Population of soil-dwelling invertebrates of the old-growth spruce forests of the Nature Reserve Friendship

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Objectives

- To study the structure, dynamics and biodiversity of soil invertebrate population of old-growth forest in northern boreal zone of Fennoscandia (with details for spruce forest in Friendship Park).
- To compare the soil populations of the Nature Reserve Friendship with the populations of other parts of the northern boreal zone.
- To find a correlation within various parts of population and due to soil conditions of the region.
- To give an assessment of biodiversity of main soil systematic groups of old-growth forests at the investigated area.
- To find out different factors which affect the soil population.

Methods

The first and main type of the watershed spruce forest is Picea abies - Hylocomium splendens - Vaccinium myrtillus and V. vitis-idea type.

The second type is the spruce forest along brooks which is obviously more diverse. The most common type of this forest is Picea abies - Athyrium filix-femina (or Thelypteris phegopteris) - Equisetum palustre - Rhytidiadelphus triquetrus type.

For studying the soil fauna population we used standard soil zoological methods such as estimations with the usage of hand-sorting method at the samples which as big as 0.0625 m² (“total” estimation). 8 or 16 soil samples per plot have been taken. The other method is the estimation of forest floor and litter fauna (the herpetobios) with the usage of Barber pitfall traps (the dynamic density assessment).

The red hill ants are the most important component of all the old-growth forests of the investigated area. In Taiga zone at the relatively little disturbed landscapes the amount of the red hill ants can be significant. In such a case the ants don’t live in single colonies but in highly organized settlements like federations which look like some series of connected ant-hills (Захаров 1991). The same settlements of ants were found in our investigations in North Karelia in Kostomuksha Nature Reserve, and in Friendship Park in Finland. The most common species here is Formica aquilonia and sometimes also F. polyctena.
When making an assessment of the biodiversity of soil fauna, it is necessary to take into consideration the influence of the settlements of the red hill ants. To determine the amount of the ants at the investigated plots direct counting and mapping of the anthills in plots with the size of 2–2.5 ha was made. On the sites the diameter of the outer side of the anthills was determined, and the amount of ant routes coming out of the hills was counted (3ахаров 1978).

To compare the results, data collected by the author in the Yenisei Taiga region at the same North Taiga zone (according to the Russian classification) was used.

**Results and discussion**

Usually, the primary assessment of the soil fauna is made in accordance with the total indexes of the numbers and biomass of the invertebrates. It is summary level reflected total condition of soil.

In comparison with the other population of North Taiga (the lowest density is 90-120 ind/m² and the highest density is 250-300 ind/m²), all the investigated soil groups in this case are characterized by low and middle densities of the invertebrates. The biomass of the soil communities is also relatively low: 1-2 g/m² for the most typical old watershed spruce forests, and the highest values of biomass - 3.2-4.5 g/m² for the spruce-tree forests near brooks. It points at relatively poor soils and relatively young (undeveloped) soil cover of this part of Karelia. When compared with investigations made in some North Taiga areas of Siberia, the value of such indexes as the average density and biomass are much lower then the same ones in North Taiga communities of European and Asian parts of Russia. The average value of the invertebrate densities in Yenisei Taiga is 1.2–1.5 times more and the biomass is 2-5 times more than in Karelia.

The comparison of the compositions of systematic groups (the level of orders and families) shows that:

Like in the majority of the communities of Kostomuksha Nature Reserve and Friendship Park, the soil fauna composition of the investigated area is rather similar at the level of families as well as at the level of genus and species. So, in the majority of soil population the most numerous groups were only four systematic groups: spiders (Aranei), larvae of Staphylinidae, larvae of Curculionidae and larvae of Elateridae. In some years there were also found rather numerous amount of larvae of Cantharidae and Lithobiomorpha - Lithobiidae.

Among them, the spiders (Aranei) predominated completely in all the coenoses. We shall take into consideration that these groups are the most common in the most Taiga communities of Eurasia, too.

But in many complexes of European and Siberian Taiga the other groups such as earthworms, Lithobiomorpha, Geophilomorpha, Opiliones, Carabidae, etc. are also diverse.

