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Regular research paper

Piotr SKUBAŁA<sup>1</sup>, Maria GULVIK<sup>2</sup>

<sup>1</sup> University of Silesia, Department of Ecology, Bankowa 9, 40-007 Katowice, Poland  
e-mail: pskubala@us.edu.pl (corresponding author)

<sup>2</sup> Sogn og Fjordane University College, Department of Landscape Ecology, P.O. Box 133, 6851 Sogndal  
Norway, e-mail: maria.gulvik@hisf.no

## PIONEER ORIBATID MITE COMMUNITIES (ACARI, ORIBATIDA) IN NEWLY EXPOSED NATURAL (GLACIER FORELAND) AND ANTHROPOGENIC (POST-INDUSTRIAL DUMP) HABITATS

**ABSTRACT:** A new habitat for many inhabitants is created as a result of glacier retreating or spoil-heap construction and these sites provide a unique experimental field for studying primary succession. The general aim of the study was to characterize oribatid fauna established in the first stage of successional process – colonization phase – on new land surfaces, e.g. deglaciated areas and post-industrial dumps. Five microhabitats in the front of two outlets (Nigardsbreen and Austerdalbreen) of the Jostedal Glacier (SW Norway) and four reclaimed and non-reclaimed post-industrial dumps (Southern Poland) were chosen to study an earliest successional stage.

Moderately diverse oribatid fauna was developed on glacier forelands or post-industrial dumps within a few years. Pioneer oribatid communities were not initially similar, especially in species composition. The pool of oribatid species, which were capable of performing the role of colonists, was broad. Fifteen species were found as dominants on nine studied plots. *Opipiella nova* (Oudemans, 1902) and *Lauropippia neerlandica* (Oudemans, 1900) were associated with the glacier foreland at Nigardsbreen, whereas *Oromurcia bicuspidata* Thor 1930 and *Trichoribates novus* (Sellnick, 1928) were typical of the foreland at Austerdalbreen. Colonizer species appearing within the first years of colonization on the non-reclaimed and reclaimed

dumps were also different. Small species of weak sclerotization, representatives of the family Brachychthoniidae (e. g. *Sellnickochthonius immaculatus* Forsslund, 1942 and *Liochthonius piluliferus* (Forsslund, 1942) dominated on the non-reclaimed dumps, whereas *Ctenobelba obsoleta* (C.L. Koch, 1841), *Scheloribates laevigatus* (C.L. Koch, 1836) and *Scutovertex sculptus* Michael, 1879, bigger species of strong sclerotization, were the most numerous on the reclaimed dumps. Only *Tectocephus velatus* (Michael, 1880) occurred as a dominant at most sites. Parthenogenetic species as well as bisexual successfully invaded glacier foreland and post-industrial dumps. The phenomenon of random colonization in the pioneer stages is well proved on glacier forelands and dumps. However, the process is possibly non-random and depends on the characteristics of an individual species. Although oribatids are known as slow colonizers of new habitats, they were the most numerous group of mites at some sites on glacier forelands and on reclaimed dumps. It is well evidenced that the reclamation measures carried out on post-industrial dumps introduces an element of randomness in the succession of oribatid fauna.

**KEY WORDS:** glacier, dump, oribatids, colonization, succession, pioneer species

## 1. INTRODUCTION

Initial theories of primary succession were developed by plant ecologists (e.g. Clements 1920, Gleason 1926) and the initial stages of primary succession were viewed as a process involving the colonization and establishment of vegetation on newly exposed substrates (Hodkinson *et al.* 2002). Later, it has become clear that animals can actively influence succession through transport of propagules, herbivory, or decomposition (Kaufmann 2001). More recently, it is proposed as a general rule the presence of simple animal communities at the very earliest stages of succession (Hodkinson *et al.* 2002). The presence of animals in this heterotrophic phase appears to be instrumental in facilitating the establishment of green plants and consolidating the assembly process.

Primary succession may be viewed as a recovery process involving specific sensitivities, or robustness and resilience, or possibly combinations of both. Thus, succession is a model for recovery from either natural or human disturbances (Kaufmann 2001). A new habitat for various inhabitants is created as a result of glacier retreating, which is an example of the natural disturbances. Post-industrial dumps are an example of human induced disturbances. These successional areas are to some extent similar as they are formed from different sort of rock material. Furthermore, they are surrounded by inhabited areas providing a species pool for rapid colonization. On the other hand, there are many differences between glacier and waste tips. The most important is the fact that pioneer organisms often actively select and occupy only favourable sheltered microhabitats (e.g. surface depressions, cracks in rocks) on glacier forelands, whereas colonizers are distributed much more uniformly on dumps.

