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Comparison of the communities of the oribatids (Acari: Cryptostigmata) of virgin and forest-ameliorated pine bogs

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The oribatid communities of virgin and forest-ameliorated pine bogs were compared when ten years had passed since artificial drainage was commenced and six years had passed since the fertilization of the ameliorated bog. The oribatid communities of the microhabitats of the bogs (hollows and hummocks) were very different. In the virgin bog the oribatid community of the hollows was dominated by *Limnozetes sphagni*, the community of the hummocks by *Oppiella nova* and *Tectocepheus velatus*. The typical peatland species had either decreased following the forest-amelioration (as with *L. sphagni*) or had shifted their main microhabitat from the hummocks to the hollows (as with *Nothrus pratensis*). Their place had been taken by the habitat generalists (e.g. *Oppiella nova*) and by the species preferring a drier environment (e.g. *Chamobates borealis*). It was concluded that the drying of the soil was the main cause of the faunal response observed.

Palaeacarus hystricinus Träg., *Trhypochthonius nigrigans* Willm., *T. badius* (Berl.) and *Eupelops acromios* (Herm.) are here reported for the first time in Finland.

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1. Introduction

The oribatid mites form a quantitatively important component of the soil fauna of peatlands (e.g. Vilkamaa 1981). The oribatid fauna of peat soil has been studied in Finland by Karppinen (1955a, 1955b, 1958a, 1972 and 1977), in central and southern Sweden by Tarras-Wahlberg (1952, 1953 and 1961), in Norway by Solhøy (1979), and in northern Germany by Knülle (1957a).

Very little is known of the oribatids in forest-ameliorated peatlands. During his study dealing with the *Camisiidae* and *Nothridae* of Finland Karppinen (1955a) also took some samples from an old drained bog. Later, Vilkamaa (1981) and Markkula (1982) compared the abundances of the whole group in virgin and forest-ameliorated bogs, but the species were not identified in these studies. The aim of this study is to compare the oribatid communities of a virgin and a forest-ameliorated raised pine bog.

2. Study area

The study was made on the bog Laaviosuo in the vicinity of Lammi biological station, southern Finland. Laaviosuo is an ombrotrophic raised pine bog, part of which was drained for forestry purposes in 1966. In 1970 the drained part was fertilized with PK-fertilizer for peatlands (400 kg/ha) and with urea (100 kg/ha). The amounts of nutrients in the fertilizers were: P 28.8, K 54.8, Ca 94.0 and N 46.3 kg/ha.

The vegetation of the bog consisted of a mosaic of *Sphagnum fuscum* -hummocks and *Sphagnum balticum—S. angustifolium* -hollows. The field layer in the hummocks consisted mainly of dwarf shrubs, especially *Calluna vulgaris* and *Empetrum nigrum*. In the hollows the field layer was dominated by the cottongrass (*Eriophorum vaginatum*). The *Sphagna* had suffered from the drainage and fertilization, but most of the plants of the field layer had benefited, so that the primary production as a whole was higher on the ameliorated part of the bog. The vegetation and primary production of the study sites are described more precisely by Vasander (1982) and by Lindholm & Markkula (1984).

There was also a great difference in the moisture conditions of the hollows and the hummocks. The hollows of the virgin bog were constantly wet because the ground water table was always near the soil surface, sometimes even above it. In the hummocks the ground water table remained at a deeper level. The drainage had lowered the ground water table by about 20 cm. The depth of the ground water also varied seasonally, rising after the snow melt and rainy periods and sinking during periods of drought. The soil moisture conditions are described more precisely by Lindholm & Markkula (1984).

3. Material and methods

Soil samples were taken from a representative quadrat (10×10 m) on both the virgin and the ameliorated part of the bog. The hollows and the hummocks were considered as different microhabitats. There is, of course, some variation, for instance in the height of the hummocks (cf. Vasander 1982), but for practical reasons only these two microhabitats were separated.

