moss (7)                      | 8.1       | 9.6   | 17.7  | 14  | 1.0      | 0.7 | 1.7 | 6   | 19.4  | 20                   | 1.89 | 0.62         | 0.54           |
| Grasses (2)                   | 6.3       | 5.3   | 11.6  | 6   | 0.4      | 0.3 | 0.7 | 2   | 12.3  | 8                    | 1.59 | 0.76         | 0.71           |
| <i>Salix polaris</i> (1)      | 20.3      | 90.3  | 110.6 | 6   | 2.2      | 1.1 | 3.3 | 2   | 113.9 | 8                    | 1.18 | 0.57         | 0.56           |
| Bare soil (4)                 | 1.5       | 0.8   | 2.3   | 4   | 0.4      | 0.2 | 0.6 | 1   | 2.9   | 5                    | 1.16 | 0.72         | 0.48           |
| Mean                          | 9.1       | 26.5  | 35.6  | 8   | 1.0      | 0.6 | 1.6 | 3   | 37.2  | 11                   | 1.45 | 0.71         | 0.60           |
| Vestpynten                    |           |       |       |     |          |     |     |     |       |                      |      |              |                |
| Moss (3)                      | 43.9      | 36.9  | 80.8  | 11  | 1.0      | 0.1 | 1.1 | 5   | 81.9  | 16                   | 1.40 | 0.51         | 0.48           |
| Moss+grasses (2)              | 84.5      | 123.5 | 208.0 | 7   | 0.7      | 0   | 0.7 | 3   | 208.7 | 10                   | 1.19 | 0.59         | 0.51           |
| <i>Cassiope tetragona</i> (1) | 111.3     | 81.8  | 193.1 | 10  | 2.0      | 0   | 2.0 | 5   | 195.1 | 15                   | 1.09 | 0.40         | 0.39           |
| <i>Salix polaris</i> (1)      | 32.2      | 22.5  | 54.7  | 8   | 0.8      | 0   | 0.8 | 1   | 55.5  | 9                    | 1.23 | 0.56         | 0.54           |
| Mean                          | 68.0      | 66.2  | 134.2 | 9   | 1.1      | <1  | 1.1 | 3   | 135.3 | 12                   | 1.23 | 0.61         | 0.52           |

Notes: Ad = adults; Juv = juveniles; Tot = total.

Petuniabukta, but the density of mites depended on plant cover and which oribatid species dominated in the communities.

*Tectocephus velatus* (Michael, 1880) was distinctly more abundant at Vestpynten, whereas *Liochthonius sellnicki* achieved greatest densities at Petuniabukta (Table 2). The mean density of *L. sellnicki* at Petuniabukta was 10,600 individuals  $m^{-2}$ , and at Vestpynten it was 1.7-fold greater than at Petuniabukta. *Liochthonius sellnicki* was sensitive to plant cover, being the most abundant in patches of *C. tetragona* and moss mixed with grasses,

but less abundant in moss and *S. polaris*, and in other plant patches densities were low. The mean density of *T. velatus* at Vestpynten was 9300 individuals  $m^{-2}$ , while near Petuniabukta it was 1.9-fold higher than at Vestpynten. *Tectocephus velatus* was the most abundant in a patch of *S. polaris* in Petuniabukta, and decreased in density in the *C. tetragona* vegetation, while in other patches it was not abundant.

In both regions *Oppiella translamellata* (Willmann, 1923) and *Diapterobates notatus* (Thorell, 1871) were relatively abundant and common, but the densities of each species were respectively 3.4-fold and 6.2-fold greater in Petuniabukta than at Vestpynten (Table 2). *Oppiella translamellata* preferred moss mixed with grasses at Vestpynten and was relatively abundant in other plant patches in this region, whereas at Petuniabukta this species was not abundant. *Diapterobates notatus* achieved maximum density in moss mixed with grasses at Vestpynten. This species was relatively abundant in patches of *S. polaris* at Petuniabukta and *C. tetragona* and moss at Vestpynten, but in other vegetation patches densities were low.

The remaining species—for example, *Camisia horrida* Hermann, 1804, *Ceratoppias phaerica* (L. Koch, 1879), *Hermannia reticulata*, and *Oribatula cf. tibialis* (Nicolet, 1855)—were more abundant at Vestpynten than Petuniabukta (Table 2). The two former species preferred moss mixed with grasses, *H. reticulata* was most abundant in patches of *S. polaris*, while *O. cf. tibialis* was most abundant in moss.