Primary succession in deglaciated areas has been extensively investigated in terms of soil formation and vegetation development (i.e. a review by Matthews 1992). Few faunal studies exist on glacier forelands (i.e. Kaufmann 2001, Kaufmann *et al.* 2002, Coulson *et al.* 2003) and they were restricted to certain taxonomic groups like carabid beetles (Greben 1994, 1995), spiders (Paulus and Paulus 1997) or dragon-flies

(Lockwood *et al.* 1991). Recently, the first study was published in which oribatids along proglacial chronosequences were analysed in details (Hodkinson *et al.* 2004). Mite fauna on post-industrial dumps is much better studied (i.e. Dunger 1989, Skubała 2004).

The general aim of the study was to characterize oribatid fauna established in the first stage of successional process – colonization phase – on new land surfaces, e.g. deglaciated areas and post-industrial dumps. The focal questions of the research are as follows:

- Are the oribatid mite communities established in the first stage of successional process on new land surfaces initially similar?
- Which oribatid species play a role as colonizers and to what extent is the pool of pioneer species limited?
- Is thelytokous parthenogenesis a preferable characteristic of oribatids, which colonize new sites?
- What is the influence of reclamation measures, carried out on dumps, on the development of oribatid communities?

## 2. STUDY AREA

Jostedalsbreen – the largest glacier of Europe – was chosen to study the formation of pioneer oribatid mite communities on a glacier foreland. The Jostedal Glacier covers an area of *ca.* 480 km<sup>2</sup> at an altitude of 300 to 2000 m a.s.l. and is situated in Sogn og Fjordane region in southwest Norway. Two outlets of the glacier were chosen. They were namely Nigardsbreen in Jostedal (61°40'32"N, 07°12'46"E) and Austerdalbreen in Veitastrom (61°34'22"N, 07°00'30"E). History of the Nigardsbreen outlet glacier is well known (Andersen and Sollid 1971). It reached its maximal position in 1784. The area between the front of the glacier and the lake is free of ice for about 30 years. Sand and gravel accumulated in hollows and cracks in rocks and initial vegetation (e.g. *Racomitrium* sp., *Salix* spp., *Betula pubescens* EHRH., *Vaccinium vitis-idaea* L., *Vaccinium myrtillus* L.) occurred at these sites. Nevertheless, initial plant assemblages are very unstable, because damaging influence of the glacier is still recognised at the forefront. Three types of microhabitats were chosen at Nigards outlet – with mosses (N1), *Salix* spp. (N2) and

*Betula pubescens* and *Vaccinium* spp. (N3) as the dominant species (Table 1). The foreland and moraines of the Austerdalbreen were not dated. Samples were taken on back moraines at sites with pioneer plant assemblages. Microhabitats with mosses (A1) and *Salix* spp. (A2), as dominant species, were selected at this site (Table 1).

Four different dumps were selected in Upper Silesia (southern Poland) to study the earliest successional stage (Table 2). Poorly-developed vegetation and lack of a layer of litter characterized all sites on dumps. The time since dumping was ceased varied from 3 to 10 years. The mine dump M (in Murcki, 50°14'44"N, 19°02'52"E) and the zinc dump W (in Wełnowiec, 50°17'30"N, 19°01'15"E) were not reclaimed. Initial plant assemblages similar in their stage of vegetation development covered the sites. High level of heavy metals was recorded on the zinc dump. For details concerning site description of these dumps see Skubała (2004) and Skubała and Ciosk (1999). Some reclamation measures were done on two other investigated dumps. The coal-mine dump CZ (in Czeladź, 50°19'11"N, 19°03'52"E) belonged to the coal-mine "Saturn". It is a "surface" dump mainly comprised of barren rock, coal shales and mudstones. Three years before sampling some herbaceous plants (e.g. *Medicago sativa* L., *Trifolium repens* L., *Trifolium pratense* L.) were planted on the dump. The dump CH (in Chorzów, 50°17'37"N, 18°57'00" E) belongs to the chemical plant "Hajduki". It is an above-ground semispherically-table dump. Slag, ash and chemical wastes of organic origin have been deposited at the site. Reclamation measures have been carried out 6 years before sampling. Five plant species were identified at the site with *Trifolium pratense* L. being the most numerous. Single seedlings of larch (*Larix polonica* RACIB.) and pine (*Pinus sylvestris* L.) have been observed at the site (Table 2).

### 3. MATERIAL AND METHODS

Samples were collected on rocky plain in the front of the glacier and on back moraines in hollows and cracks, where sand and gravel accumulated and pioneer vegetation developed. These specific pockets of concentra-

tion of animals were selected at random. The fauna was sampled in July 2002 and 2003. Samples were taken to a maximum depth of 5 cm (depends on the site) using a cylindrical steel corer of area 21.1 cm<sup>2</sup>. As regards dumps, soil samples were taken from a representative quadrat (10 × 10 metres) at each site. The fauna had been sampled seasonally on CZ (1996/97), CH (1995/96), M (1998–2000) and W (1991/92) dumps. Soil samples of 18 cm<sup>2</sup> surface and 7.5 cm depth had been collected using a steel tube corer. Mites were extracted in modified Tullgren funnels, the procedure lasting 7 days. Immatures of mites were not assigned to species. In total 9485 representatives of microarthropods (Acari and Collembola) were collected from 458 samples at glacier forelands and on dumps. A significant part of them were oribatid mites (3396 specimens) belonging to 60 species (Appendix I).

