Chapter 13

Biodiversity of Floodplain Soils in the European North-East of Russia

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Abstract

River floodplains are unique nature landscapes. In contrast to zonal communities on watersheds, soil biota of river floodplains is studied in less degree. The research was conducted in the floodplain forests in the European North-East of Russia and showed high diversity of soil biota in alluvial forest soils. Floodplain forest soils are inhabited by 70 species of micromycetes, 53 genera of Nematoda, 60 species of Collembola, and 110 species of large invertebrates. Alluvial meadow soils with stable moisture and temperature conditions are characterised by high species diversity of micromycetes, nematodes and large invertebrates. Collembola prefer alluvial soddy soils. Soil microorganisms, meso- and macro-fauna can essentially increase taxonomic diversity and number in alluvial meadow-boggy soils at warming autumn.

Keywords: European North-East of Russia, Sysola River floodplain, aspen-birch forests, alluvial soils, soil microorganisms, meso- and macro-fauna

1. Introduction

River floodplains are the most widely distributed habitats in the world, occurring from tropical to polar regions and from deserts to rainforests. Depending on their specific area of interest, various scientists view floodplains quite differently. Many ecologists perceive floodplains primarily as ecotonal extensions of river channels. Scientists who study plants and soils view floodplains as distinct habitats rather than simply ecotones between rivers and uplands. In fact, floodplains are a mosaic of sub-habitats (some aquatic, some terrestrial, some wetland), and diverse sub-habitats potentially supporting a unique biota. While most work focuses on the aquatic biota of floodplains, the terrestrial component is being increasingly recognized [1].

Due to annual snowmelt floods, river floodplains have a specific 'terraqueous' regime [2] which creates particularly special conditions for vegetation cover, soils and soil organisms. Duration and regime of floods respond for the fact that floodplain soils largely differ from watershed soils not only concerning morphological structure and physical-chemical properties of soil profiles but also by life activity of soil biota which is involved into plant residues decomposition in terrestrial ecosystems. In contrast to zonal communities on watersheds, soil biota on river floodplains is less studied. In Russia, the role of soil biota on river floodplains was intensively studied in the 1960s–1980s of the twentieth century [3–6]. This was conditioned by the fact that floodplain soils were treated as to be used in engineering and agriculture. In the twenty-first century, floodplain landscapes gained high attention in both Russia and European countries [7–12]. These studies aim at identifying the dependence in population number of soil organisms from flood regime [13–15]; adaptations of invertebrates to moisture deficient or excess [16–18]. Complete descriptions of soil biota in river floodplains are lacking, and existing research tends to focus on a few groups of soil organisms. It is known that floodplains contribute significantly to the biodiversity of the world because so many species occur solely in floodplains or at least rely heavily on floodplains to satisfy important ecological needs [1].

Globally, the soil invertebrate fauna has been extensively researched only at a few temperate-zone floodplain ecosystems, mainly in the USA, Europe and Australia. The distinctive feature of European floodplains is that they have been transformed for centuries. As a consequence, 95% of riverine floodplains have been lost [1]. But it is known that soil biota in floodplain communities has higher diversity indices as compared to that in zonal communities. And geologically ancient soils (Central Amazonia) with long-term cycles of always alternating aboveground and water phases are inhabited with endemic invertebrates whereas young ecosystems (Central Europe)—with eurytopic species [19]. Floodplain forest ecosystems are key habitats for rare invertebrates, including the representatives of the postglacial period [20]. Overall, the knowledge of the soil biota in the northern floodplain communities remains incomplete and requires a sustained taxonomic and ecological research effort to provide better estimates of species diversity, distribution and evolutionary history.

River floodplains are 'oases of life' in the northern regions. Due to the warming effect of the river waters, highly productive grass-forb meadows and deciduous forests with grassy ground cover, which atypical for the watershed landscapes of the northern part of the taiga zone, are formed in the valleys of the boreal rivers [21]. At the same time, priority attention of ecologists has been paid to the identification of biodiversity and structure of soil biota in the coniferous forests occupied watersheds [22–24]. Alluvial soils of the northern river floodplains are studied fragmentarily in this respect, particularly soil biota of floodplain aspen-birch forests [9, 10]. This was conditioned by the fact that morphological and physico-chemical properties of alluvial soils as well as ways of preservation and increase of soils fertility of floodplain meadows were studied firstly at the European northeast of Russia. The high importance of river ecosystems in shaping migration flows of substances in landscapes, the role of floodplain soils as biogeochemical barriers to the migration of chemicals, the specifics of vegetation cover at the floodplain terraces of the boreal zone and the importance of floodplains in maintaining of soil biota biodiversity are the conditions which are important to identify the features of formation of not only soil and plant cover at floodplain landscapes of the North but also the biodiversity of soil invertebrates and microorganisms, playing a leading role in the transformation of plant residues in terrestrial ecosystems. In this study, we focused at the variation of the soil biota in a river floodplain system with natural hydrological conditions and well-preserved forests that have not been modified by human disturbances. We assumed that a riverine landscape in the natural state exhibits a high level of complexity across a range of scales, which might contribute significantly to the species pool. So, the purpose of this study was to obtain new data about species diversity, number and structure of soil biota in the Sysola River floodplain located at the European North-East of Russia and to identify ecological and functional interlinks between alluvial forest soils in the taiga zone and soil biota.

2. Materials and methods

The studies were conducted in the Sysola River valley, middle taiga, Komi Republic and European North-East (**Figure 1**). The Sysola River (395 km long) is one of the largest left tributaries of the Vychegda River (1131 km) which, in turn, is a tributary of the Severnaya Dvina River (744 km), the White Sea basin. It is a typical plain river, which is occupied by meadows. Our researches were carried out in aspen-birch forest, which is located in middle part of floodplain terrace, low course of the Sysola River. This forest was divided into three plots which take different positions in relief of floodplain and greatly differ by ecological conditions as snow-melt water inundation period, ground water depth, soil type, plant composition in ground cover, etc. The plots form a natural ecological row along with increasing soil moisture content: Plot 1 (ridge top, high floodplain level) → Plot 2 (even part of floodplain, mean level) → Plot 3 (deep inter-ridge depression, low level). Spring flood regime in the Sysola River is unstable. High ridge tops soils do not became inundated or stay under water for a short period of time (1–1.5 weeks), while inter-ridge depressions sometimes stay under water for one and a half month or two months.

Morphological, physical-chemical soil properties and their hydrothermal regime were studied in accordance with the accepted methods [25, 26]. Reference sections for the morphological description of soil horizons and sampling were laid at key plots. Names of soil types and horizons indices are given according to the Russian standards [27]. Soil moisture content was identified gravimetrically, soil temperature—with an electronic transistor digital thermometer TET-TS11 (Russia) and loggers DS1921G (Russia). Carbon content was measured by the gas-chromatography method with CNHS-analyzer (Carlo Erba, Italy), pH_{KCl}—potentiometrically with glass and silver-chloride electrodes at soil:solution ratio of 1:2.5 for mineral and 1:25 for organic horizons, hydrolytic soil acidity (Ha)—by titration using CH_3COONa solution, exchangeable cations (Ca^{2+}, Mg^{2+})—by driving with NH_4Cl solution followed by atomicabsorption identification at Hitachi 180–60, and texture—by the Kachinsky method with dispergation and boiling in the presence of NaOH.

