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Oribatid mites (Acari: Oribatida) from roofs of houses in Sogn og Fjordane (Norway)

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Abstract: Oribatid mite communities in moss covering the roofs of buildings in towns of Bolstad, Luster, and Sørheim (in Sogn og Fjordane, Norway) were investigated. These mites were rather numerous and rich in species, which was caused mainly by the natural roofing material (rock slates) and the temperate and rather stable maritime climate. In these communities the most abundant were *Tectocepheus velatus*, *Dissorhina ornata*, *Oppiella uliginosa*, *Quadroppia quadricarinata*, and *Oribatula exilis*, which are typical soil species. Adults usually dominated in the mite communities, except for Bolstad, where the juveniles were slightly more abundant than the adults. *Phauloppia lucorum* and *Trhypochthonius tectorum* were the only species of the group of typical inhabitants of roofs of buildings, but were not numerous in Sogn og Fjordane. In continental climate these species are often abundant on roofs of buildings.

Keywords: urban habitats, roofs of buildings, rock slates, moss, Oribatida, juveniles

INTRODUCTION

For hundreds of years there is a tradition in Norway to cover buildings with rock slates, which are cheap, long-lasting, heavy, and therefore resistant to strong winds. With time, these slates are usually overgrown by a thick layer of moss, forming „green roofs", which effectively protect the houses against freezing. They also enlarge the green area of landscape and its species diversity, and create interesting elements for tourists. In contrast, the modern materials are more expansive, of short duration, rather light, can be easily damaged by strong wind, and are alien to the landscape.

One of the most interesting places to visit in Norway is the county Sogn og Fjordane, which occupies an area of 18 623 km^2 along the longest Norwegian fjord Sognefjord (204 km long). This is a post-glacial area, with rather high mountains sloping sharply nearly to the fjord, and with many waterfalls. The climate is maritime, with annual precipitation of about 2000 mm and prevailing west winds. Summers are relatively cold and wet there, with average temperature about 17°C, whereas winters are mild and also wet.

These climatic conditions are good for moss, which covers the slates of roofs of buildings, and also for soil animals that inhabit moss, including the oribatid mites. The rock slates are covered by thick layer of moss, which resembles the upper soil horizon, with abundant mites that decompose organic matter and release mineral elements necessary for moss (Krzysztofiak et al. 2010). Mosses covering the slates are pioneer plants, able to grow on nutrient-poor rocks and soil.

The aim of this study was to investigate the oribatid mite fauna in the specific, nutrient-poor rock habitat, i.e. moss on rock slates covering roofs of buildings in 3 towns of Sogn og Fjordane. We investigated the density and species composition of these mites, and also the age structure of species, which are rarely included in ecological papers.

MATERIAL AND METHODS

The building roofs with rock slates and moss were chosen for this study in 3 towns of Sogn og Fjordane in Norway (Fig. 1): Bolstad (61°29.43′N, 7°35.45′E), Luster (61°26.33′N, 7°27.21′E), and Sørheim (61°25.21′N, 7°29.30′E). All the roofs were situated at 30−65 m a.s.l., had a south exposure. Moss covered 100% of roof areas, with dominant *Polytrichum* sp., while *Hypnum* sp. was less abundant.

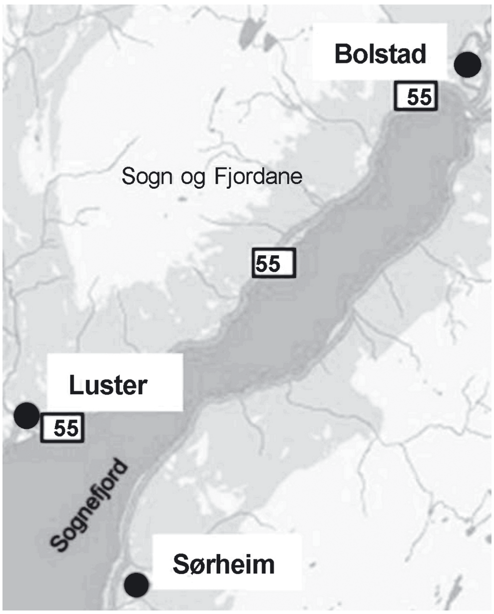

Fig 1. Location of the investigated plots in Sogn og Fjordane (http://maps.google.pl, modified)

Samples of moss (of 500 cm^3 each) were taken on 25−26 August 2005, in 20 replicates. Mites were extracted from them using high-gradient Tullgren funnels, and conserved in 70% alcohol. Oribatid mites were determined to species or genus, including the juveniles. In total, 17 385 oribatid mites were investigated.