In both regions, the gamasid mites were distinctly less abundant than oribatid mites, being more abundant at Petuniabukta than at Vestpynten. For example, *Zercon forsslundi* Sellnick, 1958, occurred exclusively in moss in the former region. *Zercon solenites* Haarløv, 1942, was the most abundant gamasid mite in bare soil, and *Arctoseius multidentatus* Evans, 1955, preferred a patch of *S. polaris* at Petuniabukta (Table 2).

The diversity of oribatid mites depends on the type of vegetation and the number of replicated samples. Greatest species diversity occurred in moss in Petuniabukta, while the poorest habitat in terms of species number was in bare soil and *S. polaris* from the same region (Table 1). Moss in Petuniabukta was not rich

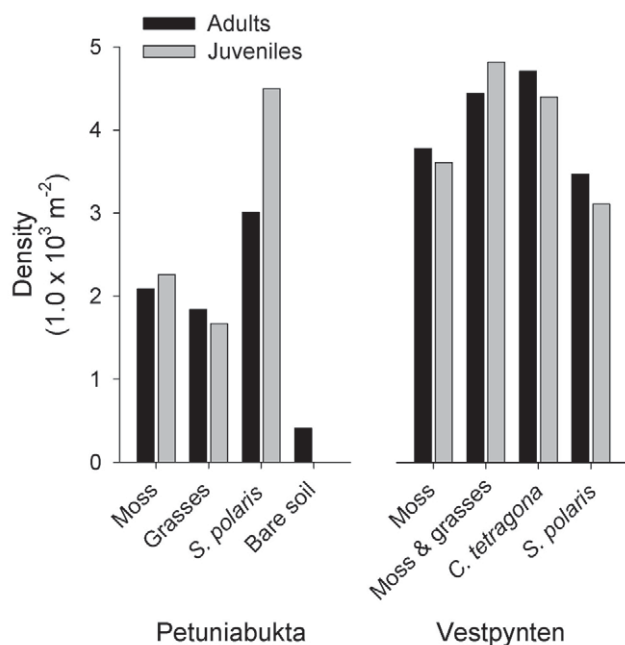


FIGURE 2. Density of Oribatida [thousand individuals  $m^{-2}$  in logarithmic scale ( $\ln$ )] in investigated microhabitats of moss-grass tundra in Svalbard.

TABLE 2

Mean density (thousand individuals m<sup>-2</sup>) of species of Oribatida (O) and Gamasida (G) in chosen microhabitats of moss-grass tundra in Svalbard. Oribatid species with a greatest density < 4.0 thousand individuals m<sup>-2</sup>, and gamasid species with a greatest density < 0.4 thousand individuals m<sup>-2</sup> are listed below the table. Ad = adult; Juv = juveniles.

