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Soil fauna of Finnish coniferous forests

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Quantitative data, collected during several years from four coniferous forest sites in southern and central Finland, are presented in order to give an overall picture about the composition of the soil fauna, its annual fluctuation and vertical distribution. Most taxa have been identified to species, including groups about which previous quantitative knowledge from Finland is scarce or lacking. Due to methodological improvements, several earlier figures have been corrected. Biomass values have also been estimated. The study covers all quantitatively important animal groups, although earthworms were very scarce at the sites studied. Comparisons are made with other related studies in northern coniferous forests.

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1. Introduction

The soil fauna of coniferous forests has been studied intensively in Finland especially from the viewpoint of its reactions to different silvicultural practices (Karppinen 1955, 1957, 1958a, Huhta 1965, 1971, 1976, Huhta et al. 1967, 1969, Nurminen 1967, Huhta & Koskenniemi 1975). However, most of these works deal with major taxonomic units: identification to species level has been carried out only on oribatid mites (Karppinen 1955, 1957, 1958a), enchytraeids (Nurminen 1967) and spiders (Huhta 1965, 1971). In addition, data on earthworms (Karppinen 1958b, Terhivuo & Valovirta 1978), and nematodes (M. L. Magnusson 1982) have been published in other connections. Estimations of biomasses were presented by Huhta and Koskenniemi (1975) and Huhta (1976), but even these are rough because they are based on simple length-weight regressions without recognizing the different shapes of species. In addition, developments in current techniques allow more effective extraction of animals from soil samples, which means that many of the earlier figures must be adjusted upwards. The previous studies have also been strictly confined to the organic horizon, thereby eliminating the populations below this sample depth.

A rather comprehensive study on the effects of fertilization on the soil fauna of Finnish coniferous forests was recently completed (Huhta et al. 1983, Huhta 1984, Vilkamaa & Huhta 1986, Koskenniemi & Huhta 1986, Huhta et al. 1986, Hyvönen unpubl). A search for data about the fauna in untreated soil would be difficult from these scattered sources, which furthermore do not cover all the material collected during those studies. This paper was written to offer an easily available summary of current quantitative data as a basis for future research. The data are supplemented with some previously unpublished material from the study by Huhta (1976).

2. Material and methods

2.1. Study sites

The material was collected at four forest stands in southern and central Finland (Fig. 1). The soil type at all study sites was a typical coniferous forest podzol with raw humus.

1. Saarijärvi, central Finland (62°40′N, 25°15′E). A Norway spruce stand of *Myrtillus*-type, aged about 40 years. *Vaccinium myrtillus* dominates the field layer vegetation, which is rather sparse and patchy. The thickness of the humus layer varies between 3 and 5 cm, locally up to 7 cm.

2. Tammela, southern Finland (60°40′N, 23°50′E). A Scots pine stand of the *Calluna*-type, c. 50 years. *Calluna vulgaris* dominates the field vegetation, otherwise similar to Site 1.

3. Tuusula (Ruotsinkylä) (60°25′N, 24°50′E). A young (ca. 30 years) Scots pine stand of the *Calluna*-type, thinned before the study. *Calluna vulgaris* strongly dominating in the field layer; otherwise similar to Sites 1 and 2.

4. Harviala (61°00′N, 24°40′E). A Norway spruce stand of the *Myrtillus*-type, aged c. 80 years. Field layer vegetation strongly dominated by *Vaccinium myrtillus*, mosses covering c. 90 % of the ground.

More details about Sites 1 to 3 are given by Huhta (1984), and about Site 4 by Huhta & Koskenniemi (1975) and Huhta (1976).

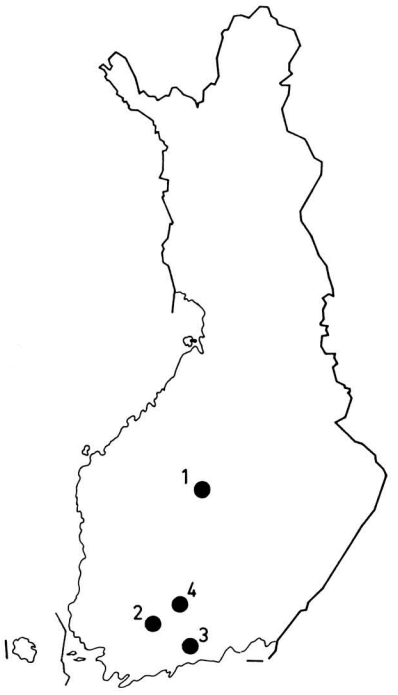

Fig. 1. Location of the study sites. 1 = Saarijärvi, 2 = Tammela, 3 = Tuusula (Ruotsinkylä), 4 = Harviala.

2.2. Sampling

Sampling was usually performed monthly during snow-free periods (May to September). Each sample consisted of ten soil cores, here called sample units, taken from two replicate 10-m squares (5+5) (Saarijärvi and Tammela). The succeeding samples were taken around fixed points, but at a minimum distance of 10 cm from previous sample holes. At Ruotsinkylä one unit was taken from 10 replicate 2-m squares, and at Harviala 8 samples of 8 units were taken at three- to four-week intervals from the same 10×10 m area. Material was collected during the years 1979−80 from Sites 1 to 3 (additional samples for enchytraeids in 1981−82), and in 1972 from Site 4. In some cases, when fertilization had no significant influence on the populations, data from up to eight test plots (= 40 units) were combined. Numbers of samples, units and sampling years are given in the results under the treatment of each animal group.

The samples were taken with cylindrical steel corers (area 9.4 cm^2 for Nematoda, 25 cm^2 for Enchytraeidae and 9.4 or 25 cm^2 for Microarthropoda), inside which plastic rings were inserted. The soil cores were cut between the rings into 0−3 and 3−6 cm layers; the layer 6−9 cm was also included in some enchytraeid samples. The layer 3−6 cm included some mineral soil to a varying depth depending on the thickness of the organic horizon (4−6 cm). The samples for macroarthropods were 25×25 cm blocks of organic soil, taken with a special spade down to the surface of the mineral soil. Samples were transported in plastic bags and extracted within a maximum storage time of 10 days at +5°C.

2.3. Extraction

Nematoda

Before extraction a subsample of 1/5 (6 cm^3) was taken after one minute's mixing with a vibro-mixer in 0.5 l of water. Nematodes were extracted using Oostenbrink's (1960) filtration method (Tammela, Site 2), or the wet funnel technique (Tuusula, Site 3) (Sohlenius 1979), using a double layer of porous paper cloth as a filter, and 40 W electric bulbs for heating (Tuusula). Heating was started after 2 h and gradually increased. After standing overnight, the temperature in the samples was about 40°C. After 22 h the heating was switched off, and 2 h later the sample tubes were removed from below the funnels (Sohlenius 1979). The animals were killed by immersing the tubes for 1 min. in hot water, after which some of the water in the tubes was removed, and concentrated TAF fixation fluid was added to produce the desired concentration.

Enchytraeidae

Enchytraeids were extracted with standard wet funnels, following the heating procedure recommended by O'Connor (1962) for efficient extraction. Sample tubes, fixed with rubber tubes below the funnels, were removed after 3 hour's (minimum) extraction and immersed for a moment in hot water. Most of the water from the tubes was then carefully sucked off with a pipette and substituted with undiluted alcohol to provide a 70 % preserving fluid.

Microarthropoda

Acari and Collembola were extracted with "high gradient" canister extractors (Macfadyen 1961), using the "medium" heating procedure recommended by Leinaas (1978) for raw humus soil. Our apparatuses were principally constructed according to the description of Lussenhop (1971), except that four 75 W spotlight bulbs were used as sources of heat. The water bath below the samples was kept at +10°C for the first day, and later at +5°C. In place of the picric acid used by most workers, we employed a 50 % aqueous solution of ethylene glycol (v/v), from which samples were transferred to alcohol by pouring through a small sieve (mesh 50 μm), washing with alcohol, and flushing the contents of the sieve with a jet of alcohol into the sample bottles. Collembola, Protura and mesostigmatid mites were always identified from whole

samples, whereas specimens from the 25 cm^2 samples were divided into two by means of a sample splitter before other mites were counted.

Macroarthropoda and Lumbricidae

Other arthropod groups were extracted with large Tullgren funnels as described by Huhta (1972; closed model of stainless steel). Heating (60 W bulbs) was kept at half capacity for the first 3 h, and thereafter at full capacity.

For earthworms no separate extraction method was adopted because preliminary samples from Sites 1 and 2, treated with the technique described by Huhta & Koskenniemi (1975), revealed that the populations were very sparse.

