ZONAL AND LATITUDINAL PECULIARITIES OF SOIL INVERTEBRATE COMMUNITIES OF SIBERIAN FOREST ECOSYSTEMS

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ABSTRACT

Studies were carried on Zonal and Latitudinal peculiarities of soil invertebrate communities of Siberian ecosystems. The results obtain are very important for assessing the contribution of eco-components. Results show that zonal-latitudinal structure of soil population is determined by climatic factors on the area. Research also emphasises the impact of edaphic-climatic conditions for the development of large invertebrates.

Key Words : Invertebrate, Ecosystem, Natural zone, Edaphic-climatic conditions, Cryogenic factors

INTRODUCTION

Carrying out the large- scale complex ecological studies in the IGBP context on megatransects (the Russian European and the Yenisei transects), which intersect several natural zones, promotes to revealing the mechanisms of impact of local and global ecological factors on biological diversity and to assessing the contribution of some ecosystem components to the ecosystem processes. Zoological studies on the ecological transects have their own specific tasks[8]:

1. assessing the direct impact of ecological factors on the structure of zoopopulation;
2. assessing the change of biotic relations (trophic links, competition, mutualistic relations) in zonal gradients;
3. studying the ecotone effects and assessing the role of ecotone zooms in the total flux of energy and bioproductivity.

This presentation is a part of complex ecological studies performed on the Yenisei meridional transect beginning from the year 1996 to present time.

Study objective is to give the ecological-trophical characteristics of soil invertebrate zooms in forest ecosystems of forest tundra and taiga zone of Central Siberia.

MATERIAL AND METHODS

Heat (radiation balance) and moisture values as well as their ratio are the main factors of geographic zonality **(Fig. 1a)**. At the same time the latitudinal- zonal regularities may be greatly modified by regional climate and geomorphology peculiarities as well as by forest growing characteristics.

Our studies were realized in forest tundra in spruce and larch open forests formed on cryosols turbic (68ºN 86ºE); in northern taiga in larch forests on podburs (65ºN 89ºE); in

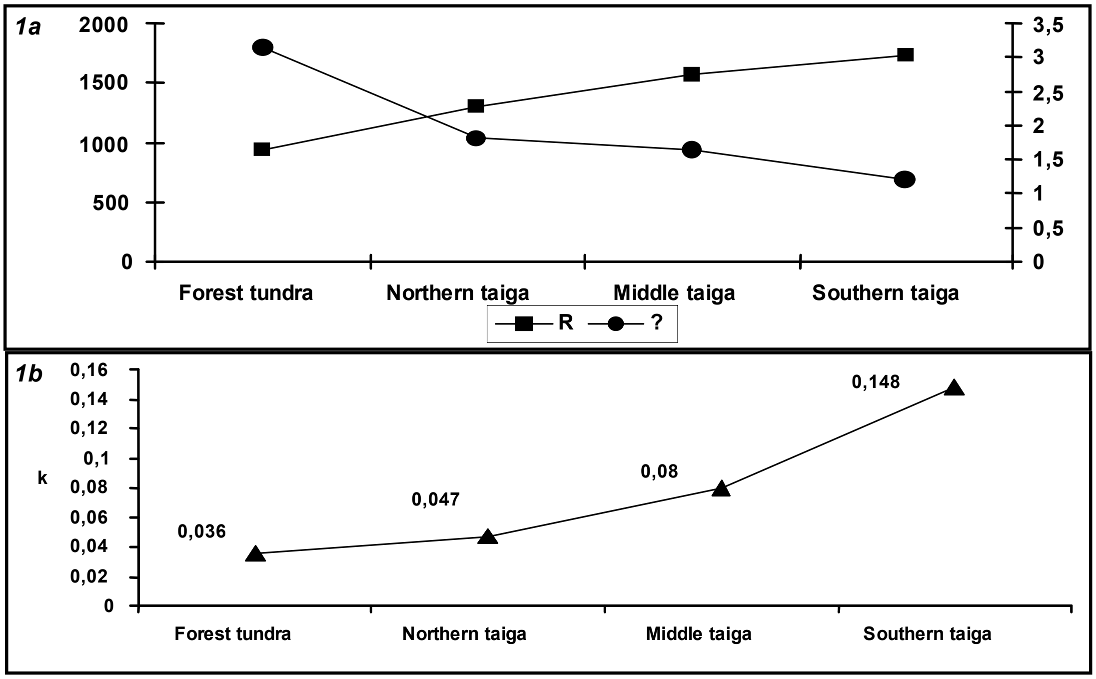

Fig. 1 : Zonal change of climatic characteristics (1a) and decomposition constant (1b): R – radiation balance, K – moistening coefficient [9]; k – decomposition constant [11]

middle taiga in pine forests on podzols rustic (60ºN 89ºE); in southern taiga in pine forests on podzols haplic (58ºN 98ºE) as well as in pine, spruce, birch and aspen forests formed on phaeozems (56ºN 92ºE).