| Name of species  | Stages | Petuniabukta |         |                      |           |      | Vestpynten |                           |                      |      |      |
|--|--------|--------------|---------|----------------------|-----------|------|------------|---------------------------|----------------------|------|------|
|  |        | Moss         | Grasses | <i>Salix polaris</i> | Bare soil | Mean | Moss+      | <i>Cassiope tetragona</i> | <i>Salix polaris</i> | Mean |      |
| <i>Camisia horrida</i><br>Hermann, 1804 (O)            | Ad     | 0.2          | 0.3     | 0                    | 0         | 0.1  | 0.5        | 2.1                       | 0.5                  | 0.6  | 0.9  |
|  | Juv    | 0.1          | 0.3     | 0                    | 0         | 0.1  | 0.4        | 5.4                       | 1.0                  | 1.9  | 2.2  |
|  | All    | 0.3          | 0.6     | 0                    | 0         | 0.2  | 0.9        | 7.5                       | 1.5                  | 2.5  | 3.1  |
| <i>Ceratoppia sphaerica</i><br>(L. Koch, 1879) (O)     | Ad     | 0.2          | 0       | 0                    | 0         | <0.1 | <0.1       | 1.6                       | 0                    | 0    | 0.4  |
|  | Juv    | 0.3          | 0       | 0                    | <0.1      | 0.1  | 0          | 2.9                       | 0                    | 0    | 0.7  |
|  | All    | 0.5          | 0       | 0                    | <1        | 0.1  | <0.1       | 4.5                       | 0                    | 0    | 1.1  |
| <i>Diapterobates notatus</i><br>(Thorell, 1871) (O)    | Ad     | 0.2          | 0.2     | 2.0                  | 0.1       | 0.6  | 3.4        | 17.4                      | 2.6                  | 0.5  | 6.0  |
|  | Juv    | 0.6          | 1.4     | 11.1                 | 0.3       | 3.4  | 3.1        | 20.2                      | 7.2                  | 0.5  | 7.7  |
|  | All    | 0.8          | 1.6     | 13.1                 | 0.4       | 4.0  | 6.5        | 37.6                      | 9.8                  | 1.0  | 13.7 |
| <i>Hermannia reticulata</i><br>Thorell, 1871 (O)       | Ad     | <0.1         | 0       | 0                    | 0         | <0.1 | 0          | 0                         | 0                    | 1.4  | 0.4  |
|  | Juv    | 0.2          | 0       | 0                    | 0         | <0.1 | 0.3        | 0.7                       | 0                    | 2.9  | 1.0  |
|  | All    | 0.2          | 0       | 0                    | 0         | <0.1 | 0.3        | 0.7                       | 0                    | 4.3  | 1.4  |
| <i>Liochthonius sellnicki</i><br>(Thor, 1930) (O)      | Ad     | 3.4          | 1.0     | 9.8                  | 1.3       | 3.9  | 21.9       | 38.0                      | 80.5                 | 15.0 | 38.9 |
|  | Juv    | 4.6          | 0.2     | 21.8                 | 0.4       | 6.7  | 26.8       | 90.9                      | 52.8                 | 15.3 | 46.4 |
|  | All    | 8.0          | 1.2     | 31.6                 | 1.7       | 10.6 | 48.7       | 128.9                     | 133.3                | 30.3 | 85.3 |
| <i>Oppiella translamellata</i><br>(Willmann, 1923) (O) | Ad     | 2.5          | 3.2     | 3.2                  | 0.1       | 2.2  | 6.9        | 22.3                      | 17.7                 | 14.2 | 15.3 |
|  | Juv    | 0.2          | 0       | 0.9                  | 0         | 0.3  | 0.1        | 0.2                       | 0                    | 0.9  | 0.3  |
|  | All    | 2.7          | 3.2     | 4.1                  | 0.1       | 2.5  | 7.0        | 22.5                      | 17.7                 | 15.1 | 15.6 |
| <i>Oribatula cf. tibialis</i><br>(Nicolet, 1855) (O)   | Ad     | 0            | 0.5     | 0                    | 0         | 0.1  | 8.7        | 0.4                       | 0.9                  | 0.2  | 2.5  |
|  | Juv    | 0            | 0       | 0                    | 0         | 0    | 3.4        | 0                         | 0                    | 0    | 0.9  |
|  | All    | 0            | 0.5     | 0                    | 0         | 0.1  | 12.1       | 0.4                       | 0.9                  | 0.2  | 3.4  |
| <i>Tectocepheus velatus</i><br>(Michael, 1880) (O)     | Ad     | 0.9          | 1.5     | 5.3                  | 0         | 1.9  | 1.7        | 2.8                       | 7.3                  | 0.1  | 3.0  |
|  | Juv    | 3.4          | 3.5     | 56.5                 | 0         | 15.9 | 1.9        | 3.2                       | 20.2                 | 0    | 6.3  |
|  | All    | 4.3          | 5.0     | 61.8                 | 0         | 17.8 | 3.6        | 6.0                       | 27.5                 | 0.1  | 9.3  |
| <i>Arctoseius multidentatus</i><br>Evans, 1955 (G)     | Ad     | 0.2          | 0.1     | 1.0                  | 0         | 0.3  | 0.6        | 0.3                       | 0.9                  | 0.8  | 0.6  |
|  | Juv    | 0.1          | 0.3     | 1.1                  | 0         | 0.4  | <0.1       | 0                         | 0                    | 0    | <0.1 |
|  | All    | 0.3          | 0.4     | 2.1                  | 0         | 0.7  | 0.6        | 0.3                       | 0.9                  | 0.8  | 0.6  |
| <i>Zercon forsslundi</i><br>Sellnick, 1958 (G)         | Ad     | 0.6          | 0       | 0                    | 0         | 0.2  | 0.0        | 0                         | 0                    | 0    | 0    |
|  | Juv    | 0.4          | 0       | 0                    | 0         | 0.1  | 0          | 0                         | 0                    | 0    | 0    |
|  | All    | 1.0          | 0       | 0                    | 0         | 0.3  | 0          | 0                         | 0                    | 0    | 0    |
| <i>Zercon solenites</i><br>Haarløv, 1942 (G)           | Ad     | 0            | 0       | 0                    | 0.4       | 0.1  | 0.2        | 0.2                       | 0.5                  | 0    | 0.2  |
|  | Juv    | 0            | 0       | 0                    | 0.2       | 0.1  | <0.1       | 0                         | 0                    | 0    | <0.1 |
|  | All    | 0            | 0       | 0                    | 0.6       | 0.2  | 0.2        | 0.2                       | 0.5                  | 0    | 0.2  |