Figure 1. Map scheme of research region.

Number of the principle ecologic-trophic groups of microorganisms was assessed by inoculation of solid nutrition media [28]. We identified concentration of ammonificators (beef-peptone agar), oligonitrophilous (Aeshbi's medium), nitrifying (Vinogradsky's medium), and denitrifying (Giltai's medium) bacteria; microorganisms using mineral nitrogen compounds (starch-ammonia agar); oligotrophic (starvation agar) and pedotrophic (soil agar) microorganisms. Saccharolytic microscopic fungi were assessed using acid Chapek's medium, cellulose-decomposing fungi—Getchinson's medium, and oligotrophic fungi —starvation agar. Total microorganisms and micromyces number was stated in CFU/g a.d.s. (colony-forming units per 1 g of absolutely dry soil). The microorganisms' biomass carbon was estimated by the rehydration technique on the base K_2SO_4 extracts [29] in fresh samples of forest litter (A0, 0–3 cm deep) and humus horizon (A1, 3–15 cm deep). Samples were collected four times during vegetation period in threefold to fourfold replication. Taxa of micromycetes were identified after their extraction as pure cultures using Chapek-Dox medium with help of manual books for the identification of different taxonomic groups of micromycetes, interactive keys, and information Internet site (http://www.indexfungarum.org).

For the evaluation of taxonomic composition and number of nematodes, soil samples (5 cm in diameter, 5 cm deep) were collected in sevenfold replication monthly from June till August. Totally, 63 samples were collected. Nematodes were extracted from soil using modified

Bermann funnels, heat-killed and fixed in 4% formaldehyde. In each soil sample, at least 100 individuals were identified to the genera level using a Leica DM4000 B inverted microscope. Nematodes were identified following the taxonomic keys [30–32]. The abundance of nematodes was recalculated per 100 cc of soil. Nematodes were assigned to six trophic groups (bacterivores, fungivores, root-fungal feeders, plant parasites, omnivores and predators), according to classification [33]. In total, 190 soil samples (5 × 5 × 5 cm) were collected for identification of Collembola. Samples at each plot were collected in fivefold replication monthly from June till September 2003–2005. Extraction of Collembola was done in Berlese-Tulgren funnels. Quantitative accounting of large invertebrates was done by hand using of soil samples (25 × 25 × 5 cm). In total, 380 soil samples were collected by analogy to the sampling procedure of Collembola at the same time but in 10-fold replication at every plot. Characterization of soil organisms was done using general ecologic indices as occurrence frequency, relative abundance of species (P, %), species richness (S), Shannon's diversity (H') and evenness (J') indices, Simpson's index of dominance (D_{SM}), Chekanovsky-Sjerensen index of similarity (Ics). The obtained data were processed by standard methods of statistics using Microsoft Excel, STATISTICA 6.0 and PAST 3.1.

3. Characterization of plant and soil cover

River valleys of the taiga zone have two forest types, particularly birch and aspen forests [21]. From position of the Russian classification, these forests are considered as floodplain cycle of plant associations. They are divided into two, herbaceous—stone bramble and hair grass sedge series. Each of the two series is composed of two associations. Communities of the herbaceous—stone bramble series (*Betula sp.—Rubus saxatilis—Climacium dendroides* and *Populus tremula—Rubus saxatilis—Climacium dendroides*) form at ridge tops of the central floodplain. They grow on alluvial soddy or meadow soils. The phytocenoses of the hair grass sedge series (*Betula sp.—Carex cespitosa* and *Populus tremula—Carex cespitosa*) prefer moist habitats and occupy shores of former river beds, inter-ridge and near-terrace depressions on alluvial meadow-boggy soils. Deciduous forests formed in river floodplains have a well-developed and diverse underbrush. The most stable and often-met species in underbrush are *Rosa acicularis*, *R. majalis* and *Frangula alnus.* The underbrush of floodplain aspen forests includes *Viburnum opulus* and *Swida alba.* Totally, the study forests consist of 18 shrub species. The crown density for shrubs can sometimes reach 0.6–0.8. Water-loving plants dominate in ground cover of floodplain deciduous forests. The most valuable species of plants are *Rubus saxatilis* and *Carex cespitosa*. *Galium physocarpum*, *Lysimachia vulgaris*, *Ranunculus auricomus*, *Hylothelephium triphyllum*, *Moehringia lateriflora* are often noted but they are not abundant. Long flooding period, thick dead leaf layer and herbal plants inhibit the development of the moss cover. Total projective cover of moss seldom exceeds 5%. The most stable and abundant ground cover component in floodplain deciduous forests is *Climacium dendroides.* Characteristic of plant and soil cover at studied plots is presented in **Table 1**. Alluvial soils formed in floodplain deciduous forests have a forest litter horizon. It is formed due to the low mineralization rate of plant residues. Plant residues total at Plot 1 and Plot 2 equals 3.5–4.0 t/ha and at Plot 3—2.0–2.5 t/ha. Forest litter thickness in soils of the study plots is 3–5 cm. The lowest values (2–3 cm) are fixed for spring-early summer period and the highest ones (5–6 cm)—for autumn due to the production of fresh leaf residues. The presence of herbs with a well-developed root system responds to the formation of a prominent humus horizon (12–23 cm thick) under f nd 2 have two layers. Loose well-textured dark-brown loam subhorizon A′ being 5–10 cm thick lies immediately after forest litter. It gets gradually replaced by subhorizon A′′ (about 10 cm) which is light-coloured loam with crumble-powder texture. The lower soil part (30 cm from soil surface) at Plot 1 is sandy alluvial layer. The lower soil part (25 cm from soil surface) at Plot 2 is gley. It has rusty and dove-coloured spots against brown background. Soil gleysation is related with a close groundwater occurrence. Soil profile at Plot 3 was cut before the depth of 80 cm only because beginning with 75 cm, and downwards, it was actively impacted by soil-ground waters. Humus horizon A1 does not have two sublayers. It is as gley as low soil profile due to high ground water level which increases in direction from ridge top (Plot 1) to inter-ridge depression (Plot 3). Depth and intensity of soil warming decrease along the same direction (**Figure 2**).