The main physical- chemical properties of studied soils have been presented in the **Table 1**. Presence of the high bedding (18-55 cm) frozen aquifuge is characteristic of cryosols turbic and soil horizons above permafrost are characterized by combination of low temperatures and moisture excess[5]. The podzols rustic are formed under good drainage and differ in thawing the frozen earth up to 200 cm. They get warmed thoroughly and even get too dry in the lichen layer (the main invertebrate habitat) in the middle of vegetation period. The light granulometric composition of podzols haplic determines their low water retaining capacity and fast drying up in summer. In addition to moisture excess the low content of nitrogen and calcium in combination with low pH is also a limiting factor[1]. Phaeozems differ in high nutrient content and moisture supply resulting from the heavier granulometric composition.

Direct methods conventional in soil-zoological studies were used to control macroedaphon representatives (*Lumbricidae, Enchytraeidae, Myriapoda, Arachnida, Insecta*): the layer- to- layer sampling with the following taking samples to pieces using columns of soil sieves[4,7]. Samples (sized 25x25 cm) were taken on each sample plot in fivefold replication in layers: litter, 0-5 cm, 5- 10, 10-20, 20- 30, 30-40 cm. Depth of sampling varied

Table 1 : Main physical- chemical soil properties in forest ecosystems of Central Siberia

Depth, cm	Humus, %	N, %	Exchanges, mg-eq/100gr				pH	
			Ca	Mg	H	Al	H_2O	HCl
Cryosols turbic								
0-10	80.6*	1.290	12.4	5.2	0.940	2.110	4.4	3.4
10-17	18.5	0.938	19.2	7.5	0.042	0.049	5.3	4.2
>17	11.7	0.582	16.7	8.4	0.008	0.008	5.6	4.1
Podzols rustic								
0-12	88.9*	-	6.7	2.7	1.830	0.035	4.6	3.7
12-21	6.7	0.341	9.9	5.6	0.173	4.140	5.3	4.0
21-31	1.4	0.177	15.7	8.9	0.086	0.087	6.3	4.6
Podzols haplic								
0-5	78.7*	0.092	-	-	-	-	3.6	2.8
5-10	0.31	0.012	-	-	-	-	4.6	3.7
10-20	0.52	0.012	-	-	-	-	4.9	4.1
20-30	0.45	0.024	-	-	-	-	5.3	4.5
Phaeozems								
0-2	-	1.072	4.9	3.2	1.690	0	6.4	5.9
0-14	12.5	0.636	21.7	5.8	0.045	0.005	6.0	5.1
14-19	4.6	0.216	14.6	4.0	0.023	0.009	6.0	4.9
19-27	1.6	0.084	11.4	6.3	0.023	0.023	5.7	4.5
27-45	1.3	0.065	17.3	13.5	0.027	0.820	5.0	3.8

depending on depth of active inhabited layer: in forest tundra and northern taiga – up to 20 cm, in the middle taiga – up to 10 cm, and in southern taiga – up to 40 cm. The registering of soil microarthropods (mesoedaphon): springels (*Collembola*), oribatids (*Oribatei*) and (*Gamasina*) mites. Samples were taken by coring tube (d = 5 cm) in the litter, in 0-5 and 5-10 cm mineral soil layer in tenfold replication. Extracting was performed using the Tulgren's eclectors[3,7].

Large and small invertebrates were sampled during the most biologically active period of time depending on the zone: in forest tundra and northern taiga sites in July, in middle taiga – in July- August, in southern taiga – in June, July and August.

RESULTS AND DISCUSSION

Climate continentality of Central Siberia, available cryogenic factor, the well expressed topography forms which result in high variability of biotopic conditions determine zonal structural- functional peculiarities of soil population in forest ecosystems of the Yenisei transect. The density of macroedaphon increases from forest tundra cryosols to phaeozems of southern taiga more than 3 times reaching its maximum (999 number/per m^2) in leafy communities on phaeozems **(Fig.2)**. The minimum amount (75 number/ m^2) is characteristic of podzols haplic of middle and southern taiga. If within zone (subzone) the varying the density of large invertebrates is determined by thickness and storage of ground vegetation and litter in local sites (R^2 = 0.25-0.81), then interzonal distinctions of the macroedaphon are not related with such parameters of environment ($R^2 < 0.20$).

Analyzing distribution of pedobionts along latitudinal temperature gradient in the tropics *Lavelle P.*[6] has concluded that density increase of large invertebrates results in reduce of density of microartropods.