**Petuniabukta**

**Moss:** *Dissorhina ornata* (Oudemans, 1900) (O); *Eniochthonius minutissimus* (Berlese, 1903) (O); *Metabelba* sp. (O); *Oppiella nova* (Oudemans, 1902) (O); *Oribatella arctica* Thor, 1930 (O); *Platynothrus punctatus* (C. L. Koch, 1839) (O); *Punctoribates punctum* (C. L. Koch, 1839) (O); Oribatida juv.; *Antennoseius (Vitzthumia) oudemansi* (Thor, 1930) (G); *Arctoseius haarlovi* Lindquist, 1963 (G); *A. weberi* Evans, 1955 (G); *Proctolaelaps parvanalis* (Thor, 1930) (G).

**Grasses:** *Suctobelbella subcornigera* (Forsslund, 1941) (O); *Antennoseius (Vitzthumia) oudemansi* (G).

*Salix polaris:* *Oppiella nova* (O); *Platynothrus punctatus* (O); *Amblyseius magnanalis* (Thor, 1930) (G).

**Bare soil:** Oribatida juv.

**Vestpynten**

**Moss:** *Oromurcia lucens* (L. Koch, 1879) (O); *Mycobates sarekensis* (Trägårdh, 1910) (O); *Parachipteria punctata* (Nicolet, 1855) (O); Oribatida juv.; *Antennoseius (Vitzthumia) oudemansi* (G); *Arctoseius haarlovi* (G); *A. weberi* (G).

**Moss+grasses:** *Arctoseius haarlovi* (G).

*Cassiope tetragona:* *Oppiella neerlandica* (Oudemans, 1902) (O); *Parachipteria punctata* (Nicolet, 1855) (O); *Platynothrus punctatus* (O); Oribatida juv.; *Antennoseius (Vitzthumia) oudemansi* (G); *Arctoseius haarlovi* (G); *A. weberi* (G).

*Salix polaris:* *Mycobates sarekensis* (O); Oribatida juv.

in oribatid mites, but because of seven replicates the total species number was the highest. Also, bare soil in the same region was inhabited by a small population of oribatid mites, but probably because of the four replicates there was one oribatid species more than in the patch of *S. polaris*, where the density of these mites was nearly 50-fold higher than in bare soil.

The diversity of the Gamasida was also distinctly lower than that of the Oribatida. The richest in gamasid species was the *S. polaris* community in Petuniabukta, and the poorest was the bare soil in this region (Table 1). The number of gamasid species also depended on the number of replicates, except for bare soil, where only one species was found in four samples. In all patches of moss-grass tundra, the Oribatida and Gamasida occurred together, and the greatest diversity of Gamasida occurred in the samples with the greatest oribatid species diversity.

The Shannon  $H'$  index of mite communities of Oribatida and Gamasida in patches of moss-grass tundra was generally low and depended mainly on the species richness of mites. The index achieved the highest value in moss in Petuniabukta and the lowest value in bare soil from this region (Table 1). The Pielou and Hurlbert evenness indices were greatest in grasses and the lowest in a patch of *C. tetragona*.

#### DOMINANCE STRUCTURE OF MITES

In patches of moss-grass tundra, the greatest dominance index achieved was by either *L. sellnicki* or *T. velatus* (Table 3). The former species dominated in all plant patches, except for grasses

and *S. polaris* in Petuniabukta where the latter species was the most abundant. In both regions, *D. notatus* and *O. translamellata* were relatively abundant and usually occupied higher dominance classes (eudominants or dominants) at Petuniabukta than at Vestpynten (dominants and subdominants) mainly because of lower dominance indices of *L. sellnicki* in the former region.