The material was analysed using the Shannon index of diversity (Pielou 1977). The differences in the abundance of oribatids between sites were tested by one-way analysis of variance (ANOVA). Log transformation was employed when the data did not meet the assumptions of normality. The post-hoc Tukey HSD test was used to compare the abundance of mites between sites. Correspondence analysis (CA) was chosen as the ordination method. Rare species (present in fewer than 3 samples) were excluded from analysis, but this had no effect on the results. All statistical calculations for this research were done in STATISTICA 5.0 (StatSoft 1997) and MVSP 3.2 software (Kovach 1998).

### 4. RESULTS

The glacier forelands at Nigardsbreen and Austerdalbreen exhibited no similar oribatid fauna (Table 1). In general oribatid fauna at Austerdalbreen was poorer than at Nigardsbreen. The abundance of oribatids was generally low and varied from 0.5 (A1) to 96.5 indiv. 100 g<sup>-1</sup> of dry detritus (N2). Statistical significant difference between sites in the total abundance of oribatids was revealed ( $F = 7.08$ ;  $df = 4$ ;  $P < 0.000$ ). Abundance of oribatids at Nigardsbreen was significantly higher than at the second forefront (the Tukey

Table 1. Characteristics of pioneer oribatid mite communities (and abundance of other groups of Acari) and general data of the sites on glacier forelands in Sogn og Fjordane (Norway). Abundance is the mean value ( $\pm$  S.E.) of the number of specimens 100 g<sup>-1</sup> of dry matter of detritus.

	Glacier forelands				One-way ANOVA	
	Nigardsbreen [N]		Austerdalbreen [A]		F-ratio	P
	Site 1 [N1]	Site 2 [N2]	Site 3 [N3]	Site 1 [A1]	Site 2 [A2]	
Abundance of adults	10.5 $\pm$ 5.3 <sup>b</sup>	63.5 $\pm$ 7.5 <sup>b</sup>	53.5 $\pm$ 5.9 <sup>b</sup>	0.4 $\pm$ 0.1 <sup>a</sup>	6.5 $\pm$ 1.5 <sup>a</sup>	<b>6.31*</b> 0.000
Abundance of juveniles	3.6 $\pm$ 1.6 <sup>a</sup>	33.0 $\pm$ 4.9 <sup>b</sup>	6.7 $\pm$ 1.3 <sup>a</sup>	0.1 $\pm$ 0.07 <sup>a</sup>	5.8 $\pm$ 1.6 <sup>a</sup>	<b>5.18*</b> 0.001
Total abundance	14.1 $\pm$ 6.9 <sup>b</sup>	96.5 $\pm$ 11.2 <sup>b</sup>	60.2 $\pm$ 6.3 <sup>b</sup>	0.5 $\pm$ 0.2 <sup>a</sup>	12.3 $\pm$ 2.9 <sup>a</sup>	<b>7.08*</b> 0.000
Number of species	7	22	17	3	8	
Species diversity (H')	1.115	1.759	1.517	1.040	1.036	
Proportion of oribatids in total abundance of mites (%)	48	89	88	8	38	
Abundance of Gamasida	4.9	3.9	2.9	3.7	9.0	
Abundance of Actinedida	10.2	8.1	5.1	2.5	10.9	
Abundance of Acaridida	–	0.4	0.3	–	0.2	
Characteristics of sites	grooves and cracks on rocky plain, streams nearby			hollows on bank moraine		
Time since deglaciation	30 years			–		
Typical pioneering plants	<b>Racomitrium sp.</b> and other mosses	<b>Salix spp.</b> <i>Empetrum nigrum</i> <i>Vaccinium uliginosum</i> <i>Deschampsia flexuosa</i>	<b>Betula pubescens</b> <i>Vaccinium vitis-idaea</i> <i>Vaccinium myrtillus</i>	<b>Racomitrium sp.</b> and other mosses	<b>Salix spp.</b> <i>Betula pubescens</i>	

The asterisk denotes a statistically significant value. The results of the Tukey HSD test are given by letters. Means sharing a common letter (a or b) do not differ significantly from other means at the 5% level. Bold type indicates the dominant species.