The species composition of forest litter and soil population of the area is not very diverse either. In all the investigated biocoenoses in many groups of the invertebrates there were found a few species. For example, it was found only one species of the earthworms - *Dendrobaena octaedra* (in Siberia in the same zone there were 3 of them) and as for the Lithobiidae, it was also found only one species: *Monotarsobius curtipes* (and 3 in Siberia) and 2-3 species of larvae of Elateridae and two the most common species - *Paranomus costalis* and *Atheta subfuscus*, and sometimes *Selatosomus impressus*.

In the territory of the National Park Friendship found 6 species of Elateridae were found. In Siberia in the same types of forest sites 10 species were found. In the traps and soil samples of the investigated area there were found 16 species of Carabidae. Only 5 of them were really common in the spruce forests: *Calathus micropterus*, *Cychrus caraboides*, *Carabus glabratrus*, *Notiophilus reitteri*, *N. biguttatus*. In some years among them were also found *Pterostichus oblongopunctatus* and *Patrobus atrorufus*. To compare it, in the old-
growth forests of Yenisei taiga we found 18 species. In accordance with the data of Boris Kashevarov, during 15 years of investigations of all the biotopes in general (including the meadows) there were found 56 species of ground beetles (Kashevarov 1995, Кашеваров 1999). And in comparison with Yenisei taiga, there were found 120 species (Рыбалов 1997).

Almost all the above-mentioned species which are typical for the old-growth spruce-tree forests of the National Park Friendship refer to the group of the forest mesophylile.

So, the amount of species in different systematic groups living in old-growth of this part of Fennoscandia is 2-3 times less than in the same old-growth forests of North Taiga in Siberia.

An exception from the general rule of “species poorness of soil population” were two systematic groups, Aranei and Staphylinidae. Until now in the collections from all the investigated forest biocoenoses of Kostomuksha Reserve and Friendship Park 135 species of Aranei and 108 species of Staphylinidae were found. In old-growth forest there were about 25-40 species in each group. In comparison, the diversity of the same groups of the soils of old-growth forests of Siberia is not too much bigger: in Siberian taiga were found 140 species of Aranei and 120 species of Staphylinidae.

In 1995-1999 106 species of Aranei and 105 species of Staphylinidae were found in Kostomuksha Reserve. At the Finnish territory of Friendship Park during the two years of collection of materials (1998-1999) 51 species of spiders and 101 species of Staphylinidae were found. So, the amount of spiders which were found in the forest soil of Kostomuksha Reserve is larger than at the Finnish part of “Park Friendship”. Probably, this difference will reduce after further investigations at the Finnish territory.

In the old-growth spruce watershed forests with green moss and cowberries in Kostomuksha Reserve 35 species of spiders were found. The total amount of spiders in the spruce forest of this type varied within 30-100 ind/m². The following species dominated here: Robertus scoticus, Asthenagus paganus and Centromerus arcanus. Relatively numerous were also Porrhomma pallidum and Hilaira herniosa. Until now in Finland in Friendship Park, in the same kind of spruce forests, two times less spider species than in the territory of Kostomuksha Reserve, only 15 species, were found. The spider population in the Finnish forests is very similar to the spider population in Kostomuksha Reserve. The composition of the dominant species, Robertus scoticus, Asthenagus paganus, Centromerus arcanus and Tapinocyba pallens, is just the same in both territories. Some differences of Aranei population at the Finnish territory are found only within the groups with smaller amount of species.

In the old-growth spruce forests near brooks in Karelia 25 species of spiders were found. With the common dominant species Asthenagus paganus, Centromerus arcanus and Tapinocyba pallens, which are typical for all the spruce forests of this territory, such species as Tenuiphantes alacris, T. tenebricola, Hilaira herniosa and Robertus lividus also dominated in some years.