2.4. Identification and estimation of biomasses

All animal groups were identified to species as far as possible. Nematodes were identified to genera or subfamilies, dipteran and coleopteran larvae to families. Enchytraeids were not properly identified, but all "thin" worms were considered to be *Cognettia sphagnetorum* (Vejd.), the few "thick" specimens belonging either to *Mesenchytraeus flavus* (Lev.) or *Bryodrilus ehlersi* Ude (see Nurminen 1967 and Lundkvist 1982). Only adult oribatids were identified, whereas nymphal stages of Mesostigmata were assumed to belong to the same species found commonly as adults, despite a small probability of misidentification in some genera. Taxonomic names are according to the following authors:

Collembola: Huldén 1984
Oribatida: Karppinen & Krivolutsky 1982.
Mesostigmata: Mainly after Karg 1971, but checked from other sources.
Coleoptera: Silfverberg 1979.

The biomasses of macroarthropods and lumbricids were measured by direct weighing. Those of Nematoda were estimated using the method of Andrassy (1959), Enchytraeidae according to Abrahamsen (1973), and Collembola with the aid of regression formulae given by Tanaka (1970) and Petersen (1975). The weights for Oribatida were mainly taken from Luxton (1975), and those of Mesostigmata from Persson & Lohm (1977) and Huhta et al. (1979). The biomass estimations are described in more detail by Huhta et al. (1986).

3. Results and discussion

3.1. Nematoda

The mean density of nematodes was rather similar at both study sites: c. 2.4 millions per square metre at Tammela and 2.2 at Tuusula. These mean values are higher than those obtained by Huhta & Koskenniemi (1975) at two spruce forest sites in southern Finland, although their maximum values were higher than those in the present study. The difference is partly explained by the lower sampling depth in the previous study (organic soil only),

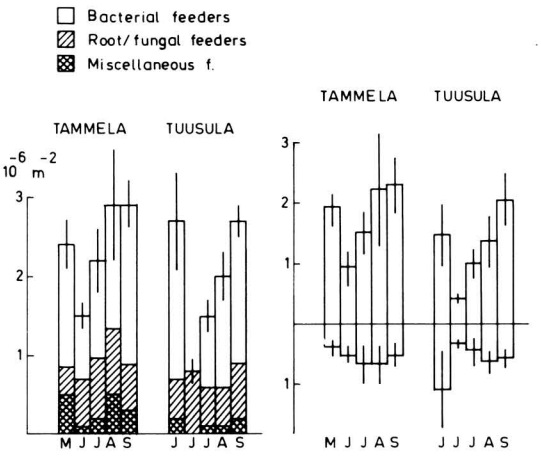

Fig. 2. Monthly numbers ($\pm SE$) of nematodes at study Sites 2 (Tammela 1980) and 3 (Tuusula 1981). The graphs on the left show the relative proportions of different trophic groups, and those on the right the vertical distribution: columns above the base line = 0—3 cm, columns below it 3—6 cm. The second sample from Tuusula (late June) was not identified.

but methodological reasons are probably also involved. Even though principally the same method ("Baermann" or "wet" funnel) was used, small variations in the procedure may considerably change the extraction efficiency. Huhta & Koskenniemi (1975) used a modified filtration technique (Oostenbrink 1960) with extraction in petri dishes at one site, and simple wet funnels with 3 hours' heating at the other. In the present study we used both filtration and funnel extraction with a prolonged heating regime. Such a regime, with samples properly submerged in water has been noted to improve extraction efficiency (Sohlenius, personal communication).

Higher average densities have been reported from Swedish studies in similar pine stands (Sohlenius 1979, C. Magnusson 1983a). However, the study by Sohlenius covers one whole year, and Magnusson took samples only in May and October. A considerable annual fluctuation, with a deep minimum in summer, has been observed in all studies made in coniferous forests at these latitudes (Huhta et al. 1967, Huhta & Koskenniemi 1975, Sohlenius 1979, present study Fig. 2). If figures for corresponding months are picked from the Swedish study (Persson et al. 1980), the same mean density is obtained as we observed at our Site 2. It should also be noted that the sample depth in the

Table 1. Mean annual numbers (1000/m^2) and biomasses (mg d.w./m^2) of nematode taxa and feeding groups at study Sites 2 (Tammela 1980) and 3 (Tuusula 1981). $n=5\times10$ and 4×10 samples$\times$units for Sites 2 and 3, respectively.

	Numbers		Biomass	
Sites:	2	3	2	3
Root/fungal feeders:	560	420	4.2	5.8
Tylenchus s.l.	280	180		
Aphelenchoides	280	240		
Bacterial feeders:	1350	1360	15.1	20.5
Rhabditis	60	120		
Bunonema	40	0		
Acrobelinae	180	480		
Teratocephalinae	380	100		
Plectus	520	590		
Wilsonema	20	50		
Alaimus	150	20		
Miscellaneous feeders:	250	110	48.8	17.8
Endorylaimus	<10	50		
Aporcelaimus	40	20		
Dorylaimus	210	40		
Grand total	2160	1890	68.1	46.2

Swedish studies was 10 cm, while we sampled only down to 6 cm. Thus, our values are certainly under-estimates as a considerable proportion of nematodes, especially root parasites (C. Magnusson 1983b), are found in the mineral soil (Wasilewska 1974, Persson et al. 1980).

An exact comparison is not possible because of the different sample depths. M. L. Magnusson (1982) observed that significantly more nematodes were found in mineral soil in a pine stand of *Calluna*-type than in other forest types. Huhta (1976) found very few nematodes in the mineral soil in spruce forests. The factors regulating the vertical distribution of nematodes are worthy of further research; distribution of roots, total organic matter, numbers of microbes, water conditions and soil texture may all be involved.

Our samples were divided into layers of 0–3 cm and 3–6 cm. There was no clear relationship between total numbers and vertical distribution (Fig. 2). This does not preclude the possibility of vertical movements; the sampling design was not planned to reveal this.

Bacterial feeders clearly accounted for more than half of the total numbers of nematodes (Fig. 2.). This accords with the result of M. L. Magnusson (1982) in a similar stand at a short distance from our study site, while (C. Magnusson 1983a) found more root/fungal feeders in his pine stand. The dominating taxa at our sites were *Tylenchus* s.l. and *Aphelenchoides* among the root/fungal feeders, *Plectus*, Acrobelinae and Teratocephalinae among the bacterial feeders, and Dorylaiminae (Site 1) among the miscellaneous feeders (Table 1). According to M. L. Magnusson (1982) *Aphelenchoides* and *Tylenchus* are the most numerous root/fungal feeding genera in different coniferous forests, and in *Calluna* type stands especially they form an overwhelming majority. In addition to these, *Malenchus tantulus* was abundant at the study site of C. Magnusson (1983b), and *Tylencholaimus mirabilis* at the site of Sohlenius & Wasilewska (1984). Sohlenius (1979) and Sohlenius & Wasilewska (1984) found the same bacterial feeding taxa to be most numerous in Swedish pine stands, while *Eudorylaimus* predominated among the miscellaneous feeders.

3.2. Enchytraeidae

There is little to add to what is already known about enchytraeids in coniferous forests in the Scandinavian countries (Nurminen 1967, Abrahamsen 1972, Lundkvist 1982). Only one representative sample was identified in the present study (P. Kairesalo, personal communication). On the basis of size and colour only a few scattered specimens at our study sites belonged to the genera *Mesenchytraeus* or *Bryodrilus*. All the rest are most likely *Cognettia sphagnetorum* Vejd. (cf. Nurminen 1967, Lundkvist 1982).

The most notable difference in comparison with previous studies is the high abundance of enchytraeids at our study sites (mean at Saarijärvi 1979 27 500/m^2, Saarijärvi 1980 48 900/m^2, Tammela 1980 39 800/m^2). This is roughly two to four times the previous estimates (Huhta et al. 1967, Abrahamsen 1972, Huhta & Koskenniemi 1975, Lundkvist 1982). Since the present study covers three localities and several years, this cannot be due to exceptional weather conditions; even higher numbers were counted at other study sites and/or years (Huhta 1984), ranging from 30 000 to 90 000/m^2.

Annual means of four years at the same site (Saarijärvi, 3 to 5 samples per year) differed by a factor of 3.3 (see Huhta 1984). The only methodological difference from the study of Huhta & Koskenniemi (1975) was that we now counted the animals under a binocular microscope from preserved samples, while in the earlier studies specimens were counted alive in

petri dishes on a black background and under good illumination.

In spite of the difference in population densities, our biomass estimates (Table 9) are of the same order of magnitude as those of Lundkvist (1982). The annual average at her study site was c. 400 mg d.w./m^2, and six of 9 annual means range between 340 and 620 mg/m^2. Our lower biomass might have resulted from differences in the time of sampling. Our sampling periods covered only the seasons from May to September, when the population consists mostly of small specimens, indicating intensive reproduction (fragmentation). The average size of individuals in our study agrees well with the lower values reported by Lundkvist (1982). Our three higher estimates are from the spruce forest (Site 1, years 1980–82) and range from 1080 to 1980 mg/m^2. (The biomass value in Fig. 1 in Huhta (1984) for 1980 is incorrect). Huhta et al. (1967) counted almost twice as many enchytraeids in a moist spruce stand as in pine stands.