HSD test,  $P < 0.05$ ). The highest abundance of oribatids was recorded at microhabitats with *Salix* spp. at Nigardsbreen. Twenty-nine species were recorded on glacier forelands in five microhabitats and their number varied from 3 (A1) to 22 (N2). The analysis of the species diversity ( $H'$ ) leads to similar conclusions about the pioneer communities. It was generally low and the highest species diversity was observed with the oribatid mite community in grooves with *Salix* spp. at Nigardsbreen. Species diversity was the lowest at Austerdalbreen. As regards the proportion of oribatids among the total abundance of mites, it was much lower at Austerdalbreen (from 8 to 38%) than at Nigardsbreen. Only at site with mosses at Austerdalbreen other group of mites (Gamasida) was more abundant than oribatids. Actinedid mites were only slightly less abundant than oribatids at the microhabitat with mosses at Nigardsbreen and the microhabitat with *Salix* at Austerdalbreen. Acaridid mites occurred in samples very rarely (Table 1).

Total abundance of oribatids was very similar and generally low (about 1 individual per 100 g of dry matter of substrate) on the dumps (Table 2). However, statistically significant differences in the mean abundance of juveniles were noted (one-way ANOVA, Tukey HSD test). As regards species richness, it was lower on dumps where toxic wastes were piled (W – 11 species and CH – 6 species). Fourteen and twenty-two species were noted on the mine dumps M and CZ. Species diversity was lower on the reclaimed dumps. The proportion of oribatids collected on the reclaimed dumps was twice and more higher than on non-reclaimed ones. Actinedid mites were two times more abundant than oribatids on the non-reclaimed dumps. Gamasid mites were significantly less abundant on most dumps than the above groups of mites. Acaridid mites were found occasionally in samples (Table 2).

Ordination by correspondence analysis (CA) was used to assess community similarities and relations between species and communities on glacier forelands and dumps. The site scores for the first two axes are shown in Fig. 1. In the interpretation of the CA analysis, the closer the data sets are to each other, the more similar is the community structure.

Eigenvalues of axis 1 and 2 were significant and attained high values (0.58 and 0.46, respectively). The ordination axes are considered as significant when their eigenvalue is higher than 0.3 (Dekkers *et al.* 1994). High eigenvalues reflect the great dissimilarity of the oribatid mite communities at the pioneer stage of primary succession.

The sites are grouped into four clusters (Fig. 1). The first axis separates artificially established mite communities on reclaimed dumps (cluster A) from communities, which developed naturally. This is the dominant gradient explaining about 29% of the total variation in species data. The second correspondence axis separates mainly poorly developed oribatid fauna on the foreland of the Austerdal glacier (cluster B) from others (cluster C – non-reclaimed dumps, cluster D – Nigardsbreen). It is noteworthy that microhabitats within an individual cluster, were also well separated from each other (Fig. 1).

Sixty oribatid species were recorded at nine studied habitats in general. Among forty-four species identified on glacier forelands and non-reclaimed dumps nineteen were parthenogenetic, and never produce functional male offspring. Among 12 species classified as dominants on glacier forelands and non-reclaimed dumps, only 6 species were parthenogens. (see Appendix I). Different colonizer species occurred at microhabitats of the studied glacier forelands. *Oppiella nova* (Oudemans, 1902) and *Lauropia neerlandica* (Oudemans, 1900) (dominants) were associated with the glacier foreland at Nigardsbreen, whereas *Oromurcia bicuspidata* Thor 1930 and *Trichoribates novus* (Sellnick, 1928) were typical of the foreland at Austerdalbreen (Fig. 1). Colonizer species appearing within the first years of colonization on the non-reclaimed and reclaimed dumps were also different. *Sellnickochthonius immaculatus* Forsslund, 1942 and *Liochthonius piluliferus* (Forsslund, 1942) on the non-reclaimed dumps and *Ctenobelba obsoleta* (C.L. Koch, 1841), *Scheloribates laevigatus* (C.L. Koch, 1836) and *Scutovertex sculptus* Michael 1879 on the reclaimed dumps were identified as connected with these man-made habitats. Species, which show no preference for any site, are crowded around the intersection point

Table 2. Characteristics of pioneer oribatid mite communities (plus abundance of other groups of Acari) and general data of the sites on post-industrial dumps in Upper Silesia (Poland). Abundance is the mean value ( $\pm$  S.E.) of the number of specimens 100 g<sup>-1</sup> of dry matter of substrate.