We characterized the oribatid species with the abundance, dominance, and constancy indices, while the mite communities were compared with the Shannon *H'* index (Odum 1971). Species structure of oribatid communities between investigated habitats was compared using Bray-Curtis similarity (Bray & Curtis 1957). The similarity matrices were subjected to cluster analysis, employing the unweighted pair-group method with arithmetic averaging (UPGMA).

Basic descriptive statistics for species were also counted. Compliance with normal distribution was tested with the Kolmogorov-Smirnov test, while the homogeneity of variance, with the Levene test. The assumptions of variance analysis have not been met, so nonparametric tests were used: Kruskal-Wallis one-way ANOVA and the *U* Mann-Whitney test, and significance of differences between averages was assessed by the Kruskal-Wallis test (Stanisz 2006a, b). The level of significance for all statistical tests was accepted at $\alpha = 0.05$. The obtained data were statistically analysed using MS Excel 2007, Statistica 6.0, and MVSP 3.2 software (Kovach Computing Services 2010). Names of oribatid species follow Weigmann (2006).

RESULTS

The density of oribatid mites in moss on the roofs of buildings was the highest in Bolstad and the lowest in Luster (Table 1). The richest in species were oribatid mite communities in Sørheim, while the poorest in species were those in Luster. Consequently, the highest Shannon *H'* index of these mites was in Sørheim, and the lowest in Bolstad. Generally, the oribatid mites were rich in species (29 species in total), but only 12 species were present in all towns.

Table 1. Characteristics of oribatid mite communities in moss from roofs of selected houses in Sogn og Fjordane: mean density (individuals per sample, i.e. 500 cm^3, $n = 20$), number of species, and Shannon index of diversity (*H'*)

Characters	Sørheim	Bolstad	Luster
Mean density of Oribatida	297.7	437.5	134.0
Mean density of juveniles	19.2	259.3	4.0
Number of species	25	23	15
Shannon index *H'*	1.94	0.69	1.32

Table 2. Characteristics of oribatid species in mosses from roofs of houses of selected towns in Sogn og Fjordane: abundance (A = individuals per mean sample, i.e. 500 cm^3, $n = 20$) and dominance (D = % of the total number of oribatid mites in the mean sample). Species with the maximum density <1.0 are listed below the table

Species	Sørheim			Bolstad			Luster				Kruskal-Wallis test	
	A	*D*	*C*	*A*	*D*	*C*	*A*	*D*	*C*	Mean *A*	*H*	*p*
Tectocepheus velatus (Michael, 1880)	0.9	0.3	10	376.8[a]	86.1	100	2.8[bc]	2.1	55	126.8	44.477	0.0000
Dissorhina ornata (Oudemans, 1900)	118.7	39.9	75	12.4[a]	2.8	35	84.3[bc]	62.9	95	71.8	18.100	0.0001
Oppiella uliginosa (Willmann, 1919)	56.4	18.9	45	0.05[a]	<0.1	5	11.0[c]	8.2	30	22.5	8.422	0.0148
Quadroppia quadricarinata (Michael, 1885)	25.5	8.6	55	2.1[a]	0.5	10	22.4[c]	16.7	40	16.7	9.077	0.0107
Oribatula exilis (Nicolet, 1855)	39.6	13.3	45	1.6	0.4	45	3.1	2.3	50	14.8	1.095	0.5782
Phauloppia lucorum (C. L. Koch, 1841)	0	0	0	18.5[a]	4.2	75	0[c]	0	0	6.2	38.282	0.0000
Sphaerozetes piriformis (Nicolet, 1855)	13.3	4.5	50	0.9	0.2	35	2.2	1.6	70	5.5	4.818	0.0899
Ceratoppia bipilis (Hermann, 1804)	9.0	3.0	40	0.3	0.1	20	1.4	1.0	30	3.6	3.338	0.1883
Camisia horrida (Hermann, 1804)	1.6	0.5	50	8.5[a]	1.9	85	0[bc]	0	0	3.4	29.593	0.0000
Liacarus coracinus (C. L. Koch, 1841)	7.7	2.6	35	0.3	0.1	20	1.4	1.0	50	3.1	4.891	0.0867
Trhypochthonius tectorum (Berlese, 1896)	4.4	1.5	35	5.0	1.1	45	0[bc]	0	0	3.1	10.865	0.0044
Scheloribates initialis Berlese, 1908	0	0	0	6.7[a]	1.53	35	0.7[c]	0.52	25	2.5	15.508	0.0004
Damaeus onustus C. L. Koch, 1844	4.3	1.4	60	0.1[a]	<0.1	10	2.3[c]	1.7	60	2.2	14.547	0.0007
Neobrachychthonius magnus Moritz, 1976	5.0	1.7	20	0[a]	0	0	0[b]	0	0	1.7	8.416	0.0149
Chamobates pusillus (Berlese, 1895)	3.9	1.3	35	0[a]	0	0	0[b]	0	0	1.3	15.508	0.0004
Eremaeus silvestris (Forsslund, 1956)	0.1	<0.1	5	0.4	0.1	10	1.8	1.3	40	0.8	2.139	0.3430
Carabodes labyrinthicus (Michael, 1879)	1.2	0.4	25	0.45	0.1	5	0.4	0.3	15	0.7	2.941	0.2298
Kunstidamaeus tecticola (Michael, 1888)	1.8	0.6	40	0[a]	0	0	0.3[c]	0.2	20	0.7	10.556	0.0051
Scheloribates latipes (C. L. Koch, 1844)	1.1	0.4	15	0.9	0.2	20	0.1	<0.1	5	0.7	4.084	0.1297
Suctobelba trigona (Michael, 1888)	1.5	0.5	30	0[a]	0	0	0[b]	0	0	0.5	13.066	0.0015