As is already known from earlier studies (Huhta et al. 1967, Nurminen 1967, Abrahamsen 1972, Huhta & Koskenniemi 1975, Lundkvist 1982), there are considerable annual fluctuations, as well as changes in the vertical distribution, in populations of *C. sphagnetorum* (Fig. 3).

In 1981 and 1982 we extended our samples down to a depth of 9 cm. 3–18 % of the population was found below our normal sampling depth, depending on the site and season (Huhta 1984). An exact comparison with Persson et al. (1980) is not possible because they divided their samples between the organic and mineral layers.

3.3. Lumbricidae

Earthworms occurred very sparsely at our study sites, even in the spruce stand at Saarijärvi (Site 1) which was considered to represent the *Myrtillus*-type. At a more southern locality (Site 4, Huhta & Koskenniemi 1975) a similar stand harboured a population of more than one hundred specimens per square metre. Even allowing for an underestimation of 50 % (dry funnel method), a density of below 30 specimens per square metre can be estimated. The numbers and biomass of earthworms tend to change rapidly along the moisture and fertility gradient in coniferous forests (Huhta et al. 1967, Abrahamsen 1972, Huhta 1979, Terhivuo & Valovirta 1978, Nordström & Rundgren 1973).

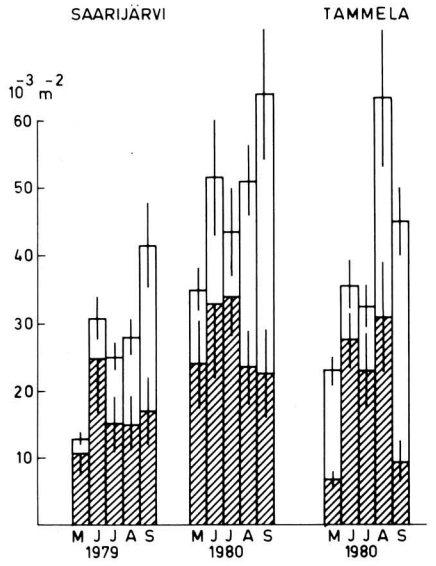

Fig. 3. Monthly numbers (±*SE*) of enchytraeids at study Sites 1 (Saarijärvi) and 2 (Tammela) during two sampling periods. White parts of columns = 0—3 cm, hatched = 3—6 cm.

3.4. Collembola and Protura

The present study revealed that earlier estimates of the total numbers of Collembola in Finnish coniferous forests (Huhta et al. 1967, Huhta & Koskenniemi 1975) must be corrected, as our figures now fell within the ranges of related studies in Sweden and Norway. Our mean values from the two study sites were close to each other: 81 000 specimens per square metre at Site 2, and 73 000 at Site 3; the biomasses were 121 and 92 mg d.w./m^2, respectively. Persson et al. (1980) counted c. 60 000/m^2 in a Swedish pine stand, and the densities obtained by Hågvar (1982) from similar sites range from 40 000 to 80 000/m^2.

The reason for previous underestimates is mainly ineffective extraction. Simple dry funnels not equipped with heating systems were used by Huhta et al. 1967. The "hot rod" technique of Valpas (1969) was then adopted (Huhta & Koskenniemi 1975) because positive results were obtained in preliminary studies (Valpas 1969, Huhta 1972). However, when the hot rod apparatus and Macfadyen's high gradient extractor were used simultaneously by Huhta & Koskenniemi, the high gradient extractor had a higher efficiency, especially in summer when the soil was dry. Similar results

Table 2. Mean numbers (hundreds) and biomasses (mg d.w./m^2) of the most abundant Collembola and Protura at Sites 2 (Tammela 1980) and 3 (Tuusula 1981). The less frequent species are listed in the appendix. $n=5\times10$ and 4×10 samples$\times$units for Sites 2 and 3, respectively.

	Numbers		Biomass	
Sites:	2	3	2	3
Willemia anophthalma Börner	85	19	6	1
Friesea mirabilis (Tullberg)	3	1	1	+
Micranurida pygmaea Börner	43	62	1	3
Onychiurus absoloni (Börner)	36	5	4	+
Mesaphorura yosii (Rusek)	185	171	7	7
M. macrochaeta Rusek	+	11	+	+
Karlstejnia norvegica Fjellberg	8	-	+	-
Anurophorus septentrionalis Palissa	130	1	51	1
Folsomia quadrioculata (Tullberg)	7	-	2	-
F. fimetarioides (Axelson)	+	205	+	45
Isotomiella minor (Schäffer)	267	121	24	12
Isotoma notabilis Schäffer	2	33	+	3
Pogonognathellus flavescens (Tullberg)	2	5	4	5
Lepidocyrtus lignorum (Fabricius)	5	1	2	+
Megalothorax minimus Willem	10	32	1	4
Total Collembola	812	727	121	92
Protura	31	124	n.d.	n.d.

have been obtained by Persson & Lohm (1977) and Takeda (1979). An improved version of Macfadyen's apparatus was later constructed, and the hot rod technique was abandoned. The "high gradient extractor" is currently the standard extraction method for microarthropods in the Nordic countries (Leinaas 1978, Petersen 1978, Persson et al. 1980).

There were many similarities but also some striking differences in the collembolan fauna at the two study sites (2 and 3). *Anurophorus septentrionalis* was abundant at Tammela but very sparse at Tuusula, while the opposite was the case in *Folsomia fimetarioides*. *Willemia anophthalma* and *Isotomiella minor* were more abundant at Tammela (Table 2). *Mesaphorura yosii* was one of the two most dominating species at both sites. (*M. krausbaueri* s.l. was identified from all samples at Tuusula but from only two at Tammela. The figure given for *Karlstejnia norvegica* is based on the assumption of the same percentage in the other samples).

Because of its relatively large body size, *A. septentrionalis* dominated strongly in the biomass at Site 2, and *F. fimetarioides* correspondingly at Site 3. The large-sized entomobryids were relatively sparse and formed an insignificant part of the biomass. Although their numbers may not be severely underestimated, the biomass probably is, because the largest specimens easily escape from small samples. Huhta & Koskenniemi (1975) compared the extraction efficiency for springtails from samples 10 cm^2 and 100 cm^2 in area, and noted that the size classes of 0.8 mm and over were under-represented in the small samples (cf. also Persson 1975). Huhta & Mikkonen (1982) estimated the mean biomass of *Lepidocyrtus lignorum* at Site 4 (Harviala) to be 21 mg/m^2, and that of *Pogonognathellus flavescens* 24 mg. They picked the animals from large samples (625 cm^2 per unit) taken for macroarthropods, and the total biomass of entomobryids (50 mg/m^2) was roughly ten times that in the present study. *Entomobrya marginata, E. corticalis* and *Orchesella bifasciata* were recorded in addition to the species found in the present study.

The springtail community at our study Site 3 (Tuusula) closely resembles that identified by Valpas (1969) from a similar stand in the vicinity. He took most of his samples during winter and early spring, which may be the reason for differences in the relative abundances of the common species. Persson (1975) and Wirén (1975) also found a similar collembolan community in Swedish pine forests. The study by Kaczmarek (1975) in related sites has many species in common with ours. Byzova (1964) has presented a similar list of species from a pine stand. Almost all abundant species at our sites are also among the most common in Norwegian coniferous forests (Hågvar 1982).

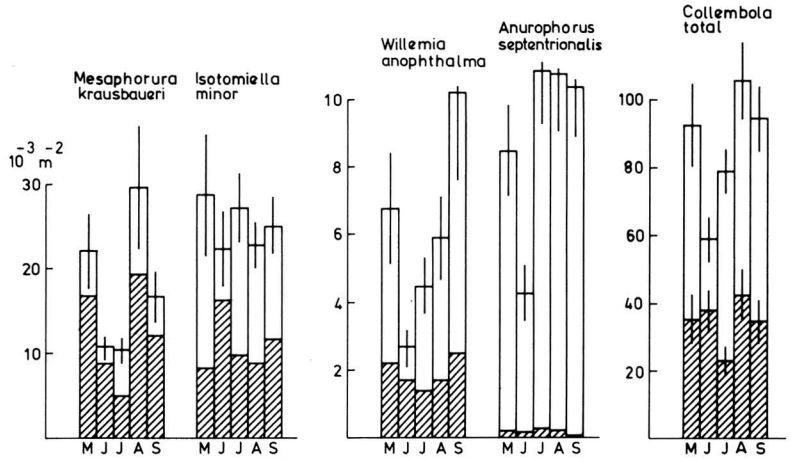

Fig. 4. Monthly numbers ($\pm SE$) of total Collembola and some representative species at study Site 2 (Tammela). Data from untreated and ash-fertilized plots have been combined in order to show the annual fluctuation with greater precision (n = 30 cores each sample). White parts of columns = 3 cm, hatched = 3—6 cm.