Among the non-abundant gamasid mites, *Z. solenites* was a eudominant in bare soil, *Z. forsslundi* a subdominant in moss, and *A. multidentatus* a recedent in moss, grass, and *S. polaris* in Petuniabukta (Table 3). At Vestpynten, only *A. multidentatus* was a recedent in a patch of *S. polaris*, while other species were subrecedents.

#### JUVENILE STAGES OF ORIBATIDA AND GAMASIDA

The patches of moss-grass tundra were generally rich in juvenile oribatid mites, but the proportion of juveniles was higher at Petuniabukta than at Vestpynten (Table 1). In most populations of oribatid species, all juvenile instars were relatively abundant, including the larvae (Table 4). For *C. sphaerica*, *H. reticulata*, *D. notatus*, and *T. velatus* the number in a particular development stage usually decreases from the larva to tritonymph.

The stage structure of *L. sellnicki* depended greatly on the vegetation (Table 4). In patches of *S. polaris* (Petuniabukta) and moss mixed with grasses (Vestpynten), the juveniles made up over 80% and 70% of population of this species, respectively, while in patches of *C. tetragona* and *S. polaris* at Vestpynten, the participation of juveniles was smaller (about 40% and 50%

Table 3

**Dominance structure of Oribatida (O) and Gamasida (G) mite communities in chosen microhabitats of moss-grass tundra in Svalbard. Dominance index of species is given in parentheses.**

| Petuniabukta   | Moss   | Grasses   | <i>Salix polaris</i>  | Bare soil   |
|----------------|--|---|---|---|
| Superdominants | <i>L. sellnicki</i> (O) - 45.1   | <i>T. velatus</i> (O) - 43.1  | <i>T. velatus</i> (O) - 55.9  | <i>L. sellnicki</i> (O) - 73.6  |
| Eudominants    | <i>T. velatus</i> (O) - 24.5   | <i>O. translamellata</i> (O) - 27.6   | <i>L. sellnicki</i> (O) - 28.6  | <i>Z. solenites</i> (G) - 21.6  |
| Dominants      | <i>O. translamellata</i> (O) - 15.0  | <i>D. notatus</i> (O) - 13.4  | <i>D. notatus</i> (O) - 11.8  | <i>D. notatus</i> (O) - 18.7  |
| Subdominants   | <i>Z. forsslundi</i> (G) - 5.4<br><i>D. notatus</i> (O) - 4.3<br><i>C. sphaerica</i> (O) - 2.8     | <i>L. sellnicki</i> (O) - 9.9   | —   | —   |
| Recedents      | <i>C. horrida</i> (O) - 1.6<br><i>A. multidentatus</i> (G) - 1.5<br><i>H. reticulata</i> (O) - 1.4 | <i>A. multidentatus</i> (G) - 2.9   | <i>O. translamellata</i> (O) - 3.7<br><i>A. multidentatus</i> (G) - 1.8 | <i>O. translamellata</i> (O) - 3.3<br><i>C. sphaerica</i> (O) - 1.1                             |
| Subrecedents   | 11 species   | 3 species   | 3 species   | —   |
| Vestpynten     | Moss   | Moss+ grasses   | <i>Cassiope tetragona</i>   | <i>Salix polaris</i>  |
| Superdominants | <i>L. sellnicki</i> (O) - 60.2   | <i>L. sellnicki</i> (O) - 61.9  | <i>L. sellnicki</i> (O) - 69.1  | <i>L. sellnicki</i> (O) - 55.4  |
| Eudominants    | —  | —   | —   | <i>O. translamellata</i> (O) - 27.6   |
| Dominants      | <i>O. cf. tibialis</i> (O) - 15.5  | <i>D. notatus</i> (O) - 18.1<br><i>O. translamellata</i> (O) - 10.8                         | <i>T. velatus</i> (O) - 14.3  | —   |
| Subdominants   | <i>O. translamellata</i> (O) - 8.6<br><i>D. notatus</i> (O) - 8.0                                  | —   | <i>O. translamellata</i> (O) - 9.2<br><i>D. notatus</i> (O) - 5.1       | <i>H. reticulata</i> (O) - 7.9  |
| Recedents      | <i>T. velatus</i> (O) - 4.5<br><i>C. horrida</i> (O) - 1.1   | <i>C. horrida</i> (O) - 3.6<br><i>T. velatus</i> (O) - 2.9<br><i>C. sphaerica</i> (O) - 2.1 | —   | <i>C. horrida</i> (O) - 4.6<br><i>D. notatus</i> (O) - 1.8<br><i>A. multidentatus</i> (O) - 1.4 |
| Subrecedents   | 10 species   | 4 species   | 11 species  | 3 species   |