Sørheim: *Achipteria coleoptrata* (Linné, 1758), *Autogneta longilamellata* (Michael, 1885), *Ceratozetes gracillis* (Michael, 1884), *Ceratoppia quadridentata* (Haller, 1882), *Diapterobates humeralis* (Hermann, 1804), *Platynothrus peltifer* (C. L. Koch, 1839), *Oribatella calcarata* (C. L. Koch, 1835).

Bolstad: *A. coleoptrata* (Linné, 1758), *C. quadridentata* (Haller, 1882), *D. humeralis* (Hermann, 1804), *P. peltifer* (C. L. Koch, 1839), *Suctobelbella subcornigera* (Forsslund, 1941), *O. calcarata* (C. L. Koch, 1835), species of the family Phtiracaridae.

Luster: species of the family Phtiracaridae.

Significant differences at $p \leq 0.05$: [a] between Sørheim and Bolstad; [b] between Sørheim and Luster; [c] between Bolstad and Luster.

Among the oribatid mites the most abundant were *Tectocepheus velatus* (Michael, 1880), *Dissorhina ornata* (Oudemans, 1900), *Oppiella uliginosa* (Willmann, 1919), and *Quadroppia quadricarinata* (Michael, 1885), but their densities in the towns were significantly differed (Table 2). For example, *Tectocepheus velatus* highly dominated in Bolstad, but was not abundant in Sørheim and Luster. In the latter towns, *Dissorhina ornata*, *Oppiella uliginosa*, and *Quadroppia quadricarinata* dominated, but those species were not abundant in Bolstad. Thus, similarity of oribatid mites was the highest between Sørheim and Luster (Fig. 2).

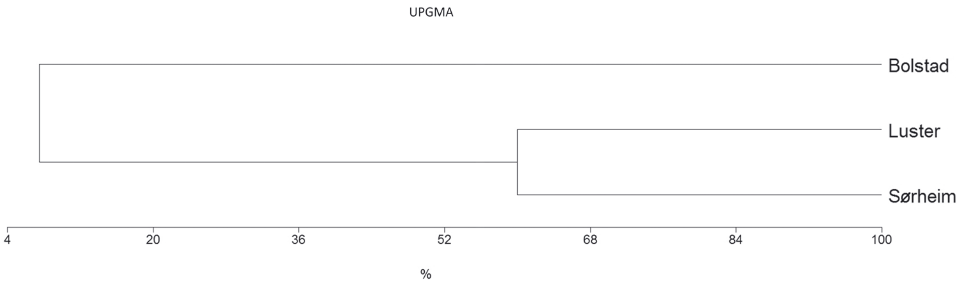

Fig 2. Cluster analysis of Oribatida groups of the investigated habitats (UPGMA method by using the percentage similarity)