Parameter	**Plot 1**	**Plot 2**	**Plot 3**
Plot location	ridge top	even part of floodplain	deep inter-ridge depression
Altitude of floodplain terrace	high level	mean level	low level
Microrelief	Not expressed	Slightly expressed	Tussocks up to 15–20 cm high
Level of groundwater	Deeper than 2.5 m	About 1.5 m	0.75 m
Vegetation community	Aspen-birch herb-stone brumble forest	Aspen-birch herb-stone brumble forest	Aspen-birch hair grass sedge forest
Stand composition	7Asp3Birch	8Birch2Asp	8Birch2Asp
Canopy density	0.9	0.8–0.9	0.8–0.9
Stand age	I layer—VI age class II layer—IV age class	I layer—VII age class II layer—IV age class	I layer—VII age class II layer—IV age class
Stand height	I layer—20–22 m II layer—14–18 m	I layer—20–22 m II layer—14–18 m	I layer—20–22 m II layer—14–18 m
Underbrush	9 species, *Sorbus*	8 species, *Sorbus aucuparia* is dominant	4 species, *Padus avium* is dominant

Parameter	Plot 1	Plot 2	Plot 3
	aucuparia and *Frangula alnus* are dominants		
Herb cover (TPC, %)	25 species, *Rubus saxatilis* is dominant (TPC 15–40%)	27 species, *Rubus saxatilis* is dominant, *Carex cespitosa* is also abundant (TPC 20–40%)	16 species, *Carex cespitosa* is dominant, *Galium palustre*, *Filipendula ulmaria*, *Mentha arvensis*, *Lysimachia vulgaris* and *Rubus arcticus* are also abundant (TPC 20–40%)
Moss cover (TPC, %)	It is not expressed	It is expressed weakly, *Climacium dendroides* is registered (TPC up to 3%)	It is expressed weakly, *Climacium dendroides* and *Calliergon* species are registered (TPC up to 10%)
Type of soil	Alluvial soddy layered soil on sandy alluvium	Alluvial meadow soil on clay alluvium	Alluvial meadow-boggy soil on clay alluvium
The structure of the soil profile	$A0\frac{0-3}{3}A1\frac{3-20}{17}$ $\mathrm{AB}\frac{20\text{-}30}{10}\mathrm{I}\frac{30-80}{50}$ $\mathrm{II}\frac{80-100}{20}$	$A0\frac{0-5}{5}A1\frac{5-25}{20}$ $\mathrm{ABg}\frac{26-38}{12}\mathrm{Bg}\frac{38-100}{62}$	$A0\frac{0-5}{5}A1\mathrm{g}\frac{5-16}{11}\mathrm{ABg}\frac{16-28}{12}\mathrm{Bg}\frac{28-46}{18}G\frac{46-80}{34}$

Note: TPC – total projective cover.

Table 1. Characteristics of vegetation and soils at studied plots in the Sysola River valley.

Soil mineral horizons at Plot 1 have favourable moisture conditions for soil organisms – 40–60% of total moisture capacity (TMC). But forest litter suffers from moisture deficiency for practically whole summer period. Forest litter moisture degree equals 20–40% of TMC in summer. Plot 2 has best moisture conditions (within 40–60% of TMC) in upper soil horizons only towards July. In the other summer months and in autumn, soil moisture degree is 60–80% of TMC. At Plot 3, soil is seriously overmoistured due to close ground water occurrence. Additionally, this plot is under water for a long period of time during spring snow-melt period. But towards in July, it also decreases in soil moisture content of forest litter to 40–60% of TMC. It resists 60–65% of TMC to the end of vegetation period. Lower mineral horizons remain overmoistured towards late autumn (80–90% of TMC). The study soils are acid, base-unsaturated with a strongly decreasing organic carbon profile distribution (**Table 2**). At 20–30-cm depth, organic carbon content was 0.5–0.9% and from 4.5–4.8 (Plot 1, Plot 2) to 3.0% (Plot 3) in humus horizon. In direction from Plot 1 to Plot 3, soil acidity in forest litter increases. In autumn, forest litter acidity in all soil types decreases due to fresh plant residues. Thus, there is a clear trend of worsening in living conditions of tree waste decomposing soil biota going from Plot 1 to Plot 3. Ecological conditions of biotopes undergo serious changes in direction from ridge top to inter-ridge depression. These changes respond for differences in qualitative and quantitative composition of plant waste, intensity of its mineralization and humification processes, structure of soil humus horizons. Upper organic soil horizons of alluvial forest soils are highly unstable by moisture content and heat provision. They are the principle habitat for invertebrates. Even overmoistured (meadow-boggy) soils have favourable conditions for soil biota life activity some time during summer-autumn.

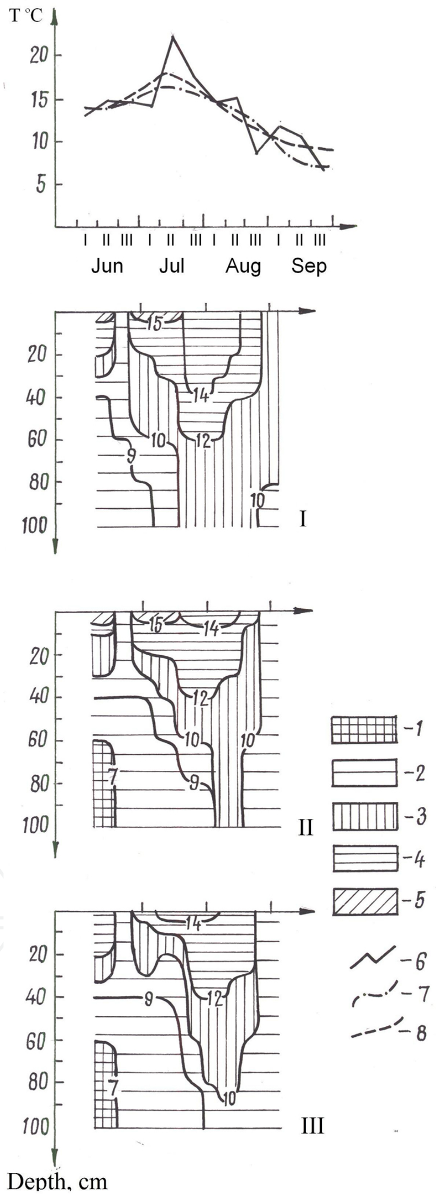

Figure 2. Temperature dynamics in alluvial forest soils of the Sysola River valley: I—alluvial soddy soil, II—alluvial meadow soil, III—alluvial meadow-boggy soil. Keys: 1 – <7°C; 2 – 7–10°C; 3 – 10–12°C; 4 – 12–15°C; 5 – 15–20°C; 6—mean-decade air temperature (by data of 2003); 7—mean-monthly long-time average annual air temperature; 8—mean-monthly air temperature (by data of 2003).