A. septentrionalis is there restricted to the driest habitats, while *W. anophthalma, M. yosii* and *Micranurida pygmaea* occur more commonly in more moist stands. Species rare or absent from our samples, but abundant in Norway, are *Folsomia quadrioculata, Onychiurus armatus* and *Mesaphorura tenuisensillata*. Conversely, *F. fimetarioides* was reported from Swedish forests by Forsslund (1943), but this species was not found in more recent studies either in Sweden (Persson 1975, Wiren 1975) or in Norway (Hågvar 1982). In a spruce stand at Lammi, southern Finland, it is one of the most abundant springtail species (Vilkamaa, unpubl.)

On the average, somewhat less than 40 % of the total numbers of Collembola occurred in the deeper layer (3—6 cm) at both study sites. During the summer minimum there was a tendency to move downwards in the soil profile. This could be observed both in the total numbers and in the numbers of several species (Fig. 4). Each species showed a typical vertical distribution, e.g. almost all *A. septentrionalis* were extracted from the surface layer, while *M. krausbaueri* s.l. was concentrated more in the deeper horizon. All abundant species in our material, with the exception of *M. pygmaea*, dwell mainly within the topmost 6 cm (Hågvar 1983). Thus, our sampling depth was sufficient to give a representative picture of the springtail community. Kuznetsova & Babenko (1984) found that *Isotoma notabilis* is concentrated in the litter layer, *I. minor* in the fermentation layer and *F. fimetarioides* in the humus in a spruce stand; these species composed two thirds of the total numbers.

The average density of Protura ranged from 3 000 (Tammela) to 12 000 per square metre. The mean of two samples from a Swedish pine stand (Persson et al. 1980) was less than 1000.

3.5. Oribatida and Astigmata

The mean total densities of oribatid mites obtained in the present study ranged from 186 000/m^2 (Tuusula) to 351 000/m^2 (Saarijärvi). These values are clearly higher than those reported by Huhta et al. (1967), but of the same magnitude as those given by Huhta & Koskenniemi (1975). However, because there is a trend to increasing densities from dry pine stands towards mesic spruce stands (Karppinen 1958a, Huhta et al. 1967), the figures to be compared with Huhta & Koskenniemi should be those from Site 1 (Saarijärvi). The present study gives much higher total densities, but there is considerable fluctuation from year to year; the mean value for 1980 was 1.6 times that for 1979. If this is kept in mind, the superiority of the high gradient extractor for oribatids is not yet an established fact (see also Huhta & Koskenniemi 1975). On the other hand, Persson et al. (1980) have obtained still higher numbers in a Swedish pine forest. These are based on two samples only, but for comparison we should pick our highest values for the

Table 3. Mean numbers (hundreds) and biomasses (mg d.w./m^2) of the most abundant Oribatida, and sums of different mite groups at study Sites 1, 2 and 3. The less frequent species are listed in the appendix. $n = 10\times40$, 5×10 and 4×10 samplé×units for Sites 1, 2, and 3, respectively.

	Numbers			Biomass		
Sites:	1	2	3	1	2	3
Phthiracarus borealis (Träg.)	+	26	3	4	86	10
Steganacarus carinatus (C. L. Koch)	16	35	3	60	130	10
Rhysotritia ardua (C. L. Koch)	-	2	5	-	4	10
Brachychthoniidae spp.	664	451	165	23	16	6
Nothrus silvestris (Nicolet)	9	30	26	16	57	48
Trhypochthoniidae spp.	-	187	38	-	7	1.5
Nanhermannia sellnicki (Forssl.)	17	109	3	12	75	-
Belba spp.	7	9	2	4	5	1
Eremaeus silvestris Forssl.	7	9	-	10	13	-
Adoristes poppei (Oud.)	3	3	1	3	3	1
Carabodes marginatus (Michael)	-	23	-	-	40	-
C. subarcticus Träg.	2	50	9	+	30	6
Tectocepheus velatus (Michael)	220	347	176	39	63	32
Oppia translamellata (Willm.)	52	5	-	4	+	-
O. falcata (Paoli)	20	-	-	+	-	-
O. splendens (C. L. Koch)	38	-	-	6	-	-
O. subpectinata (Oud.)	51	60	43	10	12	9
Oppiella nova (Oud.)	217	192	153	16	14	11
Quadroppia quadricarinata (Michael)	4	+	7	+	+	1
Suctobelbidae spp.	149	190	360	10	12	23
Autogneta tragardhi Forssl.	50	69	-	16	22	-
Scheloribates confundatus Selln.	13	60	6	8	39	4
S. latipes (C. L. Koch)	+	24	10	+	15	17
Chamobates schuetzi (Oud.)	70	50	30	18	12	7
Ceratozetes gracilis (Michael)	11	24	37	14	29	44
Parachipteria punctata (Nicolet)	21	-	-	29	-	-
Oribatida ad.	1693	1892	1085	332	777	257
Oribatida juv.	1822	875	773	145	48	31
Astigmata	109	61	0	10	3	0
Prostigmata	797	553	337	25	22	9

corresponding months (May and September, Site 1). Oribatids are clearly concentrated in the organic soil horizon (Persson et al. 1980), so that our sampling depth should be enough to reveal the bulk of the populations.

The oribatid community was strikingly similar at our three study sites. Brachychthoniidae spp. *Tectocepheus velatus, Oppiella nova* and *Suctobelbella* spp. predominated, followed by *Oppia subpectinata, Autogneta tragardhi* (not found at Tuusula), *Chamobates schuetzi* and *Ceratozetes gracilis* (Table 3). Several other *Oppia* species were found at Site 1 and the total number of species as well as individuals was highest there. The biomass was more evenly distributed between different taxa than were the numbers. The total biomass of oribatids was considerably higher at Tammela than at the other study sites.

It is interesting to compare our results with those of Karppinen (1958), who collected 25 years earlier, and whose main study sites were close to our Site 3. If we pick the data for summer periods for the sites most intensively studied by him for comparison with our data, a striking similarity emerges (Table 4). We did not identify the difficult genus *Suctobelba* (now family Suctobelbidae; Karppinen & Krivolutsky 1982), but most probably the predominating species is the same. Karppinen also omitted the families Brachychthoniidae and Trhypochthoniidae. The three most dominant species were almost the same at all sites studied. The few records from southern Finland indicate a northern distribution of *O. translamellata* and *A. tragardhi*, but methodological differences may also be involved in some cases. Karppinen included immature stages of *N. silvestris* in his data because much higher densities are listed than in the present study (cf. Persson 1975).

Similarly to Collembola, different oribatid species show typical patterns in their vertical distributions. Brachychthoniidae spp. pre-

Table 4. Comparison of the most abundant oribatids at our study sites and those of Karppinen (1958). Only the summer periods of the sites most intensively studied by Karppinen are included. The figures are rank values; the 5 most numerous species at any site are included. + = recorded, - = not recorded.

	Present study			Karppinen 1958		
	1	2	3	MT spruce	MT pine	VT pine
Suctobelba (subcornigera?)	3	3	1	1	1	1
Tectocepheus velatus	1	1	2	2	2	1
Oppiella nova	2	2	3	5	3	2
Oppia subpectinata	6	5	4	4	+	+
O. translamellata	6	+	-	+	+	-
Autogneta tragardhi	6	7	-	+	+	-
Scheloribates confundatus	+	4	+	8	4	7
Nothrus silvestris	+	8	+	3	5	5
Chamobates schuetzi	4	6	5	6	+	+
Ceratozetes gracilis	+	7	5	+	-	4