	Non-reclaimed dumps [nr]		Reclaimed dumps [r]		One-way ANOVA	
	Non-toxic mine dump [M]	Toxic zinc dump [W]	Non-toxic mine dump [CZ]	Toxic dump of a chemical plant [CH]	F-ratio	P
Abundance of adults	0.4 $\pm$ 0.1 <sup>a</sup>	0.6 $\pm$ 0.1 <sup>a</sup>	0.8 $\pm$ 0.2 <sup>a</sup>	0.9 $\pm$ 0.2 <sup>a</sup>	2.64	0.073
Abundance of juveniles	0.6 $\pm$ 0.2 <sup>b</sup>	0.3 $\pm$ 0.1 <sup>a</sup>	0.3 $\pm$ 0.1 <sup>a</sup>	0.1 $\pm$ 0.05 <sup>a</sup>	<b>4.89*</b>	0.008
Total abundance	1.0 $\pm$ 0.3 <sup>a</sup>	0.9 $\pm$ 0.2 <sup>a</sup>	1.1 $\pm$ 0.3 <sup>a</sup>	1.0 $\pm$ 0.2 <sup>a</sup>	0.39	0.674
Number of species	14	11	22	6		
Species diversity (H')	2.048	1.680	0.710	1.50		
Proportion of oribatids in total abundance of mites (%)	32	25	86	74		
Abundance of Gamasida	0.1	0.2	0.2	0.09		
Abundance of Actinedida	2.2	2.5	0.04	0.3		
Abundance of Acaridida	0.01	0.05	-	0.01		
Materials deposited	clay lumps, carboniferous sandstone, coal-mud, coal crumbs and midlines	slag, ash, wastes from discillatory and ore-roasting furnaces	barren rock, coal shales, mudstones	slag, ash, chemical wastes of organic origin		
Time since deposits stopped being added (in years)	10	8	3	6		
Typical pioneering plants	<i>Tussilago farfara</i> <i>Calamagrostis epigejos</i> <i>Agrostis capillaris</i>	<i>Festuca ovina</i> <i>Silene vulgaris</i> <i>Cardaminopsis arenosa</i>	<i>Medicago sativa</i> <i>Trifolium repens</i> <i>Trifolium pratense</i> <i>Taraxacum officinale</i> <i>Ranunculus repens</i>	<i>Trifolium pratense</i> <i>Salvia pratensis</i> <i>Lamium album</i> <i>Larix polonica</i> <i>Pinus sylvestris</i>		

The asterisk denotes a statistically significant value. The results of the Tukey HSD test are given by letters. Means sharing a common letter (a, b or c) do not differ significantly from other means at the 5% level. Bold type indicates the dominant plant species.

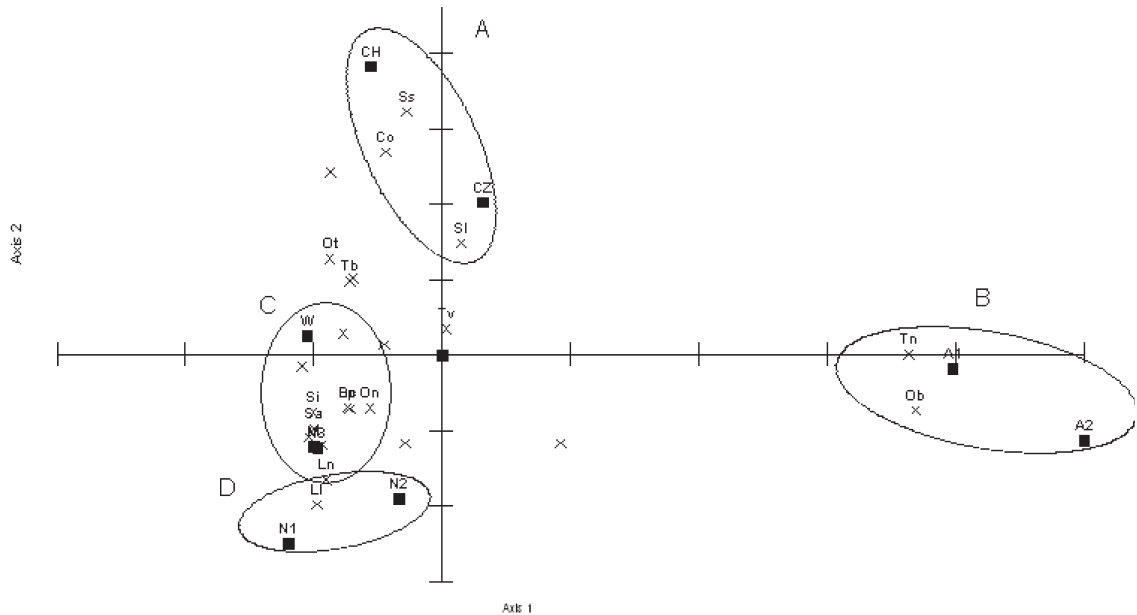


Fig. 1. A plot of the first two axes of correspondence analysis (CA) of the 9 sampling sites on the glacier forelands and the post-industrial dumps.

Codes of the sites: Table 1 and 2.