Some researchers believe that representatives of micro- and mesofauna dominate, as a rule, in soils of those ecosystems where climatic conditions limit biological activity since they have a well developed ability to survive in such severe environmental conditions as low temperatures or moisture deficit[2,10]. Under lack of development of soil macropopulation the small invertebrates experience the minimum stress from large anthropods- carnivores and do not compete with large saprophages for nutrition.

Mesoedaphon of studied sites at the Yenisei transect has not a clearly expressed latitudinal- zonal trend – the density of microarthropods in cryogenic soils of forest tundra and northern taiga (13.4 thousand ind/ m^2) is close to that one in southern taiga soils (20.9 thousand ind/m^2). Probably, the so called edaphic- climatic compensation of factors takes the place here, when different combination of climatic and soil characteristics in aggregate form the close ecological conditions. The mesoedaphon reaches its maximum (24- 31 thousand ind/ m^2) in podzols haplic where the edaphic- climatic conditions limit the development of pedocomplexes of large invertebrates.

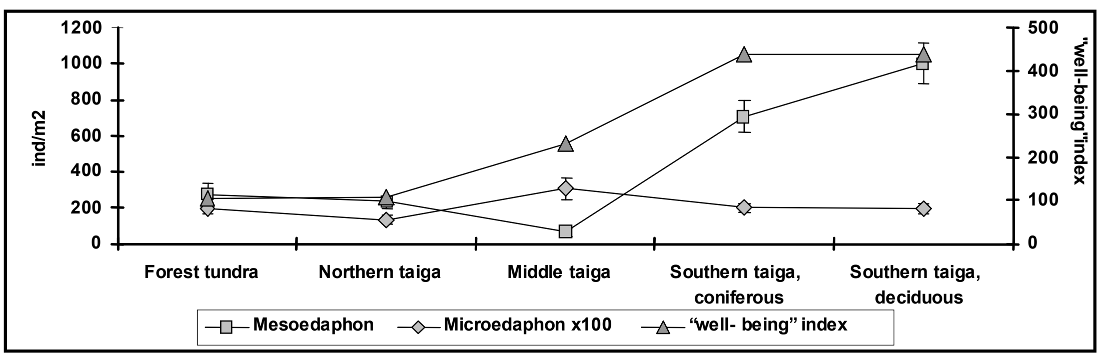

Fig. 2 : Ratio of density of micro- and mesoedaphon and "well- being" index in zonal sites of Central Siberia

The main environmental factors which determine the distinctions in abundance and structure of soil inhabitants at the local level the stores of the grassy- dwarf shrub layer, moss- lichen cover, thickness and storage of litter. The Redundancy Analysis (RDA) was used to assess the role of these environmental parameters in forming the edaphon of the transect forest ecosystems. The analysis of varying the stocks of the grassy- dwarf shrub layer, litter and moss- lichen cover has shown that they are responsible for 33% ($p = 0.04$) of varying the edaphon of the transect forest ecosystems **(Fig. 3)**. The mesoedaphon of middle and southern taiga has a negative correlation with the chosen variables. The close location of macroedaphon to crossing of axes demonstrates some tolerance to these environment parameters and formation of latitudinal- zonal peculiarities of macroedaphon is not determined by these characteristics of sites.

Ecological regime which determines formation and functioning the soil invertebrates may be shown through the so called "well- being index". The obtained correlation of the index with the macro- and mesoedaphon abundance reflects the specificity of ecological range of invertebrates **(Fig. 2)**. For its obtaining the zonal characteristics of coefficient of

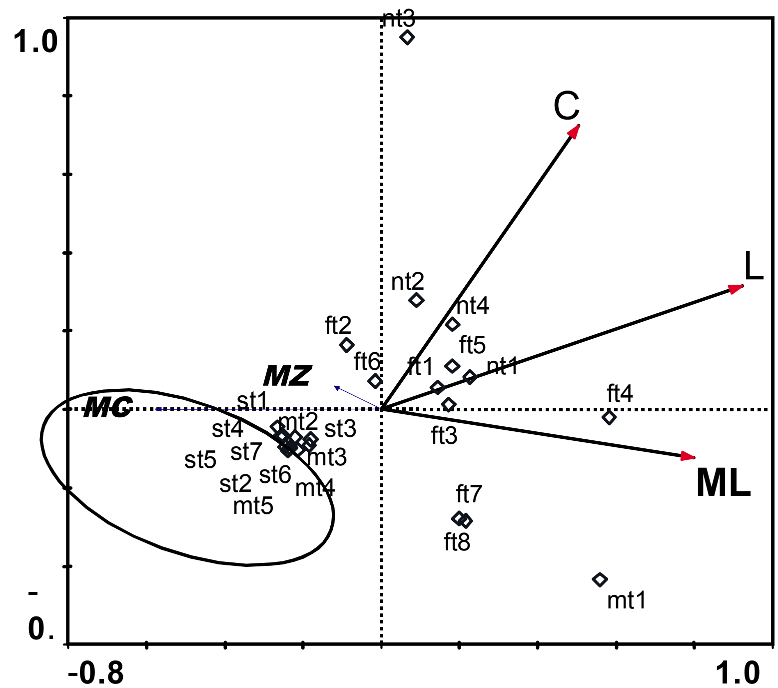

Fig. 3 : Dependence of edaphon density (MC – macroedaphon, MZ – mesoedaphon) on stocks of the grassy- dwarf shrub layer (C), litter (L) and moss- lichen cover (ML) based on RDA ordinates. Forest tundra – ft; northern taiga – nt; middle taiga – mt; southern taiga – st.