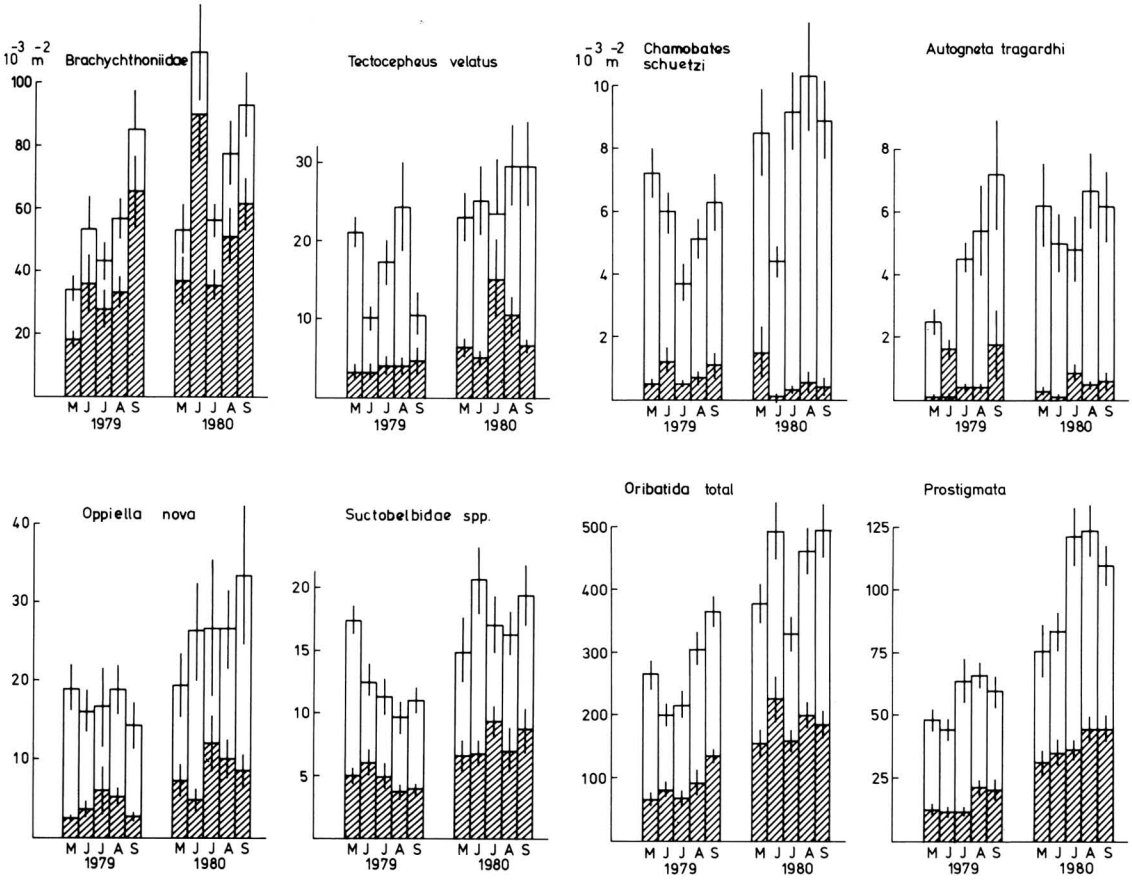

Fig. 5. Monthly numbers ($\pm SE$) of total Oribatida and Prostigmata, and of some representative oribatid species at study Site 1 (Saarijärvi). Data from fertilized plots are included because the treatments had no significant influence. (n = 40 cores each sample). White parts of columns = 0—3 cm, hatched = 3—6 cm.

Table 5. Mean numbers (hundreds) and biomasses (mg d.w./m^2) of the most abundant Mesostigmata. The less frequent species are listed in the appendix. $n = 10 \times 30$, 5×40 and 4×40 samples × units for Sites 1, 2 and 3, respectively.

	Numbers			Biomass		
Sites:	1	2	3	1	2	3
Eviphis ostrinus (C. L. Koch)	2	3	2	1	3	1
Hypoaspis aculeifer (Can.)	-	4	9	-	2	6
Dendrolaelaps rotundus Hirschem.	4	5	+	1	2	+
Pergamasus cf. *brevicornis* Berl.	2	5	+	12	37	3
Pergamasus parrunciger Bhattach.	-	-	12	-	-	15
Pergamasus lapponicus Trägårdh	7	7	-	9	9	-
Vulgarogamasus kraepelini (Berl.)	3	3	1	5	7	3
Veigaia kochi (Trägårdh)	1	2	+	7	10	3
V. nemorensis (C. L. Koch)	36	27	27[1]	31	23	59
V. cervus (Kramer)	+	2	1	+	2	1
Parazercon radiatus (Berl.)	69	57	32	9	7	4
Prozercon kochi Sellnick	3	19	-	+	1	-
P. serlachii Lehtinen	2	+	1	+	+	+
Zercon zelawaiensis Selln.	+	2	-	+	1	-
Trachytes aegrota (C. L. Koch)	14	8	2	6	3	+
T. minima Träg.	22	14	+	7	4	+
Ipiduropoda dialveolata Hirschm. & Z.-N.	4	-	-	3	-	-
Larvae	30	30	10	4	2	12
Total	204	164	100	98	114	107

[1] $n = 5 \times 10$.

dominate in deeper soil horizons, *T. velatus*, *Oppia* spp. and Suctobelbidae have an intermediate distribution, while *C. schuetzi* and *A. tragardhi* are surface-dwellers (Fig. 5). In the annual fluctuations there is a tendency to lower average numbers in summer, as was also reported by Huhta et al. (1967) and Huhta & Koskenniemi (1975), but this pattern is not followed by all species (Fig. 5).

Astigmata were not identified in the present study. No astigmatids were found at Tuusula, while at Saarijärvi they reached a density of 10 900/m^2. Two species of Astigmata (*Schwiebea cf. nova* and *S. cf. cavernicola*) occur commonly in coniferous forests in Scandinavia (Persson et al. 1980, Hågvar 1984).

3.6. Mesostigmata and Prostigmata

The total numbers of Mesostigmata are comparable with previous surveys made with the same method in corresponding kinds of forests. Our mean value at Site 1 (Saarijärvi) is almost the same as that of Huhta & Koskenniemi (1975) in a spruce stand, and that of Site 3 (Tuusula) is similar to the estimate of Persson et al. (1980) in a Swedish pine stand. Our biomass estimates are almost identical for all three sites, and somewhat higher than those in the studies cited.

Parazercon radiatus and *Veigaia nemorensis* were the two most abundant species at all three sites. Two species of the genus *Trachytes* together keep the third rank. *Pergamasus parrunciger* was common at Site 3 but absent at Sites 1 and 2, where *P. lapponicus* was common instead. Mesostigmatid mites differ enormously in their size; thus the constant but less abundant *Pergamasus brevicornis* retained the second rank in the biomass (Table 5). The mesostigmatid community at our study sites bears a close resemblance to that in Swedish pine stands (Persson et al. 1980).

There were no clear trends in seasonal fluctuations and vertical distribution, although some species, especially *V. nemorensis* exhibited a well-defined minimum in summer (Fig. 6).

The Prostigmata of our study sites had mean densities ranging from 34 000 to 80 000/m^2. These are of the same order of magnitude as those obtained in earlier studies in Finland (Huhta et al. 1967, Huhta & Koskenniemi 1975), but are less than half as large as those reported by Persson et al. (1980) from the Swedish coniferous forest site.

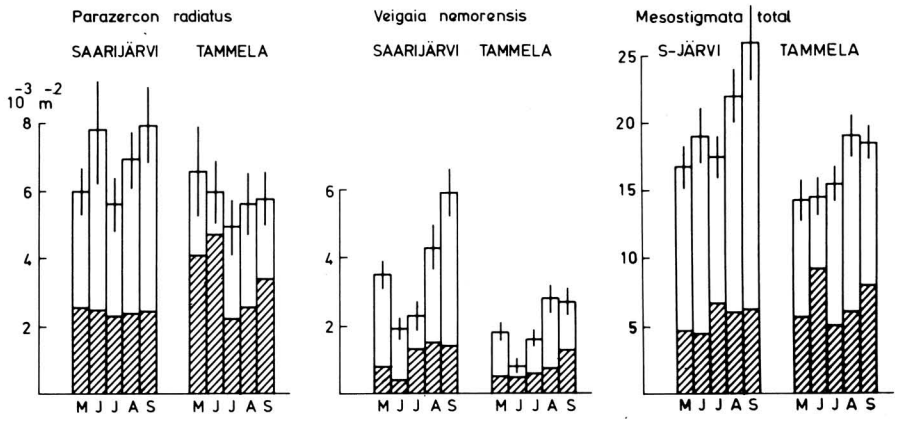

Fig. 6. Monthly numbers (±*SE*) of total Mesostigmata and two representative species at study Sites 1 (Saarijärvi) and 2 (Tammela) in 1980. Data from untreated and ash-fertilized plots have been combined (n = 30 at Saarijärvi, 40 at Tammela). White parts of columns = 0—3 cm, hatched = 3—6 cm.

3.7. Macroarthropoda

The spider fauna of Finnish coniferous forests is fairly well known from the investigations by Huhta (1965, 1971). However, most of Huhta's data are based on the hand-sorting method, which gives low estimates, especially for smaller specimens. Even adult specimens of small linyphiids may be severely underestimated by hand-sorting (Huhta 1971, 1972). Concerning total numbers, the estimates of Huhta & Koskenniemi (1975) are more reliable because the Tullgren funnel method was used; the present estimates are higher, especially those from Site 1 (Saarijärvi). The latter are of the same order of magnitude as those obtained by Huhta (1971) with the funnel method, but it should be noted that his study did not cover the summer period. Persson et al. (1980) obtained a somewhat higher mean value for numbers, and a threefold one for biomass in a similar stand.

The efficiency of the extraction method does not affect the general picture of the spider community. Most of the dominant species in the present study (Site 4, Harviala) are shared by similar habitats in southern Finland. Some of the differences are explained by different preferences of the species in regard to temperature and moisture (Huhta 1965, 1971), and some others by accidental fluctuations. Comparable data (funnel extraction) from two investigations (Huhta 1971, and Site 4, present study, have been compiled into Table 6. Two of the species (*Diplocephalus latifrons* and *Caledonia evansi*) showed enormous annual fluctuations in the survey by Huhta (1971).