Horizon	Depth, cm	pH_{KCl}	Ha*	Exchangeable bases		S**	C	N	C/N	Sum of particles	
				Ca^{2+}	Mg^{2+}					<0.01 mm	<0.001 mm
				mmol/100 g soil		%					
Plot 1. Ridge top, alluvial soddy soil											
A0	0–3	4.8	27.5	30.6	5.0	56	21.7	1.5	14	–	–
A1	3–14	3.2	17.0	6.8	1.0	31	4.5	0.4	11	19	7
-"-	14–20	3.3	17.0	1.1	0.3	8	1.7	0.16	11	14	4
AB	20–30	3.6	7.4	0.6	0.2	10	0.5	0.04	13	16	6
I layer	30–50	3.6	6.5	0.9	0.3	15	0.2	–	–	0	0
Plot 2. Even floodplain part, alluvial meadow soil											
A0	0–3	4.8	25.0	40.9	8.1	66	38.9	2.2	18	–	–
A1	3–14	3.4	17.0	5.8	1.1	29	4.8	0.3	16	64	36
-"-	14–26	3.3	16.2	2.5	0.4	15	2.1	0.20	11	44	37
ABg	26–38	3.3	16.1	2.0	0.4	13	0.4	0.04	10	34	66
Bg	38–56	3.4	11.0	2.1	0.5	19	0.3	0.04	8	–	–
-"-	56–70	3.4	9.0	2.9	0.7	29	0.3	–	–	24	76
-"-	70–100	3.4	8.4	4.1	1.0	38	0.3	–	–	–	–
Plot 3. Deep inter-ridge depression, alluvial meadow-boggy soil											
A0	0–3	3.9	36.3	26.2	5.1	46	33.8	2.0	17	–	–
-"-	3–5	3.8	37.0	19.6	3.7	39	26.9	1.4	19	–	–
A1g	5–16	3.4	17.0	3.4	0.7	19	3.1	0.22	14	54	21
ABg	16–28	3.3	13.3	4.0	1.0	27	1.3	0.11	12	42	18
Bg	28–46	3.4	9.3	4.6	1.3	39	0.2	–	–	38	16
G	46–65	3.6	5.5	4.8	1.5	53	0.2	–	–	29	14
-"-	65–80	3.7	4.8	4.3	1.5	55	0.2	–	–	20	112

Note: «–» – not identified;

* Ha – hydrolytic soil acidity;

** S – base saturation by hydrolytic acidity: $S(\%) = \frac{\sum (Ca^{2+} + Mg^{2+})}{\sum (Ha + Ca^{2+} + Mg^{2+})} \cdot 100.$

Table 2. Physical-chemical properties of alluvial soils under floodplain deciduous forest.

4. Diversity and structure of microbe communities in the alluvial forest soils

Microbe communities of alluvial soils differ from those of watershed soils [12] because of inundation of floodplain terrace and covering the surface of floodplain terrace with alluvial deposits [15]. Floodplain forest soils have a short bacterial profile. Bacteria are available within upper 60–70 cm at Plot 2 and Plot 3. Single colonies were identified at a depth of 100 cm at Plot 1. In direction from Plot 1 to Plot 3, oligonitrophilous and denitrifying microorganisms become abundant. Nitrifying, ammonificators and bacteria using mineral nitrogen compounds strongly decrease in number at Plot 3 (**Figure 3**). This normally proceeds in soils formed in conditions of excessive moisture content. Oligonitrophilous and oligotrophic microorganisms dominate at Plots 2 and 3 in the beginning of vegetation period. Ammonifiers, nitrifiers, denitrifiers, assimilators of mineral nitrogen compounds become abundant in July and towards the end of vegetation period. Their number and ratio significantly vary depending on soils type and weather conditions. When weather conditions are unfavourable (chilly weather with excessive rain precipitations), bacterial communities are presented by oligonitroflora. Unusually, warm weather with insufficient rain precipitations activates ammonifiers, assimilators of mineral nitrogen compounds and nitrifiers. Normally this increase in bacterial number also occurs in autumn when soil surface gets covered with plant waste products which decrease forest litter acidity. Microbial biomass carbon content in alluvial soils largely varies (**Figure 4**). Hydromorphic soils (Plot 2 and Plot 3) normally contain more microbe biomass carbon than automorphic soils (Plot 1). This situation is especially obvious in August and September when microbe communities in these soil types are highly active.

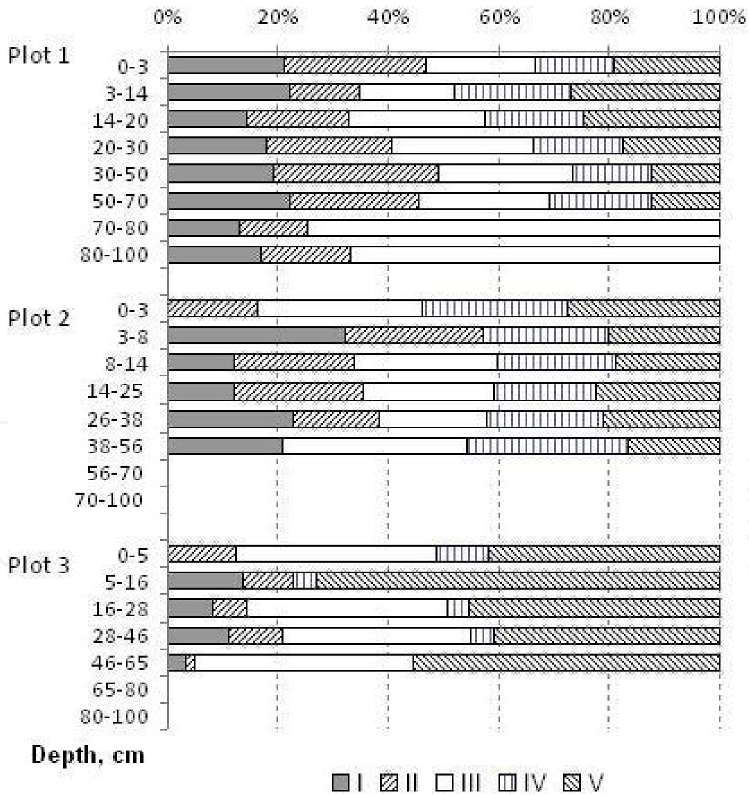

Figure 3. Profile distribution of ecologic-trophic bacterial groups in alluvial forest soils of the Sysola River valley. Microorganisms: I—on beef-peptone agar (ammonificators); II—on starch-ammonia agar; III—on Aeshbi's medium (oligonitrophilous); IV—on Vinogradsky's medium (nitrifying microorganisms); V—on Giltai's medium (denitrifying microorganisms).