moistening, sum radiation balance and decomposition constants are used : $\mathbf{A} = \mathbf{k} \times \mathbf{R} \times \mathbf{K}$, where R – the sum radiation balance; K–coefficient of moistening **(Fig.1a)**; k = decomposition constant **(Fig.1b)**. The most pessimal conditions for edaphon development have been formed under forest tundra and northern taiga conditions. In middle taiga sites the "well-being index" correlates with maximum density of mesoedaphon what emphases its dominating role in ecosystem processes under xerophilous conditions. In southern taiga sites where the decomposition processes proceeds more actively against a background of optimal combination of heat and moisture the maximum favorable conditions are formed for macroedaphon development. It is reflected on functional activity of large invertebrates in coniferous and deciduous sites of southern taiga.

The "well- being index" explains 35% of latitudinal- zonal macroedaphon varying (R^2 = 0.35). The more weak link (R2 <0.10) of the mesoedaphon and index is determined by indirect participation of small invertebrates in decomposition processes as well as by the more expressed dependence on microclimate of local sites of the transect as distinct from large invertebrates.

The limiting role of cryogenic factor in the north and that one of moistening regime in the south is characteristic of the studied area. Regarding to the moistening factor we can emphasize two variants of macroedaphon structure which differ in dominants: "mesohygrophilous" with dominating worms and "xeroresistant" with a large part of insects having a shot development cycle and resistant to moisture deficit. The small share of worms (4- 15%) and large share of insects (41- 73%) reflect pessimal conditions for invertebrates which are formed in podzols of middle and southern taiga **(Fig. 4a)**.

The maximum of *Oribatei* (86%) and a sharp weight reduce of springels up to 6% against 50% in forest tundra soils **(Fig. 4b)** is noted among microarthropods for podzols of middle and southern taiga with maximum of these invertebrates. At the same time *Oribatidi* (51-70%) dominate in the mesoedaphon of northern zooms as in the majority of boreal forests and at the southern line of taiga zone the shares are equally divided between springels and mites.

The character of edaphic- climatic conditions determines latitudinal- zonal peculiarities of functional structure of edaphon in forest ecosystems. All along the transect in the edaphon of forest ecosystems the 87- 99% fall on saprophages. The saprotroph complex has features typical of taiga zone, it means the great share (89- 100%) of microphages (mites and springels) which use soil algae, micromycetes, bacteria and the small share (<1%) of primary litter destructors.

In zooms at the southern line of southern taiga the appearance of obligatory representatives of primary destructors (*Diplopoda*) has been noted but in the total abundance their share remains too low. The saprophages are getting more diverse beginning from the forest tundra to the southern line of taiga zone: the complex of large detritophages (*Lumbricidae, Enchytraedae, Insecta larva*) is being formed, its contribution to the total edaphon abundance is increasing from 0.5 to 4%. In the edaphon of podzols in middle and southern taiga the large saprophages are absent and the destruction block is solely presented by microarthropods. The zoophages share in the total edaphon abundance does not exceed 12%, the small *Gamasina* and also ground *Aranei* and *Coleoptera* have the most shares among them.

CONCLUSION

The analysis of latitudinal- zonal peculiarities of edaphon formation in forest ecosystems of Central Siberia has shown that, on the one hand, the latitudinal- zonal structure of soil population is determined by climatic factors on this area, on the other hand, at the regional level the edaphic- climatic conditions have a prevailing impact. The macro- and mesoedaphons have shown an asynchronism of their development – maximum of microarthropods is noted in the sites where the edaphic- climatic conditions limit development of large invertebrates. Edaphic peculiarities of phaeozems combining with climatic conditions of southern taiga result in maximum of large invertebrates. The structure of most local invertebrate communities differs in prevailing the surface inhabiting and underlying forms, soil block evolution is characteristic of phaeozems of southern taiga sites. Dominating saprophilous complex with the complex of secondary organic matter destructors is characteristic of the whole edaphon of Central Siberian forest zone. Saprophilous block reaches its maximum development under southern taiga regime in zooms being formed on soils with heavy granulometric structure.

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