In Kostomuksha Reserve in the old-growth watershed spruce forests with green moss and cowberries, 26 species of Staphylinidae were found. The amount of Staphylinidae in the above mentioned old-growth spruce forests varied from 12 (1997) to 42 (1995) ind/m². The structure of the population of Staphylinidae in the spruce forests varied insignificantly year after year, the same dominant species were noticed during all the period of our investigation. In the watershed spruce forests there were the following dominant forest mesophyla species: Atheta myrmecobia, Oxypoda annularis, Othius myrmecophilus, Othius lapidicola and Liogluta micans. In some years relatively numerous were also Quedius fulvicollism and Stenus flavipalpis. The dominant species were obviously seen in comparison to the other population and the Shannon diversity index shows this comparison as well. For the Staphylinidae of the spruce forests with the green moss (of both territories) the Shannon index was 2,2-2,3.
In Finland in Friendship Park in the same type of spruce forests 20 species of Staphylinidae were found. The amount of Staphylinidae in the old-growth forests in the Finnish territory varied within approximately the same limits, 20-50 ind/m². The composition of the dominant species included almost the same species. The most numerous of them were Oxypoda annularis, Atheta myrmecobia and Liogluta micans, and the subdominant species were Othius lapidicola and Othius myrmecophilus.

In the spruce forests near brooks in both territories the amount (12-25 ind/m²) and diversities (14 species) were slightly lower than in the watershed forests. At the same time, relatively more numerous in such communities of Kostomuksha Reserve were Atheta myrmecobia and Othius lapidicola, and in the Finnish part two more species: Liogluta micans and Oxypoda annularis. The population of Staphylinidae of the spruce forests near brooks is more even in comparison with the watershed spruce forests which is reflected by Shannon index - its value is higher here (2.6-2.7).

As well as species diversity of old-growth forests in general, the diversity of population of a particular forests is low. Only one or (rarely) two species of every concrete systematic group predominated among the whole population of a particular biocoenosis during the period of study. For example, the absolute dominant among the ground beetles was Calathus micropterus (compare Kashevarov 1999). Among Elateridae in all the spruce forests Atheta myrmecobia and Oxypoda annularis predominated. The most common species among Staphylinidae in the spruce forests was Atheta myrmecobia and sometimes Oxypoda annularis. Among the forest litter and soil spiders in the spruce forests Atheta myrmecobia and sometimes Oxypoda annularis.

Evaluation of soil groups of different types of spruce forests of the Friendship Park and their further comparison with North taiga forest was also made with the usage of Shannon diversity index. The meaning of these indices confirms obvious decline of diversity in the forests of Karelia in comparison with the Siberian forests. In the forests of the Friendship Park this index usually was 2.2 - 2.5 and in Siberian old-growth forests in the similar groups it was 3.0 - 3.2. Such an index shows not only diversity but also “the degree of equality” of the group composition, as it is shown from the given data, “the degree of equality” in Siberian forests is obviously higher, so it shows a smoother species domination.

Another important feature of soil fauna is typical for this region of Karelia: in the watershed spruce biocoenoses participate some groups of saprophiles, first of all, the earthworms. Among earthworms only a forest litter species Dendrobaea octaedra was found. This species don’t play a significant role in the process of decomposition of forest litter and humus accumulation. Some saprophages in these spruce forests were scanty such as the larvae of Diptera - Tipulidae and Bibionidae. Relatively low activities of saprophages of soil fauna of the watershed spruce forests decreases the rate of organic decomposition and changes of humus type in the spruce forests. The humus type called Mor prevails there.

The most distinctive soil groups were found in the old-growth spruce forests near brooks where the highest indices of density and biomass were noticed. Also there were found the highest diversities of the soil groups and species among all the investigated communities of the old-growth forests in Karelia. It is refers to all the levels, total indexes abundance, biomass, diversities within families, and species of some groups. In such a type of spruce forest some saprophile groups prevail among the soil invertebrates, such as earthworms and larvae of Sciaridae, Bibionidae and Tipulidae. The soil invertebrates are more active there and have obviously deeper penetration into the lower layers of the soil. The densities of soil fauna and especially the soil saprophages allow to form the mull layers.

Among the other species which inhabit this spruce forest there are many species which are common in the south such as Aloconota sulcifrons, Geostiba circellaris (Staphylinidae), Trechus rivularius (Carabidae), Dolopius marginatus (Elateridae), Allomengea scopigera, Leptorhoptrum robustum and Maro sublestus (Aranei). On the basis of the research
data it can be considered that the population of the old-growth forest along rivers and brooks is relatively “southern” with the tendency to settle in the mid-taiga subzone. Such conclusion is based on some of the above-mentioned indicators and the presence of some “southern” species of the invertebrate.