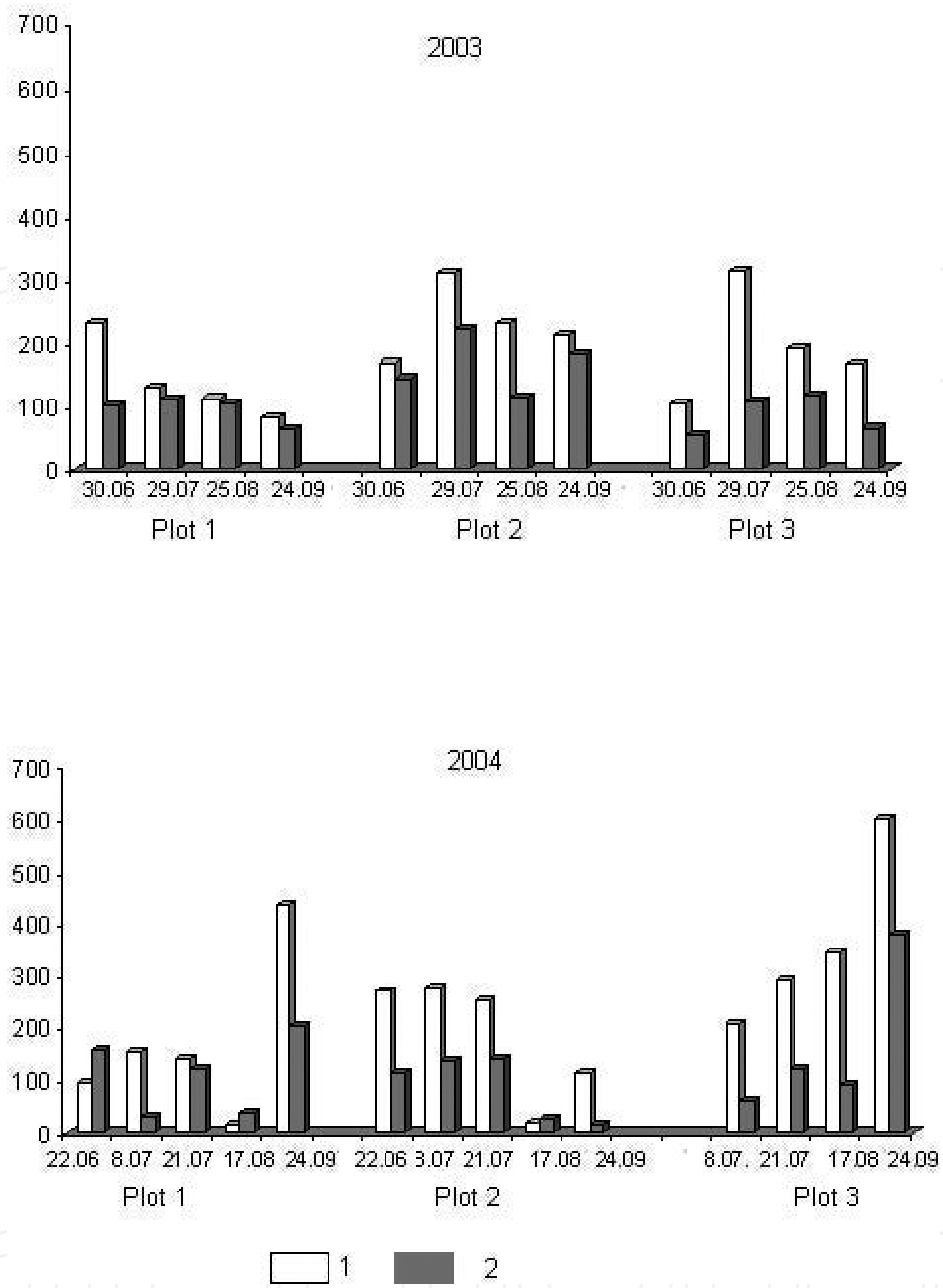

Figure 4. Microbial biomass carbon dynamics (mg C_{MB} per 100 g of dry soil) in alluvial forest soils of the Sysola River valley.

5. Micromycetes activity in the alluvial forest soils

Micromycetes are the first inhabitants of plant waste products in forests [34, 35]. Soils of coniferous forests are rich in both microscopic and basidial fungi; their mycelium largely permeates forest litter [36]. Seventy-three species of micromycetes (including sterile forms) of 18 genera inhabit soils under spruce forests on watersheds of the Sysola and the Vychegda Rivers [22]. Leaf waste of birch-aspen forests differs from that of spruce and pine forests by chemical composition and contains by 1.5–2 times more mineral elements as calcium, magnesium and nitrogen than pine or spruce needles [37]. So, deciduous leaf waste presents a well decomposition object for bacteria. Our data showed that floodplain forest soils have 70 species of micromycetes. But taxonomic diversity of microscopic fungi is truly higher in floodplain soils (31 genera). Practically, one half of micromycetes in floodplain forest soils (25 species) are species which were previously identified neither in taiga forest soils [36], nor in floodplain meadow soils of the middle taiga zone [38]. They are species of the Penicillum (*P. glaucogriseum*, *P. lapidosum*, *P. sclerotiorum)*, Paecilomyces (*P. farinosus*, *P. carneus*, *P. variotii*), and Trichoderma (*T. reesei*, *T. longbrachiatum*, *T. crassumbissett*) genera, *Aureobasidium pullulans*, *Mycogone perniciosa*, *Monosporium silvaticum*, *Trichosporium fulvum*, *Geomyses pannorum*, *Botrytis pyramidalis*, *Alternaria alternate*, non-identified species of the *Coretropsis*, *Gliocladium*, *Circinella*, *Mycogone*, *Rhinocladiopsis*, *Rhizopus*, *Scopulariopsis*, *Phycomyces* genera. The genera of *Penicillium* (17 species), *Trichoderma* (7), *Chaetomium* (5) and *Paecillomyces* (4) are characterised by high species diversity in alluvial forest soils. The *Mucor*, *Cladosporium* and *Umbelopsis* genera count three species each, *Mycogone*, *Altenaria* and *Aureobasidium*—two, and the other genera—one species each. Spruce forest soils are characterised by high diversity of *Penicillium* genera (25 species), the constant presence of representatives of *Mucor* and *Trichoderma* genera, and domination of *Chaetomium* species [36]. *Trichoderma sympodianum*, *Umbelopsis vinacea*, *U. isabellina*, *U. ramanniana*, *Mucor racemosus*, *Chaetomium globosum*, *Ch.spirale*, *Geomyses pannorum*, as well as non-identified species of the *Mucor*, *Paecillomyces* and *Penicillium* genera are met in alluvial forest soils. Totally, there are 13 common species, including two sterile mycelium forms. In contrast to floodplain meadows [38], mycobiota taxonomic structure in floodplain forests is better represented (71 species of 22 genera). Micromycetes which inhabit only particular alluvial forest soils are characterized by the following features. Plant waste decomposition at Plots 2 and 3 is fulfilled by *Alternaria tenuis*, *A.alternata*, *Fusarium sp.*, *Paecillomyces farinosus*, *Trichoderma reesei*, at Plot 1—*T.crassum*. *Chaetomium spiraliforum*, *Cladosporium potebniae*, *Gliocladium sp.*, *Mycogone sp.*, *Penicillium nigricans*, *Trichoderma koningii*. On the whole, microscopic fungi in alluvial forests soils form a specific complex: the Ics index is less than 50%. With increasing of soil moisture content in floodplain forest soils, number of micromycetes in forest litter (A0) and in mineral humus horizons (A1) becomes similar.