Table 3. Age structure of selected species of oribatid mites, which are usually rich in juveniles (mean density of individuals in 500 cm^3), in moss from roofs of houses in 3 towns of Sogn og Fjordane (Norway): juv = juveniles; ad = adult; tot = total

Species	Town	juv	ad	tot
Camisia horrida	Bolstad	6.5	2.0	8.5
	Sørheim	1.4	0.2	1.6
Ceratoppia bipilis	Sørheim	6.3	2.7	9.0
	Luster	0.8	0.6	1.4
Damaeus onustus	Sørheim	3.0	1.3	4.3
	Luster	1.3	1.0	2.3
Kunstidamaeus tecticola	Sørheim	0.2	1.6	1.8
Phauloppia lucorum	Bolstad	15.1	3.4	18.5
Oribatula exilis	Sørheim	9.8	29.8	39.6
	Bolstad	0.4	1.2	1.6
	Luster	0.7	2.4	3.1
Sphaerozetes piriformis	Sørheim	5.1	8.2	13.3
	Luster	1.3	0.9	2.2
Tectocepheus velatus	Bolstad	232.8	144.0	376.8
	Luster	1.3	1.5	2.8
	Sørheim	0.5	0.4	0.9
Trhypochthonius tectorum	Sørheim	4.3	0.1	4.4
	Bolstad	4.2	0.8	5.0

Age structure of oribatid mites depended on species. *Tectocepheus velatus* in Bolstad was rich in juveniles, which constituted 61.8% of its population, while in other towns the density of this species was smaller, with a lower participation of juveniles (Table 3). The juveniles also dominated in *Camisia horrida* (Hermann, 1804), *Phauloppia lucorum* (C. L. Koch, 1841), and *Trhypochthonius tectorum* (Berlese, 1896). In *Ceratoppia quadridentata* (Haller, 1882), the juveniles dominated only in Bolstad, while in *C. bipilis* (Hermann, 1804) and *Damaeus onustus* C. L. Koch, 1844, they dominated in Sørheim and Luster. In other species, the adults were more abundant than the juveniles.

DISCUSSION

Moss microhabitats on rock slates on roofs of buildings in the 3 selected towns at Sogn og Fjordane create favourable habitats for oribatid mites, so the mite communities were abundant and rich in species, compared to typical roofs covered with tar paper and asbestos cement. The density of oribatid mites was the lowest in Luster, comparable with that on roofs covered with tar paper and asbestos cement in suburbs of Bydgoszcz (Poland). However, the number of species of oribatid mites in Luster was about 2-fold higher than in Bydgoszcz (Graczyk et al. 2011).

In oribatid mite communities in Sogn og Fjordane, the most abundant were *Tectocepheus velatus*, *Dissorhina ornata*, *Oppiella uliginosa*, and *Quadroppia quadricarinata*, which belong to typical soil species and require rather high air humidity (Rajski 1968). This is partly confirmed by an observation of Bonnet et al. (1975), who found *Tectocepheus velatus* and *Oribatula exilis* (Nicolet, 1855) abundant in moss and lichens covering the rocks, but the former species preferred the bottom of these rocks, while the latter species the top of rocks. Gjelstrup (1979) found *T. velatus* to be the most abundant in lower parts of beech trunks, near the root collar with *Mnium hornum*, while *Oribatula exilis* occurred in *Hypnum* sp. covering the higher part of the trunks. On birch trunks, the former mite species occurred in the *Dicranum* zone, covering the lower part of the trunks, while *Carabodes labyrinthicus* (Michael, 1879) dominated in the lichen zone above the *Dicranum* zone. In saxicolous lichens covering the northern cliff of Bornholm, sloping to the Baltic Sea, *Phauloppia coineaui* Travé, 1961 was most common, while *Ph. lucorum* (C. L. Koch. 1841) and *Carabodes labyrinthicus* were less abundant (Gjelstrup & Søchting 1979). Juveniles of *Phauloppia* were abundant there.