Codes of the species: Co – *Ctenobelba obsoleta*; Ln – *Lauroppia neerlandica*; Ll – *Liochthonius lapponicus*; Lp – *Liochthonius piluliferus*; Ob – *Oromurcia bicuspidata*; On – *Oppiella nova*; Ot – *Oribatula tibialis*; Sc – *Sellnickochthonius cricoides*; Si – *Sellnickochthonius immaculatus*; Sl – *Scheloribatetes laevigatus*; Ss – *Scutovertex sculptus*; Sa – *Suctobelbella acutidens*; Tv – *Tectocepheus velatus*; Tb – *Trichoribatella baloghi*; Tn – *Trichoribatetes novus*.

of the two axes. Only *Tectocepheus velatus* (Michael, 1880) was located near the intersection point of the two axes. The species reached high proportion in the total number of oribatids at almost all sites. CA analysis indicates slightly distinctive community and species overlap between oribatids of the Nigards glacier and the non-reclaimed dumps. These sites were grouped in the negative part of axis 1 and 2. *O. nova*, *S. immaculatus*, *Liochthonius lapponicus* (Trägårdh, 1910) and *Suctobelbella acutidens* (Forsslund, 1941) formed a group of oribatids connected with non-reclaimed dumps and microhabitats at Nigardsbreen (Fig. 1).

## 5. DISCUSSION

Colonization and establishment of viable populations is a fundamental ecological process which most existing ecosystems have gone through at some time in the past (Kaufmann *et al.* 2002). Barren moraines uncovered by receding glaciers as well as post-industrial dumps piled from different

materials represent a natural experiment and provide the opportunity for a detailed study of the formation of pioneer animal communities. The early animal colonisers of newly exposed substrates are predators or scavenging detritivores/omnivores (Hodkinson *et al.* 2002). Oribatid mites are known to predominate over other groups of mites and mesofauna in most soils (Wallwork 1970), however, due to the low mobility (Weigmann 1982) and their low reproduction rate (Lebrun and Van Straalen 1995), oribatids are not the “leaders” in the colonization phase (Dunger 1989).

The abundance of oribatids was much higher at deglaciated area than on dumps. It is noteworthy that these data should not be compared. Mites (and generally most animals) occupied favourable sheltered microhabitats on a glacier foreland and they are practically absent on barren rock. Samples of detritus were collected only at these microhabitats. On the contrary, we had no such pockets of concentration of mites (and other animals) on dumps and animals are much

more uniformly distributed on this terrain. Samples were taken at random on dumps and oribatids were found in many samples of industrially created substrate. A limited group of authors have been studied pioneer oribatid mite communities on post-industrial dumps. Most of the studies were associated with the reclamation of dumps and oribatid fauna was analysed only quantitatively. The abundance and species richness of the initial oribatid fauna varied considerably. For details see Skubała (2004, pages 69–81). With regard to oribatids recorded at microhabitats on the glacier forelands, it was impossible to compare data because such studies were not previously made. Oribatids are mentioned only in one publication on invertebrate communities along proglacial chronosequences in the high Arctic (Hodkinson *et al.* 2004). Authors, however, calculated an abundance of oribatids as the number of individuals per m<sup>2</sup>, which is doubtful, in our opinion, in this early stage of succession. Only four oribatid species were collected at a similar sampling plot in this study.

Differences in the structure of nine analysed oribatid communities were observed. The presence of different initial fauna of oribatids on dumps than at the forefront of glacier may be explained by the nature of substrate of the habitat and the fact that dumps and the glacier are situated at different geographical latitudes. However, the differences between oribatid fauna at similar microhabitats on non-reclaimed dumps or at the foreland of a glacier were also observed. Only slight similarity of the structure of communities at glacial outlet Nigardsbreen and the non-reclaimed dumps was noted. Skubała (2004) noted initially varied pioneer oribatid communities at dumps composed of the same substrate. The results suggest that the chance may rule the formation of pioneer oribatid communities.

The dissimilarities between oribatid fauna on the reclaimed dumps and other analysed sites are easier to explain. The structure of oribatid mite communities on reclaimed dumps (e.g. high proportion of oribatids in the total number of mites and a different set of species) seems to be still artificial after several years since reclamation measures (delivery of soil, introduction of vegetation) have

been done. Surely, oribatid communities will influence important rebuilding within next years. Some suggestions on this process have been done by Skubała (2004).

The zinc dump W and the dump CH of a chemical plant were specific as toxic wastes were deposited on them. The impoverishment of oribatid populations on contaminated sites was observed by some authors (Stamou and Argyropoulou 1995, Weigmann 1995, Seniczak *et al.* 1996, Zaitsev and Van Straalen 2001). As regards analysed contaminated dumps, the abundance of oribatids was only slightly lower, but species richness was twice lower than on the non-contaminated dumps.