6. Communities structure and diversity of nematodes in the alluvial forest soils

Soil nematodes of the alluvial soils include 53 genera of 30 families. Number of nematodes varies between 635 inds./100 cm^3 (Plot 3) and1105 inds./100 cm^3 (Plot 1). Diversity of nematodes in the floodplain forests is higher than that in non-flooded spruce (35) and pine forests (31 genera) in the study region (not-published data). Number of nematodes in the alluvial soils is also a little bit higher than that under watershed forests. It is 55–239 inds./100 cm^3 in pine forests [23] and 300 inds./100 cm^3 in deciduous forests. The greatest number of genera is found for soil at Plot 2—42 genera and the lowest one is noted for soil at Plot 3—32 genera (**Table 3**). Plot 3 is characterized by lowest diversity of nematodes. It is probably explained by unfavourable life conditions (overmoisture) for them. Excessive moisture of soil results into its poor aeration and reduction of qualitative and quantitative vegetation composition. Consequently, the taxonomic similarity of nematodes at the study plots is not high and it is equalled about 60%. Along with low diversity of nematodes, the rising of predomination of single taxa in soils of plot 3 is observed. All studied soils are characterized by high proportion of the *Filenchus* and *Eudorylaimus* genera. Soil at Plot 1 also has high relative abundance of *Plectus*, *Aphelenchoides*, *Acrobeloides* genera, soil at Plot 2—representatives of *Plectus*, *Teratocephalus*, *Metateratocephalus*, *Aphelenchoides*, *Alaimus* genera, and overmoistured soil at Plot 3—*Dorylaimus* representatives. Abundant genera of nematodes at Plot 1 and Plot 2 are typical for boreal ecosystems [39]. Ratio of dominants at Plot 3 is differed which seems to be related to overmoisture. Nematodes in studied soils belong to six trophic groups. Bacterivores nematodes are abundant at Plot 1 and Plot 2 (**Figure 5**). It is typical situation for different habitats [40]. Nematodes at Plot 3 are mainly omnivores. High soil moisture content at Plot 3 leads to massive reproduction of the hydrophilous and omnivores *Dorylaimus* genera.

Genera, parameter	**Studied soils**		
	Plot 1	**Plot 2**	**Plot 3**
Filenchus	21.0	17.0	7.0
Eudorylaimus	11.4	15.0	9.0
Plectus	9.6	6.0	3.7
Metateratocephalus	3.4	6.0	2.6
Teratocephalus	3.7	5.1	<1
Aphelenchoides	16.0	12.0	4.3
Dorylaimus	–	<1	52.9
Acrobeloides	5.1	2.0	2.9
Alaimus	4.3	5.8	1.0
Others	25.5	31.1	17.6
Number of genera	39	42	32
Density (inds./100 cm^3)	1105 ± 185	745 ± 94	635 ± 90
Shannon diversity index (H')	2.30 ± 0.12	2.63 ± 0.13	1.93 ± 0.34
Simpson's index of dominance (DSM)	0.15 ± 0.03	0.12 ± 0.03	0.29 ± 0.12

Note: Table contains genera with relative abundance >5% at least at one plot.

Note: Values of abundance and index are mean ± SE, n=7.

Table 3. Characteristics of nematodes population in alluvial forest soils.

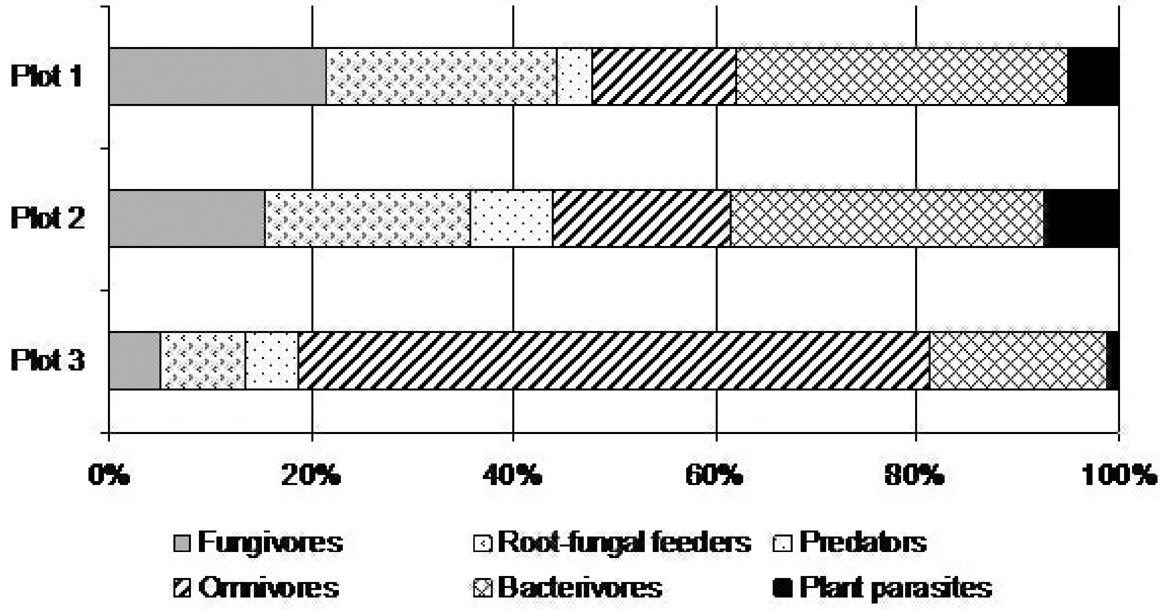

Figure 5. Trophic structure (ratio of group abundance) of nematodes communities in alluvial soils of the Sysola River valley: Plot 1—alluvial soddy soil, Plot 2—alluvial meadow soil, Plot 3—alluvial meadow-boggy soil.

7. Diversity and structure of Collembola in the alluvial soils

Collembola of floodplain communities in the taiga zone of the European part of Russia are understudied in comparison with coniferous forests on watersheds. For example, 65 Collembola species are registered in the floodplain ecosystems of the Komi Republic [11] whereas 173 species are noted in the coniferous forests of the European part of Russia [24]. The greatest number of species and stenobionts (species which exist only in particular habitats) are found at Plots 1 and 3 (**Table 4**). It is confirmed by the Shannon indices (2.70–2.94) that indicate their high taxonomic diversity. It is noticed that *Agrenia riparia* and *Ptenothrix atra* inhabit only Plot 1, whereas *Mesaphorura krausbaueri*, *Stenaphorura quadrispina*, *Brachystomella parvula*, *Folsomia kuznetsovae*, *Isotomurus fucicolus*, *Marisotoma tenuicornis* inhabit only Plot 3. Collembola groups of alluvial soils are quite similar by species composition, as widely distributed species form the basis of their communities. Springtails communities in alluvial forest soils have the same dominant species as in coniferous forests [24]. *Isotomiella minor* is typical species for boreal zone of the European part of Russia. *F. quadrioculata* prefers moist soils in Central Europe [41], but it is not met at moist forests of East Europe [42]. *Folsomia kuznetsovae* prefers moist and oligotrophic habitats [43]. It is revealed that soil moisture degree decreases number of epigeic species and increases ratio of euedaphic forms. Complexes of hemi- and euedaphic species are not much change from year to year and so form a stable part of Collembola group whereas epigeic species are most mobile in alluvial forest soils [9]. Collembola occupy upper soil horizons with high organic matter content and they are not found at depths under 20 cm from soil surface [10]. The population density of springtails varies during vegetation period and observation years [9]. Average density of Collembola in alluvial soils is low, but it can reach 100 thous. inds./m^2 at some sampling terms and so significantly exceed that parameter in zonal communities. The highest population density of springtails is registered for Plot 2 (37.5 thous. inds./m^2). It is 24.3 and 21.8 thous. inds./m^2 for Plots 3 and 1, correspondingly.