By contrast, in moss covering the typical roofs in suburbs of Bydgoszcz (tar paper and asbestos cement) the most abundant were xerophiles, like *Trichoribates trimaculatus*, *Trhypochthonius tectorum*, *Scutovertex* Michael, 1879, and *Phauloppia lucorum*. Those species are considered typical of moss patches that cover solid substrates, including rock and roofs of buildings (Travé 1963; Smrž 1992a; Graczyk et al. 2011). *Trichoribates trimaculatus* and *Phauloppia lucorum* were the most abundant in lichens covering the tree trunks (André 1984, 1985), where the former species preferred foliose lichens.

The dominance structure of xerophilous species probably depends on geographic region. In moss covering typical roofs of buildings in central Bohemia (Czech

Republic), investigated by Smrž (1992a), the most abundant was *Scutovertex minutus* (C. L. Koch, 1835) and next most abundant were *Trichoribates trimaculatus* and *Phauloppia lucorum*. Out of these species, in Sogn og Fjordane only *Phauloppia lucorum* and *Trhypochthonius tectorum* occurred, but rather in small numbers, which was probably caused by higher air moisture. The former species was also observed on roofs of buildings by Willmann (1931). Generally, the oribatid mites inhabiting roofs of buildings are specific to this habitat type, and many species can be transferred from one roof to another by birds, which carry them in feathers (Krivolutsky & Lebedeva 2002).

In oribatid mite communities in Sogn og Fjordane, the adults usually dominated, except for Bolstad, where juveniles were slightly more abundant than adults, and this age structure is typical of soil mites. In contrast, the oribatid mites inhabiting the typical roofs were richer in juveniles, which often dominated in oribatid mite communities (Smrž 1992a; Graczyk et al. 2011). The numerous juvenile mites play an important role in decomposition of organic matter and releasing the nutrients for moss, because they are more active than the adults (Berthet 1963), and have a more active gut microflora, which digests even decay-proof substances, such as cellulose, lignin, and chitin (Stefaniak & Seniczak 1976).

According to Smrž (1992b), some species of oribatid mites inhabiting the roofs of buildings are well adapted to arid climate by the strongly sclerotized integument of adults and the plicate and rather thick cuticle of juveniles, like in *Scutovertex*. In juveniles of *Trichoribates trimaculatus* and *Phauloppia lucorum*, secretion of opisthonotal glands is important. It covers the body and lowers the water loss by mites. *Scutovertex minutus* tolerates both arid climate and flooding for several weeks (Smrž 1994), and these climatic conditions may occur on roofs of buildings.

Smrž (1992a) investigated in detail the annual dynamics of density of *S. minutus* and *Trichoribates trimaculatus*. The former species was the most abundant in July, both as juveniles and adults, but in the latter species the adults dominated in July, whereas the juveniles in October. Presence of abundant juvenile mites of these species on roofs of buildings indicates that they live and develop there. These species differ also in rate of locomotion, resistance to drought, and food selection (Smrž 2006), which is important on roofs of buildings. *Trichoribates trimaculatus* is running quickly, both as juvenile and adult, while *Scutovertex minutus* is a slow-moving mite. The former species can swim due to hydrophobic body, while the latter species is hydrophilic and sinks to the bottom. Both species are panphytophagous (Luxton 1972), but *Trichoribates trimaculatus* prefers algae and omits the fungi, while *Scutovertex minutus* has a broader diet, including fungi (Smrž 2006).

The presented results illustrate some characters of populations of oribatid mites, which enrich our knowledge on ecology of some species of oribatid mites. The green roofs from Norway are also promoted by new Polish and European building industry, in order to enlarge green areas and improve the landscape value of new buildings. Therefore, when these green roofs in Poland will develop their own flora and fauna, the results on oribatid mites can be compared with our results from Norway.

CONCLUSIONS

1. Oribatid mites on roofs of buildings in Sogn og Fjordane were abundant and rich in species, which was caused mainly by the natural substrate (rock slates) and the temperate, maritime climate.
2. In the oribatid mite communities, the most abundant were *Tectocepheus velatus*, *Dissorhina ornata*, *Oppiella uliginosa*, and *Quadroppia quadricarinata*, which are typical soil species.
3. Adult mites usually dominated in the oribatid communities, except for Bolstad where the juveniles were slightly more abundant than the adults.
4. *Phauloppia lucorum* and *Trhypochthonius tectorum* were the only species representing the group of typical inhabitants of roofs of buildings in continental climate, but were not numerous in Sogn og Fjordane.

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