The sample cores were taken with a steel borer to a depth of 15 cm and their area was 10 cm^2. Each sample core was cut into four vertical layers for the extraction. The microarthropods were extracted from the soil with a modified dry funnel, the "hot rod"-apparatus of Valpas (1969).

During May—November 1974 and May—September 1976 a total of 11 samplings were made. The number of sample units taken from each microhabitat during each sampling was 4—6. The abundances of oribatids and other microarthropods calculated from these samples have been published earlier by Markkula (1982). In the hummocks of both sites the average number of oribatids was about 140 000 individuals/m^2, in the hollows of the virgin bog about 110 000 ind./m^2 and in the hollows of the ameliorated bog about 90 000 ind./m^2.

The oribatid species were identified from 12 sample units from each microhabitat, taken during May—August 1976. Only adult specimens were identified. The nomenclature follows the identification guide of Chilarov & Krivolutsky (1975).

4. Results and discussion

4.1. The oribatid communities of the microhabitats of the virgin bog

The average abundances of different species are shown in Table 1. In the hollows of the virgin site *Limnozetes sphagni* was clearly dominant, comprising slightly more than half of all individuals. Next to this, the most abundant species were *Trimalaconothrus foveolatus, Hoplophtiracarus pavidus* and *Trhypochthoniellus setosus*. A total of 19 species was found.

The oribatid fauna of constantly wet or even submerged peatlands has been previously studied by Tarras-Wahlberg (1953) in southern Sweden, by Knülle (1957a) in northern Germany, and by Karppinen (1958a) in Finland. The exact species composition varies among these studies rather a lot, but a common feature seems to be a relatively low number of species (from 5 to 15) and a large proportion of species belonging to the genera *Limnozetes* and *Trimalaconothrus*. These characteristics are in agreement with my results.

In the hummocks of the virgin site, the most abundant and constant species were *Oppiella nova* and *Tectocepheus velatus*, which together comprised about half of all individuals. The next most abundant species were *Malaconothrus globiger* and *Hoplophtiracarus pavidus*. A total of 31 species was found.

Tarras-Wahlberg (1961) has studied the oribatid community of a similar habitat in a central Swedish bog: *Sphagnum fuscum* hummocks with dwarf shrubs, cottongrass and lichens. The most abundant taxa in his material were: *Oppia* + *Suctobelba* spp., *Brachychthoniidae* spp. (2 species), *Tectocepheus velatus, Malaconothrus gracilis* v.d. Hammen, *Nanhermannia coronata, Nothrus pratensis* and *Hoplophtiracarus pavidus* The *M. gracilis* mentioned is probably the *M. globiger* of my material (cf. Knülle 1957b). Of the 33 soil-living species in the material of Tarras-Wahlberg (1961) at least 15 were present in the oribatid community of the hummocks of Laaviosuo. The communities were quite similar, though not as similar as the plant communities.

The oribatid communities of the hollows and the hummocks of the virgin bog were markedly different. This is to be expected, as the vegetation and moisture conditions in these microhabitats are also very different. The intermediate zone between the hollows and the hummocks was not studied separately, and so it is not possible to say whether the communities are sharply delimited or whether there exists a continuum of species.

4.2. Comparison of the virgin and the ameliorated site

In the hollows of the ameliorated site, six species had a significantly lower abundance compared to the hollows of the virgin site (Table 1). The abundance of *Limnozetes sphagni* had decreased most sharply, from 28 000 ind./m^2 to almost zero. Other significantly decreased species were *Trhypochthonius nigrigans, Trimalaconothrus foveolatus, Tectocepheus velatus* and *Ceratozetes parvulus*.

Four taxa had a significantly higher abundance in the hollows of the ameliorated site compared to the hollows of the virgin site.