Apart from total biomass, data of taxa that were not identified are not presented here. Larvae of Coleoptera and Diptera were identified to families, and the most abundant of them are included in Table 7. Among Coleoptera, small larvae of Cantharidae were most numerous, followed by Staphylinidae and

Table 6. Comparison of the most abundant spider species at study Site 4 (Harviala) and at two sites studied by Huhta (1971). The figures show numbers of specimens/m^2, and all species with a density exceeding 10/m^2 at any site are included.

	Site 4	Huhta 1971	
	MT spruce	OMT spruce	VT pine
Robertus scoticus Jackson	0.5	8	1
Minyriolus pusillus (Wider)	1	7	54
Tapinocyba pallens (Cambr.)	52.5	63	39
Diplocephalus latifrons (Cambr.)	-	13	-
Caledonia evansi Cambr.	-	-	11
Diplocentria bidentata (Emerton)	10	-	10
Porrhomma pallidum Jackson	10	7	14
Centromerus arcanus (Cambr.)	11	35	21
Macrargus rufus (Wider)	17	18	3

Table 7. Mean numbers/m^2 and biomasses (mg d.w./m^2) of larval Coleoptera and Diptera at Sites 1 (Saarijärvi) and 2 (Tammela). Biomasses of the dipteran families were not measured separately. $n=4\times10$ and 3×10 samples×units for Sites 1 and 2, respectively.

	Numbers		Biomass	
Sites:	1	2	1	2
Coleoptera:				
Carabidae	2.9	9.8	1.0	5.2
Staphylinidae	69.1	14.4	9.9	4.4
Cantharidae	432	229	32.9	17.4
Elateridae	95.2	34.2	124.6	43.8
Cryptophagidae	17.4	-	3.5	-
Curculionidae	9.8	0.6	0.5	+
Total	627	288	172.4	70.9
Diptera:				
Tipulidae	3.6	5.3		
Ceratopogonidae	11.6	10.7		
Chironomidae	11.6	7.5		
Cecidomyiidae	148	99		
Rhagionidae	1.2	3.7		
Empididae	4.8	8.5		
Phoridae	3.6	8.5		
Lonchaeidae	6.8	4.7		
Muscidae	6.4	4.8		
Total	325	157	12.6	25.3

Elateridae. The latter family was clearly dominant in the total biomass of larval Coleoptera. Cecidomyiidae was by far the most numerous family of Diptera, the remaining material being distributed rather evenly over several families.

It must be emphasized that the efficiency of the funnel extraction for dipterous larvae is not known, and some families or species may be gross underestimated in the data. In addition, since only the larval phases of the life cycles of Diptera are completed in the soil, sampling should cover all potential seasons for the dominating species. According to Altmüller (1979) most soil-living dipteran larvae are univoltine, and about 85% of specimens hatch in spring or early summer.

The coleopteran fauna of Finland is well known, but little quantitative material exists from the coniferous forest floor. We therefore consider it valuable enough to publish our data from Site 4 (Harviala), identified in connection with a previous study (Huhta 1976). This material, together with the spider material from the same site, was used by Huhta (1979) in an evaluation of similarity indices as measures of succession after clear-cutting (Table 8).

The Staphylinidae is by far the most abundant family of Coleoptera in the coniferous forest soil. *Geostiba circellaris* and *Atheta myrmecobia* predominated in the spruce stand studied. *Amischa analis*, a species found only sporadically in the untreated stand, became very numerous after clear-cutting, and *Othius myrmecophilus* increased also. Curculionidae were rather abundant in the control forest but decreased after cutting. *Hylastes cunicularius* (Scolytidae) occurred especially numerously in the youngest clear-cut area (Table 8; see Huhta 1976 for site description).

3.8. Total biomass

Because sampling was not performed simultaneously at all study sites and for all animal groups, the total picture becomes somewhat complicated, but it can be constructed on the basis of the available data (Table 9).

The estimates for sites 1 and 2 come very close to each other (2.1−2.2. g d.w./m^2, while that for Site 3 is considerably lower (c. 1.3 g). The latter value is almost the same as in the Swedish pine stand (Persson et al. 1980). The higher estimates come closer to the average values for temperate coniferous forests compiled by Petersen & Luxton (1982) from several sources. It should be noted that earthworms play an essential role in contributing to the total biomass. At our study sites they were extremely scarce. If the earthworm biomass of two spruce forest sites in southern Finland (1.5 g/m^2; dry weight assumed to be 18% of fresh weight; Huhta & Koskenniemi 1975) were taken to be representative of Finnish forests and added to the present values, this would mean an additional contribution of 70−100%.

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Table 8. Mean numbers of Coleoptera (per m^2) at study Site 4 (Harviala). Plot 1 = untreated stand, plots 2–4 clear-cut areas 3,6 and 9 years after cutting, respectively. $n = 8 \times 8$ samples $\times$ units, size 625 cm^2 each.

Plots:	1	2	3	4
Calathus micropterus (Duftschmid)	8	2	6	1
Amara lunicollis Schiödte	-	-	12	6
Trichocellus placidus (Gyllenhal)	-	-	11	4
Acrotrichis intermedia (Gillmeister)	5	39	-	-
Othius lapidicola Kiesenwetter	6	8	9	-
O. myrmecophilus Kiesenwetter	22	79	110	10
Mycetoporus lepidus (Gravenhorst)	1	10	15	4
Mycetoporus splendidus (Gravenhorst)	27	-	1	-
Oxypoda annularis Mannerheim	16	7	146	-
O. soror Thomson	1	-	1	82
Liogluta letzneri (Eppelsheim)	13	-	-	1
Geostiba circellaris (Gravenhorst)	156	92	128	61
Atheta myrmecobia (Kraatz)	106	9	-	-
A. fungi (Gravenhorst)	3	1	23	-
Amischa analis (Gravenhorst)	4	148	315	193
Stenus clavicornis (Scopoli)	-	-	8	10
Corticaria impressa (Olivier)	-	13	-	-
Corticarina fuscula (Gyllenhal)	1	7	7	3
Anthicus ater (Panzer)	-	11	3	6
Chaetocnema hortensis (Fourcroy)	-	8	1	9
Otiorhyrchus scaber (Linnaeus)	34	16	2	2
Strophosoma capitatum (Degeer)	16	-	2	1
Hylastes cunicularius Erichson	1	107	2	-
Total	490	600	887	432

Table 9. Construction of biomass estimates (mg d.w./m^2) for the study sites. n.d. = not determined. The total biomasses have been obtained by summing the figures for the year when a given group was studied, and taking the mean values if both years were included. Missing values for Site 1 have been "loaned" by taking the averages of Sites 2 and 3. The years when only enchytraeids were sampled have been omitted.

	Site 1 Saarijärvi		Site 2 Tammela	Site 3 Tuusula	
	1979	1980	1980	1981	1982
Nematoda	n.d.	n.d.	68	46	n.d.
Enchytraeidae	557	1286	627	355	525
Lumbricidae	n.d.	53[1]	0	33	n.d.
Collembola	n.d.	n.d.	121	n.d.	92[2]
Oribatida	385	571	825	n.d.	288[2]
Mesostigmata	n.d.	98	115	n.d.	67[2]
Other mites	33	35	25	n.d.	9[2]
Macroarthropods	n.d.	441	313	346	n.d.
Total, mg d.w./m^2	2189		2094	1321	

[1] Includes a sample in Aug.–Sept. 1979.
[2] Samples taken in Sept. 1981, May and July 1982, and May 1983.

References

Abrahamsen, G. 1972: Ecological study of Enchytraeidae (Oligochaeta) in Norwegian coniferous forest soils. — Pedobiologia 12:26—82.

—"— 1973: Studies on body-volume, body-surface area, density and live weight of Enchytraeidae (Oligochaeta). — Pedobiologia 13:6—15.

Altmüller, R. 1979: Untersuchungen über den Energieumsatz von Dipterenpopulationen im Buchenwald (Luzulo-Fagetum). — Pedobiologia 19:245—278.

Andrassy, I. 1959: Die Rauminhalts- und Gewichtsbestimmung der Fadenwürmer (Nematoden). — Acta Zool. Acad. Sci. Hung. 11:1—15.

Byzova, Yu.B., (Бызова, Ю. Б.) 1964: Фауна почвенных ногохвосток и клещей севера среднеевропейской тайги (Fauna of soil springtails and mites in northern middle-european taiga). — Pedobiologia 3:286-303.

Forsslund, K.-H. 1943: Studier över det lägre djurlivet i nordsvensk skogsmark. — Medd. Stat. Skogsförsöksanstalt 34:1—266.

Hågvar, S. 1982: Collembola in Norwegian coniferous forest soils I. Relations to plant communities and soil fertility. — Pedobiologia 24:255—296.

— " — 1983: Collembola in Norwegian coniferous forest soils II. Vertical distribution. — Pedobiologia 25:383—401.