TABLE 4

Stage structure of some Oribatida (O) and Gamasida (G) species in chosen microhabitats of moss-grass tundra in Svalbard. LV = larva, PN = protonymph, DN = deutonymph, TN = tritonymph, Np = not present. Density in thousand individuals m<sup>-2</sup> is given.

| Name of species                     | Habitat                         | Juvenile stages |      |      |      | Total | % of total | Adults | Total |
|-------------------------------------|---------------------------------|-----------------|------|------|------|-------|------------|--------|-------|
|                                     |                                 | LV              | PN   | DN   | TN   |       |            |        |       |
| <i>Camisia horrida</i> (O)          | Vestpynten, moss+grasses        | 1.6             | 1.0  | 1.0  | 1.8  | 5.4   | 72         | 2.1    | 7.5   |
|                                     | Vestpynten, <i>S. polaris</i>   | 1.2             | 0.4  | 0.3  | 0    | 1.9   | 76         | 0.6    | 2.5   |
| <i>Ceratoppia sphaerica</i> (O)     | Petuniabukta, moss              | 0.1             | 0.1  | 0.1  | <0.1 | 0.3   | 60         | 0.2    | 0.5   |
|                                     | Vestpynten, moss+grasses        | 1.1             | 0.8  | 0.7  | 0.3  | 2.9   | 64         | 1.6    | 4.5   |
| <i>Diapterobates notatus</i> (O)    | Petuniabukta, <i>S. polaris</i> | 2.0             | 5.2  | 2.5  | 1.4  | 11.1  | 85         | 2.0    | 13.1  |
|                                     | Petuniabukta, grasses           | 0.2             | 0.6  | 0.3  | 0.3  | 1.4   | 88         | 0.2    | 1.6   |
|                                     | Vestpynten, moss+grasses        | 10.0            | 6.8  | 2.1  | 1.3  | 20.2  | 54         | 17.4   | 37.6  |
|                                     | Vestpynten, <i>C. tetragona</i> | 5.4             | 0.8  | 0.5  | 0.5  | 7.2   | 73         | 2.6    | 9.8   |
|                                     | Vestpynten, moss                | 1.2             | 0.9  | 0.7  | 0.3  | 3.1   | 48         | 3.4    | 6.5   |
| <i>Hermamia reticulata</i> (O)      | Vestpynten, <i>S. polaris</i>   | 1.4             | 0.9  | 0.6  | 0    | 2.9   | 67         | 1.4    | 4.3   |
|                                     | Vestpynten, moss+grasses        | 0.2             | 0.2  | 0.2  | 0.1  | 0.7   | 100        | 0      | 0.7   |
| <i>Liochthonius sellnicki</i> (O)   | Petuniabukta, <i>S. polaris</i> | 3.2             | 7.2  | 5.1  | 6.3  | 21.8  | 69         | 9.8    | 31.6  |
|                                     | Petuniabukta, moss              | 0.9             | 1.3  | 1.0  | 1.4  | 4.6   | 58         | 3.4    | 8.0   |
|                                     | Petuniabukta, bare soil         | 0               | 0.1  | 0.2  | 0.1  | 0.4   | 24         | 1.3    | 1.7   |
|                                     | Vestpynten, <i>C. tetragona</i> | 0.4             | 29.9 | 17.0 | 5.5  | 52.8  | 40         | 80.5   | 133.3 |
|                                     | Vestpynten, moss+grasses        | 15.8            | 32.1 | 31.6 | 11.4 | 90.9  | 71         | 38.0   | 128.9 |
|                                     | Vestpynten, moss                | 5.1             | 7.6  | 5.8  | 8.3  | 26.8  | 55         | 21.9   | 48.7  |
|                                     | Vestpynten, <i>S. polaris</i>   | 0.8             | 5.2  | 3.6  | 5.7  | 15.3  | 50         | 15.0   | 30.3  |
|                                     | Petuniabukta, <i>S. polaris</i> | 30.5            | 8.5  | 9.4  | 8.1  | 56.5  | 91         | 5.3    | 61.8  |
| <i>Tectocephus velatus</i> (O)      | Petuniabukta, grasses           | 1.0             | 1.8  | 0.4  | 0.3  | 3.5   | 70         | 1.5    | 5.0   |
|                                     | Petuniabukta, moss              | 1.2             | 0.4  | 0.9  | 0.9  | 3.4   | 79         | 0.9    | 4.3   |
|                                     | Vestpynten, <i>C. tetragona</i> | 7.9             | 5.2  | 3.9  | 3.2  | 20.2  | 73         | 7.3    | 27.5  |
|                                     | Vestpynten, moss+grasses        | 0.4             | 0.9  | 0.7  | 1.2  | 3.2   | 53         | 2.8    | 6.0   |
|                                     | Vestpynten, moss                | 0.2             | 0.2  | 0.5  | 1.0  | 1.9   | 53         | 1.7    | 3.6   |
|                                     | Petuniabukta, <i>S. polaris</i> | 0               | 0.5  | 0.6  | Np   | 1.1   | 52         | 1.0    | 2.1   |
| <i>Arctoseius multidentatus</i> (G) | Petuniabukta, grasses           | 0               | 0.1  | 0.2  | Np   | 0.3   | 67         | 0.1    | 0.4   |
|                                     | Petuniabukta, moss              | 0               | <0.1 | 0.1  | Np   | 0.1   | 33         | 0.2    | 0.3   |
|                                     | Petuniabukta, bare soil         | 0               | 0.1  | 0.1  | Np   | 0.2   | 33         | 0.4    | 0.6   |
| <i>Zercon solenites</i> (G)         | Vestpynten, moss                | 0               | 0    | <0.1 | Np   | <0.1  | 13         | 0.2    | 0.2   |