Table 1. The mean numbers per sample unit of the most common oribatid species on different microhabitats. n = the number of sample units where the species was present. + = single find. The statistical significance of the difference between the means (tested with the analysis of variance) is presented at probability levels of 0.001 (***), 0.01 (**), and 0.05 (*). ns = not significant. The significance was tested only when the species was present in more than two sample units at one or both of the microhabitats compared. The species marked with an asterisk are recorded for the first time in Finland.

	Hollows					Hummocks				
	virgin			ameliorated		virgin			ameliorated	
	mean	n		mean	n	mean	n		mean	n
Limnozetes sphagni (Mich.)	28.0	11	**	+		–			–	
Trimalaconothrus foveolatus Willm.	4.7	8	*	0.8	3	–			–	
Hoplophtiracarus pavidus (Berl.)	4.2	9	ns	2.7	9	3.3	11	**	0.3	3
Trhypochthoniellus setosus Willm.	3.2	4	ns	+		–			–	
Nanhermannia coronata Berl.	2.4	5	ns	5.9	10	2.4	8	***	–	
Tectocepheus velatus (Mich.)	2.3	8	*	0.2	2	10.7	12	ns	34.7	12
Ceratozetes parvulus (Selln.)	1.8	6	*	+		–			–	
Trhypochthonius nigrigans Willm. *	1.5	7	**	–		–			–	
Oppiella nova (Ouds)	1.2	6	***	24.6	12	16.3	12	ns	13.2	12
Banksinoma lanceolata (Mich.)	0.4	4	ns	0.3	2	0.9	6	**	–	
Malaconothrus globiger Träg.	0.4	3	ns	1.4	7	5.5	12	*	1.1	6
Steganacarus striculus (C.L.K.)	0.3	3	**	1.1	9	2.6	8	ns	0.8	8
Suctobelbella subcornigera (Forssl.)	0.2	1	ns	2.4	8	1.4	8	**	5.2	11
Nothrus pratensis Selln.	0.2	1	*	0.9	8	1.3	10	***	–	
Oppia subpectinata (Ouds)	0.2	1	ns	0.6	4	1.0	6	**	6.1	11
Brachychthoniidae spp.	–		*	1.1	6	3.2	6	ns	3.3	8
Oppia translamellata (Willm.)	–		ns	1.1	4	0.2	1		0.3	1
Suctobelbella falcata (Forssl.)	–			0.2	1	2.1	8	*	4.8	12
Carabodes subarcticus Träg.	–			+		2.0	6	ns	0.4	4
Suctobelbella longirostris (Forssl.)	–			–		0.7	6	ns	1.8	7
S. acutidens (Forssl.)	–			–		+		*	1.1	5
Chamobates borealis (Träg.)	–			–		–		*	1.6	8

In addition to the species listed above, 21 species were found in lower numbers (mean < 1.0, n < 6 at all microhabitats). The numbers of individuals found are given in parenthesis (A = hollows of the virgin site, B = hollows of the ameliorated site, C = hummocks of the virgin site, D = hummocks of the ameliorated site):
Camisia lapponica (Träg.) (A:1, D:1), *Carabodes labyrinthicus* (Mich.) (C:1, D:1), *C. marginatus* (Mich.) (D:4), *Eupelops acromios* (Herrm.) * (D:2), *E. bilobus* Selln. (D:5), *Hypochthonius rufulus* (C.L.K.) (B:1, C:1, D:3), *Melanozetes mollicomus* (C.L.K.) (B:4, C:1), *Micreremus brevipes* (Mich.) (C:1), *Mucronothrus nasalis* (Willm.) (B:6), *Oppia minus* (Paoli) (B:1), *Palaeacarus hystricinus* Träg. * (C:1, D:1), *Pergalumna nervosa* (Berl.) (A:2, B:5, C:4), *Phtiracarus borealis* (Träg.) (B:1, D:5), *Porobelba spinosa* (Selln.) (D:2), *Rhysotritia ardua* (C.L.K.) (A:1, B:1, C:4, D:7), *Scheloribates laevigatus* (C.L.K.) (B:2, C:5), *S. latipes* (C.L.K.) (C:3), *Suctobelbella palustris* (Forssl.) (A:3, C:3, D:1), *S. sarekensis* (Forssl.) (D:10), *Trhypochthonius badius* (Berl.) * (C:1), *T. cladonicola* Willm. (D:2).
The family Brachychthoniidae included at least six species (in parenthesis the microhabitats where the species was found to be present): *Brachychthonius immaculatus* Forssl. (C,D), *Eobrachychthonius latior* Berl. (C,D), *Liochthonius perpusillus* (Berl.) (B,C,D), *L. simplex* (Forssl.) (B,C,D), *Sellnickochthonius zelawaiensis* (Selln.) (C,D), *Synchthonius crenulatus* (Jacot) (C).
The size of *Liochthonius simplex* specimens in my material was much larger than that given in the original description of the species (Forsslund 1942). The body length varied between 202–230 µm (four measurements), when the length variation measured by Forsslund (1942) was 166–177 µm. Otherwise the specimens fitted well with the original description. The oribatid material of this study is preserved in the collections of the Museum of Kuopio, Myhkyrink. 22, 70100 Kuopio, Finland.