— " — 1984: Six common mite species (Acari) in Norwegian coniferous forest soils: Relation to vegetation types and soil characteristics. — Pedobiologia 27:355—364.

Huhta, V. 1965: Ecology of spiders in the soil and litter of Finnish forests. — Ann. Zool. Fennici 2:260—308.

— " — 1971: Succession in the spider communities of the forest floor after clear-cutting and prescribed burning. — Ann. Zool. Fennici 8:483—542.

— " — 1972: Efficiency of different dry funnel techniques in extracting Arthropoda from raw humus forest soil. — Ann. Zool. Fennici 9:42—48.

— " — 1976: Effects of clear-cutting on numbers, biomass and community respiration of soil invertebrates. — Ann. Zool. Fennici 13:63—80.

— " — 1979: Effects of liming and deciduous litter on earthworm (Lumbricidae) populations in a spruce forest, with an inoculation experiment on Allolobophora caliginosa. — Pedobiologia 19:340—345.

— " — 1984: Response of Cognettia sphagnetorum (Enchytraeidae) to manipulation of pH and nutrient status in coniferous forest soil. — Pedobiologia 27:245—260.

Huhta, V. & Koskenniemi, A. 1975: Numbers, biomass and community respiration of soil invertebrates in spruce forests at two latitudes in Finland. — Ann. Zool. Fennici 12:164—182.

Huhta, V. & Mikkonen, M. 1982: Population structure of Entomobryidae (Collembola) in a mature spruce stand and in clear-cut reforested areas in Finland. — Pedobiologia 24:231—240.

Huhta, V., Karppinen, E., Nurminen, M. & Valpas, A. 1967: Effect of silvicultural practices upon arthropod, annelid and nematode populations in coniferous forest soil. — Ann. Zool. Fennici 4:87—143.

Huhta, V., Nurminen, M. & Valpas, A. 1969: Further notes on the effect of silvicultural practices upon the fauna of coniferous forest soil. — Ann. Zool. Fennici 6:327—344.

Huhta, V., Ikonen, E. & Vilkamaa, P. 1979: Succession of invertebrate populations in artificial soil made of sewage sludge and crushed bark. — Ann. Zool. Fennici 16:223—270.

Huhta, V., Hyvönen, R., Koskenniemi, A. & Vilkamaa, P. 1983: Role of pH in the effect of fertilization on Nematoda, Oligochaeta and microarthropods. — Proc. VIII. Int. Coll. Soil Zool. 61—73. Louvain-la-Neuve.

Huhta, V., Hyvönen, R., Koskenniemi, A., Vilkamaa, P., Kaasalainen, P. & Sulander, M. 1986: Response of soil fauna to fertilization and manipulation of pH in coniferous forests. — Acta Forest. Fennica 195:1-*30*.

Huldén, L. (ed.) 1984: A check list of the Finnish insects. Small orders. — Notulae Entomol. 64:1—29.

Kaczmarek, M. 1975: An analysis of Collembola communities in different pine forest environments. — Ekol. Polska 23:265—293.

Karg, W. 1971: Acari (Acarina), Milben. Unterordnung Anactinochaeta (Parasitiformes). Die freilebenden Gamasina (Gamasides), Raubmilben. — Tierwelt Deutschlands 59:1—475.

Karppinen, E. 1955: Ecological and transect survey studies of Finnish Camisiids. — Ann. Zool. Soc. "Vanamo" 17(2):1—80.

— " — 1957: Die Oribatiden-Fauna einiger Schlag- und Brandflächen. — Ann. Entomol. Fennici 23:181—203.

— " — 1958a: Über die Oribatiden (Acar.) der finnischen Waldböden. — Ann. Zool. Soc. "Vanamo" 19(1):1—43.

— " — 1958b: Lierolajeistamme ja niiden esiintymisestä metsämaassa. — Luonnon Tutkija 62:137—144.

Karppinen, E. & Krivolutsky, D. A. 1982: List of oribatid mites (Acarina, Oribatei) of northern palearctic region. — Acta Entomol. Fennica 41:1—18.

Koskenniemi, A. & Huhta, V. 1986: Effects of fertilization and manipulation of pH on mite (Acari) populations of coniferous forest soil. — Rev. Ecol. Biol. Sol 23:271-286.

Kuznetsova, N. A. & Babenko, A. B. (Кузнецова, Н. А. & Бабенко, А. Б.) 1984: Многолетняя динамика численности коллембол в ельнике-зеленомошнике (Long-term dynamics of Collembola in a spruce forest). — In: Ghilarov, M. S. & Chernova, N. M. (eds.), Fauna i ekologia nogohvostok (Collembola):57—67. Moscow.

Leinaas, H.-P. 1978: Sampling of soil microarthropods from coniferous forest podzol. — Norw. J. Entomol. 25:57—62.

Lundkvist, H. 1982: Population dynamics of Cognettia sphagnetorum (Enchytraeidae) in a Scots pine forest soil in Central Sweden. — Pedobiologia 23:21—41.

Lussenhop, J. 1971: A simplified canister-type soil arthropod extractor. — Pedobiologia 11:40—45.

Macfadyen, A. 1961: Improved funnel-type extractors for soil arthropods. — J. Anim. Ecol. 30:171—184.

Magnusson, C. 1983a: Abundance and trophic structure of pine forest nematodes in relation to soil layers and ground cover. — Holarctic Ecology 6:175—182.

— " — 1983b: Abundance, distribution and feeding relations of root/fungal feeding nematodes in a Scots pine forest. — Holarctic Ecology 6:183—193.

Magnusson, M. L. 1982: Nematodes in some coniferous forests in Finland. Seloste: Nematodien esiintymisestä Suomen havumetsissä. — Commun. Inst. Forest. Fenn. 103:1—12.

Nordström, S., & Rundgren, S. 1973: Associations of lumbricids in Southern Sweden. — Pedobiologia 13:301—326.

Nurminen, M. 1967: Ecology of enchytraeids (Oligochaeta) in Finnish coniferous forest soil. — Ann. Zool. Fennici 4:147—157.

O'Connor, F. B. 1962: The extraction of Enchytraeidae from soil — In: Murphy, P. W. (ed.), Progress in soil zoology: 279—285. London.

Oostenbrink, M. 1960: Estimating nematode populations by some selected methods. — In: Sasser, J. N. & Jenkins, W. R. (eds.), Nematology: 85—102. Durham, N.C.

Persson, T. 1975: Markarthropodernas abundans, biomassa och respiration i ett äldre tallbestånd på Ivantjärnsheden, Gästrikland — en första studie. —

Swedish Coniferous Forest Project, Internal Report 31:1—35.
Persson, T. & Lohm, U. 1977: Energetical significance of the annelids and arthropods in a Swedish grassland soil. — Ecol. Bull. 23:3—211.
Persson, T., Bååth, E., Clarholm, M., Lundkvist, H., Söderström, B. E. & Sohlenius, B. 1980: Trophic structure, biomass dynamics and carbon metabolism of soil organisms in a Scots pine forest. — In: Persson, T. (ed.), Structure and function of northern coniferous forests — an ecosystem study. — Ecol. Bull. 32:419—459.
Petersen, H. 1975: Estimation of dry weight, fresh weight and calorific content of various Collembolan species. — Pedobiologia 15:222—243.
— " — 1978: Some properties of two high-gradient extractors for soil microarthropods, and an attempt to evaluate their extraction efficiency — Natura Jutlandica 20:95—122.
Petersen, H. & Luxton, M. 1982: A comparative analysis of soil fauna populations and their role in decomposition processes. — Oikos 39:287—388.
Silfverberg, H. 1979: Enumeratio Coleopterorum Fennoscandiae et Daniae. — 6+79 pp. Helsinki.
Sohlenius, B. 1979: A carbon budget for nematodes, rotifers and tardigrades in a Swedish coniferous forest soil. — Holarctic Ecology 2:30—40.
Sohlenius, B. & Wasilewska, L. 1984: Influence of irrigation and fertilization on the nematode community in a Swedish pine forest soil. — J. Appl. Ecol. 21:327—342.
Takeda, H. 1979: Extraction process and efficiency of Macfadyen high gradient extractor. — Pedobiologia 19:106—112.
Tanaka, M. 1970: Ecological studies on communities of soil Collembola in Mt. Sobo, southwest Japan. — Japanese J. Ecology 20:102—110.
Terhivuo, J. & Valovirta, I. 1978: Habitat spectra of the Lumbricidae (Oligochaeta) in Finland. — Ann. Zool. Fennici 15:202—209.
Valpas, A. 1969: Hot rod technique, a modification of the dry funnel technique for extracting Collembola especially from frozen soil. — Ann. Zool. Fennici 6:269—274.
Vilkamaa, P. & Huhta, V. 1986: Effects of fertilization and pH on communities of Collembola in pine forest soil. — Ann. Zool. Fennici 23:167—174.
Wasilewska, L. 1974: Vertical distribution of nematodes in the soil of dunes in the Kampinos forest. — Zeszyty Problemowe Postępów Nauk' Rolniczyh 154:203—212.
Wirén, A. 1975: Kvantitativa data för Collembolfaunan på Ivantjärnsheden, Gästrikland, samt några andra tallskogslokaler. — Swedish Coniferous Forest Project, Internal Report 25:1—13.