of population, respectively). In contrast, the stage structure of *T. velatus* depended on the location; in Petuniabukta the participation of juveniles was distinctly higher (70%–91%) than at Vestpynten (53%–73% of total populations). In some species, such as *D. notatus*, *C. horrida*, and *C. sphaerica*, the participation of juveniles in populations was also high (54%–88%, 72%–76%, and 60%–64%, respectively), whereas the participation of juveniles of *O. translamellata* in both regions was low (<10%). Generally, the mean proportion of juveniles of the larger species of oribatid mites (*C. horrida*, *D. notatus*, and *H. reticulata*) were greater (74%, 70%, and 84%, respectively) than that of small species, such as *T. velatus* and *L. sellnicki* (63% and 52%, respectively).

The proportion of juveniles of gamasid mites was generally low, except for *A. multidentatus* in a patch of *S. polaris* at Petuniabukta, where the juveniles were slightly more abundant than the adults (Table 4).

## Discussion

The densities of oribatid and gamasid mites in moss-grass tundra was highly heterogeneous (2300–208,700 individuals m<sup>-2</sup>), and were probably related to the patchy vegetation cover. In mite communities, the Oribatida dominated. These are mainly saprophages and therefore their density strongly depends on quantity and quality of the organic matter. Some species of oribatid mites achieved different densities in plant patches with similar appearances, raising interesting questions about microhabitat requirements among species. For example, the density of *Liochthonius sellnicki* was similar in patches of *Salix polaris* in the two investigated locations, while that of *Tectocephus velatus* and *Diapterobates notatus* was distinctly higher in Petuniabukta than at Vestpynten, although all three species extract well from soil cores. Answering these questions requires more microhabitat data, including those linking biotic distributions to soil chemistry (Magalhães et al., 2012) and at a molecular level (Stevens and Hogg, 2006).

The oribatid mite communities of moss-grass tundra were poor in species with a low Shannon  $H'$  index, similar to mite communities from Mediterranean areas (Seniczak and Seniczak, 2006, 2010b, 2012b; Seniczak et al., 2009, 2011, 2012) and indicates a low soil fertility (Thienemann, 1939). These biocenotic principles themselves refer to aquatic ecosystems, but they also hold true for land vascular plants and the oribatid mites (Puchalski and Prusinkiewicz, 1975), where the density and species diversity depend greatly on the amount and form of plant litter. However, while those communities in the Mediterranean region are stressed by a high temperature and low precipitation, the oribatid mite communities of moss-grass tundra are limited by a low temperature and high soil moisture, which is consistent with the Shelford principle (Shelford, 1931) that either a lack or excess of particular environmental factors, such as temperature and moisture, can limit the development of mite communities.