It might be surprising that among sixty species (Appendix I) recorded at nine studied sites, the only species which did not prefer any of the studied sites on glacier forelands and dumps and reached high abundance at most of them was *T. velatus*. The species is one of the most frequent and common species of microarthropods throughout the world. It is an extremely ubiquitous species with very wide ecological tolerance, whose habitat includes preserved natural areas (Luxton 1981, Skubała 1999a) on one hand and highly distributed biotopes (Luxton 1982, Skubała 1995) on the other. Four representatives of the family Brachychthoniidae were found in comparatively high numbers near the glacier and on the dumps. The species were previously classified as “early” successional species by some authors (Luxton 1982, Skubała 2004). Seniczak *et al.* (1994) observed them as tolerant to air pollutants and Niedbała (1976) noted the family as the most successful colonizers of a young pine forest.

With regard to other dominant species in pioneer oribatid communities, only *O. nova* was previously observed as colonizers of newly formed habitats (e.g. Babenko 1980, Luxton 1982, Bielska 1995, Skubała 2004). *Oribatula tibialis* (Nicolet, 1855) was absent or noted in low numbers on dumps (Bielska 1982, Bielska and Paszewska 1995, Skubała 1995, Skubała 1999b) or was classified as “late” successional species (Skubała 2004). Others [*C. obsoleta* (C.L. Koch 1841), *L. neerlandica* (Oudemans, 1900), *S. acutidens* (Forsslund, 1941),



Fig. 2. *Oromurcia bicuspidata* Thor 1930 – a characteristic species of Scandinavian Mountains, the pioneer species on the glacier foreland at Austerdalbreen (Norway).

*Trichoribatella baloghi* Mahunka, 1983, *T. novus* (Sellnick, 1928)] were not described as early successional species so far. The occurrence of *O. bicuspidata* (numerous at Austerdalbreen) is worthy to mention. It is a species of characteristic circumpolar distribution, occurring in a cold climate such as Scandinavian Mountains and northern Iceland (Seniczak and Solhoy 1987) (Fig. 2).

The occurrence of many pioneer species on glacier forelands and dumps supports the species redundancy hypothesis (Wardle *et al.* 1997), which predicts that there is considerably “redundancy” in a species pool and that several species are capable of performing the function in each soil system.

Norton and Palmer (1991) noted that in many studied disclimax or “newly-created” habitats pioneering oribatid species were parthenogenetic. Studying oribatid mite succession on the glacier forelands and on dumps, we found parthenogenetic species in abundance, but bisexual species were also common (see Appendix I). For example,

apart from *L. lapponicus*, *O. nova* and *T. velatus* (parthenogenetic species), sexual oribatid species – *O. bicuspidata*, *T. novus* and *L. neerlandica* dominated on glacier forelands. With regard to non-reclaimed dumps, among six dominant species only *T. novus* is bisexual. Thelytokous parthenogenesis in oribatids is rather regarded as a feature, which make some preference for certain species (Norton and Palmer 1991). However, the authors stressed that parthenogens among oribatids were also commonly present in more complex habitats. Therefore, thelytoky is suggestive of broad rather than narrow adaptation.

Although oribatids are known as slow colonizers of new habitats (Karg 1967, Dunger 1989), they were the most numerous group of mites at most sites on a glacier forefront and the reclaimed dumps (Table 1 and 2). As regards other studied sites, actinedid mites dominated on the non-reclaimed dumps and gamasid mites at site with mosses (A1) on the glacier foreland.

## 6. CONCLUSIONS

- Pioneer oribatid mite communities on glacier forelands or post-industrial dumps are initially varied, especially in species composition. Oribatid fauna may dominate among mites at habitats with initial plant vegetation.

- The pool of oribatid species, which are capable of performing the role of colonists, is broad. Parthenogenesis is not significantly favoured over sexuality in communities at new habitats.

- The phenomenon of random colonization in the pioneer stages is well proved on glacier forelands and dumps. However, the process is possibly non-random and depends on the characteristics of an individual species.

- It is well evidenced that the reclamation measures carried out on post-industrial dumps introduces an element of randomness in the succession of oribatid fauna.

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Appendix I. Check-list of the oribatid species on the forelands of the glacier (Norway) and on the post-industrial dumps (Poland). Codes of sites see Table 1 and 2.