But of all the investigated biocoenoses of the Kostamuksha Reserve and Friendship Park, the most diverse group was found not in an old-growth site but in a mixed birch tree forest which is gradually being replaced by a spruce forest. Here we found the highest possible amount of microbiontopes.

In all studied old-growth forests, numerous settlements of the red hill ants (*Formica aquilonia* and *F. polyctena*) of federative type were found. It can bring obvious changes into the composition of the populations of soil invertebrates and change the amount of some species, especially the predators.

At every plot there are biotopes which are good for the ants and there are biotopes which are almost unfavorable for them. There is a lot of variation in the densities of the ant settlements (Tables 1-2). All the plots in the table 1 are placed in accordance with increasing of the amount of ants. In the communities where the ant estimations were made it was found out an obvious tendency of increasing of the predatory invertebrate densities in the line of the plots 1-4. This data correlate with the gradual decrease of the ant densities (Table 1).

Such a phenomenon connects with the densities of the Carabidae, Aranei and Staphylinidae - the main predatory groups of the forest litter complex. If the amount of the ants decreases the biomass of the predatory invertebrates increases with the highest rate (more than in 2 times) and the amount increases with a less rate - in 1,2 - 1,5 times (table 2).

**Table 1. The main characteristics, showing the ant densities at the 4 investigated plots.**

<table>
<thead>
<tr>
<th>Plots</th>
<th>The area of the plot</th>
<th>The amount of the ant-hills</th>
<th>The amount of the columns in general</th>
<th>Total area of the ant-hills</th>
<th>Total area of the ant-hills/1 ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce forest N1</td>
<td>3,24(2,84)</td>
<td>12</td>
<td>50</td>
<td>12,59</td>
<td>5,27 (4,73)</td>
</tr>
<tr>
<td>Spruce forest N2</td>
<td>4,2(2,35)</td>
<td>8</td>
<td>41</td>
<td>7,43</td>
<td>3,77 (3,03)</td>
</tr>
<tr>
<td>Spruce forest N3</td>
<td>4,68(4,68)</td>
<td>8</td>
<td>34</td>
<td>5,03</td>
<td>2,50 (2,30)</td>
</tr>
<tr>
<td>Spruce forest N4</td>
<td>4,32(3,6)</td>
<td>5</td>
<td>26</td>
<td>3,1</td>
<td>1,18 (1,42)</td>
</tr>
</tbody>
</table>

1) in the brackets is the area, which suits for the ant foraging; 2) in the brackets is the area of the ant settlements per ha which suits for the ant foraging at a part of a site.

**Table 2. The amount (ind/m²) and the biomass (mg/m²) of the predatory invertebrates in summer 1997 and 1998 in different biocoenoses of Kostomuksha Reserve**

<table>
<thead>
<tr>
<th>Plots</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The amount of the predators</td>
<td>80(47)</td>
<td>108(55)</td>
<td>122(62)</td>
<td>160(72)</td>
</tr>
<tr>
<td>The biomass of the predatory groups in general</td>
<td>92 (8)</td>
<td>120 (12)</td>
<td>148 (17)</td>
<td>332 (25)</td>
</tr>
</tbody>
</table>

Comments. 1) in the brackets % of total number and biomass.

Increasing of the biomass of the predatory groups and decreasing of the amount of ants in the absolute numbers as well as in the percentage can be seen. Such a tendency remains during the three seasons. This study showed the correlation of the dynamic density of the ground beetles and the densities of the ants especially for the similar (in accordance with their hydrothermal conditions) plots. The lowest level of the ground beetles density was found in the spruce forest with highest level of abundance of ants.
Besides the increasing of Carabidae density, their species composition also changed. In the spruce forest where the maximal density of the ants was observed, three species were found, and only one of them dominated, *Calathus micropterus*. This is the species which prefers the deeper (to compare it with the ants) layers of the forest litter. In the forest with low density of ants more diverse communities of Carabidae (7 species) were found. Having similar ecological niches with the ants, these species of the ground beetles are their competitors.

References