*Liochthonius sellnicki* or *T. velatus* dominated in the Svalbard soils and *Oppiella translamellata* and *D. notatus* were relatively abundant; all species are typical of tundra, and most of them were abundant in moss-lichen-tundra (Seniczak and Plichta, 1978; Coulson et al., 2003). However, the oribatid mite communities investigated here differ slightly from those investigated by Seniczak and Plichta (1978) by greater numbers of *D. notatus* in the latter tundra. The oribatid mite communities of moss-grass tundra have similarities to those inhabiting the glacial foreland zones at Hardangerjøkulen (Norway) (Seniczak et al., 2006). In

the youngest moraine, *T. velatus* and *L. sellnicki* dominated, and their densities decreased along with the age of moraines (Hågvar et al., 2009).

An interesting habitat for further examination is the bare soil in Petuniabukta, which was poor in organic matter, but was inhabited by two oribatids, *L. sellnicki* and *D. notatus*, and a gamasid, *Z. solenites*. For all three species the juveniles were present, which suggests that these species develop there, although immigration from neighboring vegetated patches cannot be excluded.

Juveniles dominated adult densities in most of the oribatid species studied, and the mean proportion of juveniles in the larger species of oribatid mites was higher than in small species, which can be explained by shorter time of development of small mites. *Tectocephus velatus* is a small (the adult is approximately 0.3 mm) and ubiquitous species with a rather short time of development. In temperate climates, it has three to five generations per year (Niedbała, 1980), but in the High Arctic its development is probably much slower. The larger Arctic oribatid species *Ameronothrus lineatus* (Thorell, 1871) requires 5 years or more to reach maturity (Søvik et al., 2003). The juveniles of some species, such as *O. translamellata*, have a thin cuticle and soft body and do not survive the extraction process (Seniczak, 1978), which explains the lower juvenile-to-adult ratios observed for this species.

A high juvenile-to-adult ratio for oribatid mites increases nutrient cycling because these stages transform organic matter more actively than the adults (Berthet, 1963), probably due to more abundant and active gut microflora that is able to decompose even decay-resistant substances, such as cellulose, lignin, and chitin (Stefaniak and Seniczak, 1976, 1981). In temperate climates, the juveniles of soil oribatid mites usually form one-third of the total population of these mites (Niedbała, 1980), but in oribatid mite communities that are species-poor, the juveniles are often more abundant than the adults (Seniczak and Seniczak, 2006, 2010b, 2012b; Seniczak et al., 2009, 2011, 2012), such as observed in this study. With the lack of lumbricid earthworms and generally low diversity of Enchytraeidae in Svalbard, the role of the microarthropod fauna in nutrient cycling may be enhanced (Coulson et al., 2014).

In the regions of Petuniabukta and Vestpynten, the seven gamasid species were relatively common and are all typical for tundra vegetation (Gwiazdowicz and Gulvik, 2008; Ávila-Jiménez et al., 2011; Gwiazdowicz and Coulson, 2011). Their density was low, so it is difficult to identify microhabitat preferences. Most gamasid mites are considered to be predators of small invertebrates, including the oribatid mites, and although the immediate connections between particular species of Gamasida and Oribatida are poorly known, the occurrence of the greatest gamasid diversity in the more diverse communities of Oribatida studied here possibly reflects the trophic relation between these groups. Thus, the presence of gamasid mites in tundra undoubtedly increases the activity of soil biology. *Eniochthonius minutissimus* (Berlese, 1903) and *Metabelba* sp. are recorded for the first time from this archipelago. Both taxa are considered cosmopolitan (Subías, 2004; Weigmann, 2006).

## Conclusions

We observed that (1) the oribatid mites were distinctly more abundant and richer in species than the gamasid mites, and their density and diversity varied between vegetation and location; (2) diversity of Oribatida and Gamasida and the Shannon  $H'$  index of mite communities were low; (3) *Liochthonius sellnicki* or *T. velatus*



dominated the Oribatida, and *O. translamellata* and *D. notatus* were relatively abundant, while the Gamasida were dominated by *A. multidentatus*, with *Z. forsslundi* and *Z. solenites* relatively abundant; and (4) juvenile densities of the Oribatida were usually greater than adults.

## Acknowledgments

We thank the anonymous reviewers for the thorough review of this manuscript and all suggestions that were very professional and considerably improved the value of this paper. We also thank the Associate Editor, Prof. Scott Armbruster, for all editorial suggestions.

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MS accepted April 2014