Appendix.

List of the less frequent species found in the samples. Numbers above the columns refer to study Sites 1, 2 and 3, except for Coleoptera (Site 4), for which 1 = untreated stand and 2 = clear-cut area. ≡ = New species to Finland.

Sites:	1	2	3
Collembola			
Willemia aspinata Stach		+	+
Pseudachorutes subcrassus Tullberg		+	+
P. dubius Krausbauer		+	
Anurida granulata Agrell		+	+
Neanura muscorum (Templeton)		+	+
Onychiurus sibiricus (Tullberg)		+	
O. armatus (Tullberg)		+	+
Pseudanurophorus binoculatus Kseneman		+	
Folsomia dovrensis Fjellberg		+	+
Proisotoma minima (Absolon)		+	
Isotoma viridis Bourlet		+	
I. hiemalis Schött		+	+
I. blekeni Leinaas		+	+
Orchesella flavescens (Bourlet)		+	+
Entomobrya nivalis (Linnaeus)		+	
Arrhopalites cochlearifer Gisin ≡)		+	+
Sminthurinus aureus (Lubbock)		+	+
Allacma fusca (Linnaeus)		+	
Dicyrtoma fusca (Lubbock)		+	+
Oribatida			
Phthiracarus piger (Scopoli)	+	+	+
P. globosus (C. L. Koch)	+		
P. italicus (Oud.)	+	+	+
Oribotritia loricata (Rathke)	+		
Euphthiracarus monodactylus (Willm.)	+	+	
Microtritia minima (Berl.)	+		
Parhypochthonius aphidinus (Berl.)	+		
Hypochthonius rufulus C. L. Koch		+	
Eulohmannia ribagai (Berl.)	+		
Camisia biurus (C. L. Koch)		+	+
C. segnis (Hermann)	+		
C. spinifer (C. L. Koch)	+		
Heminothrus paolianus Berl.	+	+	+
Platynothrus peltiger (C. L. Koch)	+		
Trhypochthonius cladonicola Willm.	+		
Nanhermannia nana (Nicolet)		+	
Cepheus cepheiformis (Nicolet)	+		
Liacarus coracinus (C. L. Koch)	+	+	+
Furcoribula furcillata (Nordensk.)		+	+
Ceratoppia bipilis (Hermann)	+	+	+
Carabodes femoralis (Nicolet)	+	+	+
C. labyrinthicus (Michael)	+	+	+
Oppia unicarinata (Paoli)	+		
O. minus (Paoli)	+	+	+
Autogneta parva Forssl.	+	+	
Calaremaeus monilipes (Michael)	+		
Liebstadia similis (Michael)	+		
Oribatula tibialis (Nicolet)	+		
Scheloribates laevigatus (C. L. Koch)	+	+	
S. pallidulus (C. L. Koch)	+		
Protoribates lophotrichus (Berl.)	+		
Melanozetes mollicomus (C. L. Koch)	+		
Eupelops planicornis (Schrank)	+		
Tectoribates latitectus (Berl.)	+		
Achipteria coleoptrata (Linnaeus)	+		
Galumna spp.	+	+	+
Pergalumna nervosus (Berl.)	+	+	+

Sites:	1	2	3	4
Mesostigmata				
Geholaspis longispinosus (Kramer)			+	
Amblyseius messor Wainstein			+	
Amblyseius jugortus Athias-H.		+	+	
Proctolaelaps robustus Evans	+	+		
Iphidozercon gibbus (Berl.)	+	+		
Asca aphidioides (Linnaeus)			+	
Gamaselloides bicolor (Berl.)	+	+		
Saprosecans baloghi Karg	+		+	
Rhodacarus coronatus Berl.+	+			
Rhodacarellus silesiacus Willm.			+	
Dendrolaelaps foveolatus (Leitner)			+	
D. arvicolus (Leitner)	+			
Stylochirus minor Willm.	+			
Pergamasus similis Willm.		+		
Veigaia exiqua (Berl.)	+	+	+	
Epicrius reticulatus (Grube)	+			
Microsejus truncicola Träg.		+		
Urodiaspis tecta (Kramer)	+	+		
Coleoptera				
Leistus ferrugineus (Linnaeus)			+	
Notiophilus palustris (Duftschmid)		+	+	+
N. biguttatus (Fabricius)	+	+		+
Pterostichus oblongopunctatus (Fabricius)	+			
P. diligens (Sturm)			+	+
Amara brunnea (Gyllenhal)	+			
Trichocellus cognatus (Gyllenhal)			+	
Bradycellus caucasicus Chaudoir	+	+	+	
Dromius sigma (Rossi)			+	
Agabus congener congener (Thunberg)	+			
Helophorus flavipes Fabricius				+
Sphaeridium lunatum Fabricius	+			
Cercyon pygmaeus (Illiger)				+
Hydnobius spinipes (Gyllenhal)				+
Leiodes punctulata (Gyllenhal)		+		
L. silesiaca (Kraatz)			+	+
L. obesa (Schmidt)			+	+
L. nigrita (Schmidt)				+
Amphicyllis globus (Fabricius)	+		+	
Agathidium seminulum (Linnaeus)	+	+	+	
Stenichnus collaris (Müller & Kunze)	+	+		
S. bicolor (Denny)			+	
Philonthus corvinus Erichson			+	
P. decorus (Gravenhorst)			+	+
P. cognatus Stephens			+	+
Euryporus picipes (Paykull)	+			
Quedius molochinus (Gravenhorst)				+
Q. limbatus (Heer)	+			
Gyrohypnus angustatus Stephens			+	+
Xantholinus tricolor (Fabricius)	+	+	+	+
X. clairei Coiffait	+	+		
Othius punctulatus (Goeze)	+	+		
Astenus gracilis (Paykull)			+	

Sites:	1	2	3	4
Lathrobium brunnipes (Fabricius)	+			
L. longulum Gravenhorst		+		
Omalium brevicolle Thomson	+			
Arpedium quadrum (Gravenhorst)				+
Acidota crenata (Fabricius)	+		+	
Anotylus nitidulus (Gravenhorst)		+		
Mycetoporus monticola Fowler			+	+
M. longulus Mannerheim			+	+
M. clavicornis (Stephens)			+	+
Lordithon thoracicus (Fabricius)	+	+		
L. lunulatus (Linnaeus)			+	
Sepedophilus constans (Fowler)			+	
S. pedicularius (Gravenhorst)			+	
Tachyporus obscurellus Zetterstedt		+	+	+
T. hypnorum (Fabricius)				+
T. chrysomelinus (Linnaeus)			+	+
Tachinus laticollis Gravenhorst	+			
Oxypoda skalitzkyi Bernhauer	+			
Schistoglossa gemina (Erichson)			+	
S. curtipennis (Sharp)				+
Drusilla canaliculata (Fabricius)	+		+	
Stenus impressus Germar	+			
S. palustris Erichson	+			
Bibloplectus ambiguus (Reichenbach)				+
Trimium brevicorne (Reichenbach)	+		+	+
Pselaphus heisei Herbst			+	
Aphodius fimetarius (Linnaeus)	+			
Lampyris noctiluca (Linnaeus)				+
Rhagonycha atra (Linnaeus)	+			
Athous subfuscus (Müller)		+		
Cidnopus aeroginosus (Olivier)		+		
Dalopius marginatus (Linnaeus)		+		
Simplocaria semistriata (Fabricius)		+		
Cryptophagus setulosus Sturm		+		
Atomaria contaminata Erichson		+		
A. peltata Kraatz		+		
A. umbrina (Gyllenhal)		+	+	
Scymnus haemorrhoidalis Herbst			+	
Coccinella septempunctata Linnaeus		+		
Calvia quattuordecimguttata (Linnaeus)			+	
C. quattuordecimpunctata (Linnaeus)				+
Myzia oblongoguttata (Linnaeus)	+			
Thea vigintiduopunctata (Linnaeus)	+			
Corticaria umbilicata (Beck)			+	
C. serrata (Paykull)		+		
Cortinicara gibbosa (Herbst)			+	
Lythraria salicariae (Paykull)			+	+
Platystomos albinus (Linnaeus)	+			
Cimberis attelaboides (Fabricius)	+			
Brachysomus echinatus (Bonsdorff)	+	+		
Hylobius abietis (Linnaeus)	+	+	+	
H. pinastri (Gyllenhal)	+	+		
Hylurgops glabratus (Zetterstedt)			+	
H. palliatus (Gyllenhal)			+	
Hylastes brunneus Erichson	+	+		
H. opacus Erichson	+	+	+	

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