Species	Glacier forelands					Post-industrial dumps			
	N			A		nr		r	
	N1	N2	N3	A1	A2	M	W	CZ	CH
1	2	3	4	5	6	7	8	9	10
<i>Acrogalumna longipluma</i> (Berlese, 1904)									+
<i>Atropacarus</i> ( <i>Atropacarus</i> ) <i>striculus</i> (C.L. Koch, 1836)									+
<i>Brachychthonius berlesei</i> Willmann, 1928*								+	
<i>Camisia biurus</i> (C.L. Koch, 1839)*		+	+						
<i>Camisia solhoeyi</i> Colloff, 1993*	+	+							
<i>Ceratozetes gracilis</i> (Michael, 1884)							+		
<i>Ceratozetes peritus</i> Grandjean, 1951								+	+
<i>Ceratozetella sellnicki</i> (Rajski, 1958)									+
<i>Ctenobelba obsoleta</i> (C.L. Koch, 1841)									+
<i>Dissorhina ornata</i> (Oudemans, 1900)						+			
<i>Edwardezetes edwardsi</i> (Nicolet, 1855)			+			+			
<i>Eniochthonius minutissimus</i> (Berlese, 1903)*				+					
<i>Epidamaeus karelicus</i> B.-Z., 1957				+					
<i>Eremaeus silvestris</i> Forsslund, 1957									+
<i>Eupelops plicatus</i> (C.L. Koch, 1835)			+						
<i>Euphthiracarus monodactylus</i> (Willmann, 1919)*									+
<i>Euzetes globulus</i> (Nicolet, 1855)									+
<i>Hemileius initialis</i> (Berlese, 1908)				+			+		
<i>Heminothrus capillatus</i> (Berlese, 1914)*			+						
<i>Heminothrus humicolus</i> (Forsslund, 1955)*			+	+					
<i>Heminothrus peltifer</i> (C.L. Koch, 1839)*			+						
<i>Hypochthonius luteus</i> Oudemans, 1917									+
<i>Hypodamaeus riparius</i> (Nicolet, 1855)									+
<i>Lauropia neerlandica</i> (Oudemans, 1900)	+	+	+						
<i>Liebstadia similis</i> (Michael, 1888)									+
<i>Limnozetes ciliatus</i> (Schränk, 1803)				+					
<i>Liochthonius lapponicus</i> (Trägårdh, 1910)*	+	+					+		
<i>Liochthonius piluliferus</i> (Forsslund, 1942)*							+		
<i>Liochthonius propinquus</i> Niedbala, 1972*							+		
<i>Liochthonius sellnicki</i> (Thor, 1930)*			+	+		+			
<i>Medioppia subpectinata</i> (Oudemans, 1910)						+			+
<i>Micropia minus</i> (Paoli, 1908)*							+		

Species	Glacier forelands					Post-industrial dumps				
	N			A		nr		r		
	N1	N2	N3	A1	A2	M	W	CZ	CH	
1	2	3	4	5	6	7	8	9	10	
<i>Mucronothrus nasalis</i> (Willmann, 1929)		+								
<i>Mycobates tridactylus</i> Willmann, 1929		+	+							
<i>Nothrus anauniensis</i> Canestrini et Fanzago, 1876*									+	
<i>Oppiella nova</i> (Oudemans, 1902)*	+	+	+		+	+	+	+	+	+
<i>Oribatula tibialis</i> (Nicolet, 1855)			+							+
<i>Oromurcia bicuspidata</i> Thor, 1930		+		+	+					
<i>Protoribates variabilis</i> Rajsiki, 1958									+	
<i>Punctoribates punctum</i> (C.L. Koch, 1839)							+			
<i>Quadroppia quadricarinata virginalis</i> Lions, 1982*		+	+			+				
<i>Ramusella (Insculptoppia) insculptum</i> (Paoli, 1908)						+				
<i>Rhysotritia ardua</i> (C.L. Koch, 1841)*									+	
<i>Scheloribates laevigatus</i> (C.L. Koch, 1836)									+	
<i>Scheloribates latipes</i> (C.L. Koch, 1841)									+	
<i>Sellnickochthonius cricoides</i> (Weis-Fogh, 1948)*						+				
<i>Sellnickochthonius immaculatus</i> Forsslund, 1942*		+	+			+	+			
<i>Scutovertex sculptus</i> Michael, 1879									+	
<i>Suctobelba sorretensis</i> Hammer, 1961		+								
<i>Suctobelbella acutidens</i> (Forsslund, 1941)	+	+	+				+		+	
<i>Suctobelbella alloenasuta</i> Moritz, 1971						+				
<i>Suctobelbella perforata</i> (Strenzke, 1950)							+			
<i>Suctobelbella sarekensis</i> (Forsslund, 1941)							+		+	
<i>Suctobelbella subcornigera</i> (Forsslund, 1941)		+	+				+			
<i>Suctobelbella vera</i> (Moritz, 1964)						+				
<i>Tectocephus minor</i> Berlese, 1903		+	+						+	
<i>Tectocephus velatus</i> (Michael, 1880)*	+	+	+	+	+	+	+	+	+	+
<i>Trichoribatella baloghi</i> Mahunka, 1983							+	+		
<i>Trichoribates monticola</i> (Trägårdh, 1902)	+	+								
<i>Trichoribates novus</i> (Sellnick, 1928)				+	+				+	

\* – parthenogenetic species.