The abundance of *Oppiella nova* had increased the most, and the other increased taxa were *Steganacarus striculus, Brachychthoniidae* spp. and *Nothrus pratensis.*

The most abundant species in the hollows of the ameliorated site was *Oppiella nova,* comprising more than half of all individuals. Next to this, the most abundant species were *Nanhermannia coronata, Hoplophtiracarus pavidus* and *Suctobelbella subcornigera.* A total of 27 species was found.

In the hummocks of the ameliorated site five species had significantly lower abundances compared to the hummocks of the virgin site (Table 1). These were *Hoplophtiracarus pavidus, Nothrus pratensis, Malaconothrus globiger, Nanhermannia coronata* and *Banksinoma lanceolata.*

Five species had increased significantly, i.e. *Oppia subpectinata, Suctobelbella subcornigera, S. acutidens, S. falcata* and *Chamobates borealis*. The average abundance of *Tectocepheus velatus* in the hummocks of the ameliorated site was more than three times greater than in the hummocks of the virgin site. However, the difference was not statistically significant due to great variation.

The most abundant species in the hummocks of the ameliorated site were *Tectocepheus velatus, Oppiella nova, Oppia subpectinata* and *Suctobelbella subcornigera*. A total of 30 species was found.

Those species which had suffered mostly from the amelioration of the bog were usually typical peatland species. *Limnozetes sphagni* and *Trimalaconothrus foveolatus* are inhabitants of constantly wet swamps, while *Hoplophtiracarus pavidus, Trhypochthonius nigrigans* and *Ceratozetes parvulus* have been reported from many kinds of peatland types (Tarras-Wahlberg 1953 and 1961, Knülle 1957a, Popp 1962, Karppinen 1962, 1966, 1972 and 1977). Obviously, the artificial drainage had made the environment too dry for these species.

Nothrus pratensis is also a typical bog species (Karppinen 1955a). It had decreased in the hummocks, but at the same time had increased in the hollows. Obviously it had reacted to the environmental change by performing a microhabitat shift. A similar sort of change was observed in the abundance of *Steganacarus striculus, Malaconotrus globiger* and *Nanhermannia coronata*, even though the change was not statistically significant in all of these cases. The two last-mentioned species at least are typical bog inhabitants (Tarras-Wahlberg 1953, 1961, Karppinen 1955b, 1966, 1977, Popp 1962). This kind of microhabitat shift is understandable, as the moisture conditions in the hollows of the ameliorated site are fairly similar to those of the hummocks of the virgin site (Lindholm & Markkula 1984).