Species, parameter	**Plot 1**	**Plot 2**	**Plot 3**
Folsomia quadrioculata	41.7	59.2	24.3
Isotomiella minor	11.8	15.3	40.9
Folsomia fimetarioides	7.2	9.4	10.7
Protaphorura boedvarssoni	3.5	5.5	<1
Ceratophysella denticulata	5.5	1.2	1.3
Friesea mirabilis	<1	<1	2.2
Anurida ellipsoides	<1	<1	5.7
Folsomia kuznetsovae	-	-	4.6
Xenyllodes armatus	6.8	<1	<1
Folsomia manolachei	3.1	<1	3.5
Supraphorura fucifera	1.5	1.4	<1
Total number of individuals	21,574	13,642	8248
Total number of species (S)	45	35	39
Shannon diversity index (H')	2.94	2.14	2.70
Shannon evenness index (J')	0.48	0.41	0.51

Note: Table contains species with relative abundance (%).

Table 4. Characteristics of Collembola population in alluvial forest soils.

8. Diversity and structure of soil macrofauna in the alluvial soils

Macrofauna of alluvial soils has a rich species composition (**Table 5**). Invertebrates in floodplain soils inhabit only the upper 30-cm soil layer. About 80% of large invertebrates occupy the upper 0–10-cm soil layer. Under the mark of 20 cm, there are only single individuals of earthworms [5]. Six species of Lumbricidae are registered in alluvial soils. *Octolasion lacteum* is dominant at Plot 3. It has high hemoglobin content in blood, so it inhabits badly aerating soils [6]. When litter became dry, soil at Plot 3 is inhabited by *Lumbricus rubellus*. Earthworms at Plot 2 are presented by *L. rubellus*, *Eisenia nordenskioldi*, *Dendrobaena octaedra*, *Aporrectodea*

Taxa	Plot 1	Plot 2	Plot 3
Gastropoda	+	+	+
Lumbricidae	4	6	2
Lithobiidae	1	1	1
Polyzoniidae	1	1	–
Carabidae, imago	31	33	16
Halyplidae, imago	1	1	–
Dytiscidae, imago	3	3	2
Silphidae, imago	2	1	–
Staphylinidae, imago	38	32	8
Scarabaeidae, imago	1	–	–
Cantharidae, imago	1	1	–
Elateridae, imago	12	8	1
Hymenoptera, larvae	+	+	–
Lepidoptera, larvae	+	+	–
Diptera, larvae	+	+	+
Aranei	+	+	+
Pseudoscorpiones	+	+	–
Total number of taxa	17	16	9
Total number of species	95	87	30

Note: «+» – taxa found, «–» – taxa not found.

Table 5. Taxonomical composition (species number) of soil macrofauna in alluvial forest soils.

caliginosa, *A. rosea*, *O. lacteum*. The abundant species of Lumbricidae at Plot 1 are *E. nordenskioldi*, *D. octaedra*, *L. rubellus*. These species inhabit litter of moist forests and clear cut areas. *A. caliginosa* is eurybiotic species, but it is seldom met at Plot 1. It prefers middle soil horizons with average soil moisture degree, and it can sink into anabiosis to survive in unfavourable conditions. The above distribution of Lumbricidae species by soil types is confirmed in literature [44]. The list of species can be considered complete because 12 Lumbricidae species were registered for periodically inundated beech forests in Germany [20]. Reduction in species diversity and number of Lumbricidae in inundated forests occurs regularly due to summer floods, not due to spring snow-melt floods [45]. Taxonomic composition of Myriapoda in alluvial soils is not as rich as in Central Europe. For example, 12 species of the *Lithobius*, *Geophilus*, *Strigamia* and *Schendyla* genera are found in different-aged (3, 30, and 80 years old) floodplain Czech forests [46]. Only two species *Lithobius curtipes* and *Polyzonium germanicum* are registered in studied soils. Spring, autumn, and summer floods greatly impact population structure of Myriapoda [18]. *Polyzonium germanicum* which is badly represented in floodplain forests and *Lithobius curtipes* which is abundant in long-inundated forests do best survive under water, for about 688.2 and 126.3 h, respectively [47]. The diversity of ground beetles (Carabidae) in alluvial forest soils is high. In compare, 28 Carabidae species were found in the floodplain of the Dnepr River middle course [5] and 42 Carabidae species were registered in the Czech floodplain forests [46]. *Carabus granulatus*, *Pterostichus oblongopunctatus*, *Pt. melanarius*, *Agonum fuliginosum*, *Amara brunnea* are often met in alluvial forest soils. The revealed

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distribution of Carabidae at plots corresponds with species distribution in forest soils of the middle taiga. The abundant species (*C. granulatus*, *Pt. oblongopunctatus*, *A. brunnea*) in alluvial soils of Plots 1 and 2 are the same. *Elaphrus cupreus* is dominant at Plot 3. The high predominance of Carabidae community is noted at Plot 1, as high species richness and diversity is characterized for Plot 2 (**Table 6**). The species similarity of Carabidae communities in alluvial soils comprise**s** over 60%. But ground beetles communities of Plots 1 and 2 show the highest similarity degree (about 75%). Ecological conditions at Plots 1 and 2 are equally favourable for Carabidae independently of soil type. The beetles can actively move and so look for better habitats. Rove beetles (Staphylinidae) are characterized by high species diversity in alluvial forest soils. The genera *Philonthus*, *Quedius*, *Tachyporus*, *Tachinus and Atheta* are abundant in floodplain forests. In autumn, alluvial soils are inhabited by *Arpedium* and *Omalium* genera which are best resistant to low temperatures. Staphylinidae communities at Plots 1 and 2 have a high species similarity (70%). But the absence of such similarity is noted for elevated Plots 1, 2 and Plot 3 (only 35%). The high diversity of rove beetles is characterized for Plots 1 and 2, but domination indices are extremely low (**Table 6**). Click beetles (Elateridae) in alluvial soils count 13 species, that is 25% of total fauna in the European North-East of Russia. The majority

Species, parameter	Plot 1	Plot 2	Plot 3
Carabidae			
Carabus granulatus	**21.6**	7.5	**26.5**
Patrobus assimilis	1.6	**17.8**	1.6
Pterostichus oblongopunctatus	**27**	**13.4**	1.6
Amara brunnea	6.5	**10.5**	2.2
Elaphrus cupreus	2.4	2.8	**15**
Shannon diversity index (H')	3.50	4.38	3.84
Shannon evenness index (J')	0.69	0.86	0.74
Simpson's index of dominance (D_{SM})	0.16	0.07	0.12
Staphylinidae			
Geostiba circellaris	**15.1**	2.4	**15**
Atheta graminicola	8.5	8.5	**27.5**
Stenus flavipalpis	-	-	**25**
Shannon diversity index (H')	4.55	4.72	2.58
Shannon evenness index (J')	0.87	0.94	0.86
Simpson's index of dominance (D_{SM})	0.06	0.03	0.18
Elateridae			
Selatosomus impressus	**27.2**	**38.7**	3.2
Agriotes obscurus	**20.4**	-	-
Dalopius marginatus	**18.4**	**11.9**	-
Shannon diversity index (H')	2.95	2.64	-
Shannon evenness index (J')	0.82	0.88	-
Simpson's index of dominance (D_{SM})	0.16	0.20	-

Note: Table contains species with relative abundance (%), «–» – species not found; bold indicates high domination degree.

Table 6. Characteristics of soil macrofauna in alluvial forest soils.

of species (4) belong to the *Selatosomus* genera. Larvae of click beetles prefer alluvial soddy soils. Abundant species are *Dalopius marginatus*, *Agriotes obscurus* and *Selatosomus impressus*. *S. impressus* is ecologically tolerant species, but it became abundant in alluvial meadow and meadow-boggy soils only at the warmest season, that is in July. The species similarity comprises 65% for Plots 1 and 2. But species richness is higher at Plot 2 (**Table 6**).

9. The impact of ecological conditions of the alluvial soils on soil biota

Deciduous birch and aspen forests in river floodplains cause development of specific biotopes. They, in turn, affect soil cover formation, species composition of plants, soil microorganisms, meso- and macro- fauna. But very similar floristic composition of plant communities within one series of floodplain forests evidences different tree species be not as pronounced edificators in specific floodplain ecotope conditions as those on watersheds. Ecological conditions considerably affect taxonomic diversity and number of biota in alluvial forest soils. The highest number of species and genera of micromycetes was found in alluvial meadow soil (Plot 2). Soil of this plot takes a transitional position between alluvial soddy soil (Plot 1) and alluvial meadow-boggy soil (Plot 3). It is well moistured, not extremely dry or moist. The large number of micromycetes species is found in alluvial soddy soil with moisture deficiency. The lowest number of species is found in alluvial meadow-boggy soil. Generally, complex of microscopic fungi is specific for each soil type. Taxonomic diversity of microscopic fungi in floodplain forest soils is higher than that in floodplain meadow and coniferous forest soils of the taiga zone. Nevertheless, species composition is practically the same. High taxonomic diversity of microscopic fungi in floodplain forests of the North could be conditioned by specific plant waste. Plant waste in spruce forests is homogenous and consists of moss and needle residues, so it has a specific biochemical composition and it is decomposed mainly by *Penicillium*. Taxonomic diversity of fungi in floodplain meadow soils is a bit higher (22 genera of micromycetes) possibly due to diverse plant waste (meadow grasses). Taxonomic diversity of fungi in floodplain forest soils is the highest (31 genera). Apparently, plant residues in floodplain forests is more diverse by chemical composition as consists of tree (aspen and birch) leaves, underbrush (mountain ash, dog rose, honeysuckle) leaves, dead grasses and branches. High taxonomic diversity of nematodes is revealed in alluvial meadow forest soil (Plot 2). Changes in nematode communities which happen at deviation from the ecological optimum (in alluvial soils of inter-ridge depression) fully correspond with the biocenotic principles on ratio between diversity and number of specimens in natural ecosystems. Collembola communities in floodplain forests occupy soil litter (which is typical of zonal communities) and differ by dominants and vital forms. Structure of such communities has a wide number of potential dominants, on one hand, and a high share of rare species, on the other. Due to this fact, high species diversity of Collembola is noted in alluvial soils of relief elevations (Plot 1) and depressions (Plot 3). In spite of low species richness of Collembola in floodplain ecosystems (relatively to zonal taiga communities), they do significantly contribute to biodiversity conservation of Collembola on the North [11]. Macrofauna in alluvial forest soils counts 17 taxa. Among them, Lumbricidae include six species, Myriapoda—two species, Carabidae—

40, Staphylinidae—49, Elateridae—13 species. High taxonomic diversity of macrofauna is revealed in alluvial soddy forest soil (Plot 1). But soil invertebrates can essentially increase taxonomic and species diversity in alluvial meadow-boggy soil (Plot 3) at warming autumn. This happens due to available fresh plant waste, low ground waters level, low moisture degree of upper soil horizons and, consequently, formation of appropriate ecological conditions for both soil fauna and microbiota [10]. High number and functional activity of bacteria at Plots 2 and 3 along with high number of meso- and macro-fauna leads to active mineralization of forest litter not only in alluvial soddy soils but also in alluvial meadow-boggy soils at inter-ridge depressions in the second half of vegetation period. For this reason, forest floodplain soils at deep inter-ridge depressions do not accumulate plant residues as a thick litter peaty layer like soils on watersheds. The obtained results well correspond with the idea about high biogenic potential of floodplain soils [48, 49]. Floodplain forests and wetlands are amongst the most diverse and species rich habitats on earth as the changing moisture conditions result in a wide variety of ecological niches. The banks of rivers and floodplains are in a permanent transformation. Many wetland areas in river valleys are 'biodiversity hotspots' containing high density of soil biota taxa [2, 14].

10. Conclusion

For the first time, we conducted a comprehensive study on major components of floodplain forests for middle taiga territory of European north-eastern Russia. Alluvial soils were shown to distinguish by ecological habitat conditions, particularly ridge top, levelled floodplain part and deep inter-ridge depression. Soils formed on different parts of floodplain terrace were revealed for different taxonomic composition of microorganisms, meso- and macro-fauna. Floodplain forest soils of the middle taiga subzone are inhabited 70 species from 31 genera of micromycetes, 53 genera from 30 families of nematodes, 60 species from 39 genera and 13 families of Collembola, 110 species from 17 taxa of large invertebrates. Alluvial meadow soils with stable moisture and temperature conditions are most diverse by species composition of micromycetes, nematodes, and large invertebrates. Springtails prefer alluvial soddy soils. Towards the end of vegetation period, every alluvial soil type increases in number of bacteria, microscopic fungi, and soil invertebrates in forest litter and becomes inhabited by new species. This is related with fresh plant waste and appropriate moisture conditions. So, fresh plant residues is actively transformed at this period not only in soils at elevated places (with favourable water-air regime at whole vegetation period) but also in overmoistured soils at inter-ridge depressions. Alluvial soils under floodplain forests in the European North-East of Russia are habitats with a high life density. In contrast with soils under coniferous forests on watersheds, alluvial soils in river valleys have a high taxonomic diversity of soil biota. Floodplain forest soils are habitats for rare species which cannot be met in soils under coniferous forests. As result of our research, 29 species of Collembola were noted at first for the Komi Republic, 2 species of Collembola were identified as new for science [11], 2 rare species of large invertebrates were included in the Red List of Komi Republic. The obtained data on quantitative and qualitative composition of micromycetes, nematodes, springtails and large invertebrates can be used for assessment of spatial-temporal changes of floodplain soils under anthropogenic impacts.

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