In the virgin bog, especially in the hummocks, lived some species capable of inhabiting a wide variety of habitats without having any obvious optimum habitat. These habitat generalists were *Oppiella nova, Tectocepheus velatus, Suctobelbella subcornigera* and *Oppia subpectinata* (Knülle 1957a, Karppinen 1958b). In general they had benefited from the amelioration and comprised more than half of the oribatid communities of the ameliorated site, in the hollows as well as in the hummocks. Among those species which had benefited from the amelioration there were also some species which are typical inhabitants of forest soil, e.g. *Chamobates borealis, Suctobelbella falcata* and *S. acutidens* (Knülle 1957a, Karppinen 1958b).

In the hummocks of the ameliorated site there even occurred some species which are known to prefer very dry habitats. These were *Trhypochthonius cladonicola, Carabodes marginatus, Eupelops bilobus* and *E. acromios*. According to Knülle (1957a), their optimum habitat is the dry sandy soil or raw humus of *Calluna* heaths, but they have been also found in bogs, mainly climbing on the lichens and dwarf shrubs (Tarras-Wahlberg 1961, Popp 1962). Even though they were very sparse in my material, these species may indicate an increase in suitable dry microhabitats due to the artificial drainage and improvement of the field layer vegetation.

Of course, all the observed differences between the sites are not necessarily consequences of amelioration. The original faunal similarity of the sample sites is not known. For instance, the occurrence of *Mucronothrus nasalis* only in the hollows of the ameliorated site can hardly be explained as resulting from artificial drainage, since this species is usually considered to prefer very wet habitats like cold springs (see Hammer & Wallwork 1979).

4.3. Faunal similarities between the microhabitats

The similarity of the oribatid fauna in the different microhabitats was compared using the "quotient of similarity" (QS) of Sørensen (1948): $QS = 100 \times 2c/(a+b)$, where a = number of species in sample A, b = number of species in sample B, and c = number of species common to samples A and B. The similarity matrix is given in Table 2.

The values of the quotient clearly demonstrate that the same types of microhabitat on different sites had more similar oribatid faunas (65 and 66) than different types of microhabitat on the same site (48 and 49). A more interesting observation is that the hummocks of the virgin site and the hollows of the ameliorated site had the greatest similarity value (69). This is probably correlated with the similarity of the moisture conditions in these microhabitats.

The least similar were the oribatid faunas of the hollows of the virgin site and of the hummocks of the ameliorated site. This may also indicate the importance of the soil moisture factor, since these microhabitats represent the moisture extremes in the study area (Lindholm & Markkula 1984).

Table 2. QS-values between the microhabitats. A = hollows of the virgin site, B = hollows of the ameliorated site, C = hummocks of the virgin site, D = hummocks of the ameliorated site.

	B	C	D
A	65.2	48.0	40.8
B		69.0	49.1
C			65.6

4.4. General discussion

As a general conclusion it can be noted that the typical peatland oribatids had either decreased or shifted their main microhabitat from the hummocks to the hollows. Their place had been taken by the habitat generalists and by those species which prefer drier environments. Thus, the faunal changes following the forest-amelioration seemed to be mainly correlated with the drying of the bog soil. This conclusion is supported by the observations on the faunal similarities of the microhabitats. It is in agreement with the general assumption that soil moisture is the major factor affecting the distribution of the oribatids (Mitchell 1979).

However, the effects of fertilizers cannot be ruled out. Eitminavichiute et al. (1972) have studied the changes of the oribatid fauna in some Lithuanian bogs which were drained but not fertilized. Their main conclusion was that the eurytopic species began to replace the hydrophilic ones, which is in agreement with my observations.

The effect of nitrogen fertilization without drainage has been studied in conjunction with the oribatids of forest soil (for instance Lohm et al. 1977, Huhta et al. 1984). No significant effect upon oribatids was observed in these studies, even when the amounts of nitrogen used were three to four times greater than the amounts used on my study site. Hence, it could be concluded that the direct effect of the fertilizers upon the observed faunal response is insignificant. However, the fertilizers surely affect the environment of the oribatids, for instance by changing the microbial activity and vegetation. In this study it is not possible to distinguish these effects from the effect of drainage.

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