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Springtails (Hexapoda: Collembola) of some plant communities of the Pechora delta

Ногохвостки (Hexapoda: Collembola) растительных сообществ побережья дельты Печоры

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KEY WORDS: springtails, diversity, Pechora sea coast, North-Eastern Europe.

КЛЮЧЕВЫЕ СЛОВА: ногохвостки, разнообразие, побережье Печорского моря, Северо-Восточная Европа.

ABSTRACT. A quantitative study of collembolan assemblages on the Pechora Bay coast was performed. Altogether, 81 species of springtails from 43 genera and 15 families were registered. Among them four species are noted for the first time in East European tundra. The boreal species prevailed, only four true arctic forms were found. The springtail population of the studied tundra landscapes is characterized by a very high degree of dominance of a few mass species inhabiting a wide range of diverse communities, which indicates insignificant differences of these assemblages between plant ecosystems.

РЕЗЮМЕ. Поведено обследование фауны и населения ногохвосток основных растительных сообществ побережья Печорского залива. Всего в данном районе обнаружен 81 вид ногохвосток из 43 родов и 15 семейств, четыре из которых впервые отмечены для восточно-европейских тундр. Преобладают бореальные виды, арктический комплекс выражен слабо и включает только четыре вида. Население ногохвосток исследованных тундровых ландшафтов характеризуется очень высокой степенью доминирования немногих массовых видов, заселяющих широкий спектр разнообразных растительных сообществ. Это указывает на незначительные различия сообществ коллембол между растительными экосистемами.

Introduction

Last years there is an increased interest in inventory and assessment of species richness levels of certain areas, countries, natural zones and the whole world [Chernov, 2002]. These data are considered as a necessary basis for development of principles and technologies of biological diversity conservation. Due to this context the arctic and subarctic territories are especially of interest. Information about what is happening in ecosystems with an increase of anthropogenic impact on native landscapes in high latitudes is important for understanding of the general trends and mechanisms determining biotic reactions complexes for negative effects.

The Pechora Delta region and the neighboring East-European tundra's are the most important landscape complexes of the European North-East of Russia. The unique character of the Pechora Delta nature complex and its flora and fauna, was already noticed by F.V. Sambuk as far back as in 1929 [Pechora Delta, 2000]. This area belongs to the tundra zone, but the presence of the Pechora Delta leads to intrusion of boreal plant and animal species into the region. The region's unique natural landscape complexes are determined by the close relation to the Pechora River and by the geological history of the territory. The simultaneous existence of boreal, tundra and intermediate ecosystems on a rather small territory determines the unique species and community diversity of the Pechora landscapes.

Despite the inaccessibility, the faunas of two arthropod groups, namely spiders and beetles have been studied more or less completely [Pechora Delta, 2000]. No special study of springtails have been carried out in the tundra areas of Pechora Bay. The available material has been until recently restricted to faunistic collections on the Kuznetskaya and Bolvanskaya Bay [Babenko et al., 2017]. Thus, the main goal of this work is the primary inventory of the local fauna of this region.

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Materials and methods

The lower Pechora region is situated in the north-eastern part of European Russia. The Pechora lowland is bordered by elevated areas, the Ural mountains in the East and the Timan Ridge in the West and South-West. The vegetation cover in the lower Pechora Delta consists mainly of communities typical for the southern or subarctic tundra zone, also referred to as shrub and tussock tundra [Chernov, Matveyeva, 1997]. Especially elevated areas within the region also include communities characteristic for the typical tundra zone. The southern tundra zone is the dominant subzone of the tundra in north-east European Russia stretched along the coast of the Arctic Ocean. According to the climate map of the Nenets Autonomous Region this area is located in the subarctic climate zone. Climatic conditions in this zone are determined by the amount of solar irradiation, the radiation balance, intensive air convection streams and a noticeable influence of the Arctic Ocean. The region is characterized by an excess moisture regime. The average long-term precipitation amounts to 450±90 mm, distributed over 211±45 days during the year. The temperature regime shows large seasonal fluctuations. The long-term 24-hour average temperature varies from –20°C in January to 13°C in July [Pechora Delta, 2000].

The quantitative surveys were carried out in the Malozemelskaya and Bolshezemelskaya tundra. On the coast of the Malozemelskaya tundra six local faunas were studied. The first two points are situated in Pechorskaya Bay: 1. Khabuika — the coast of Zakhrebet Bay, the vicinity of the village Khabuika; 2. Lovetsky — an island (41 km^2) is washed by Pechora sea in the north and Korovinsky Bay in the south. The other four points are located in Korovinskaya Bay: 3. Sanev; 4. Kashin — island is not big but with a significant height difference; 5. cape Erennoy Nos; 6. Kostyanoy Nos — peninsula between Korovinskaya and Srednaya Guba. On the coast of the Bolshezemelskaya tundra only one local fauna was studied: Bolvansky Nos — peninsula between the river Bolshaya Pechora and Bolvanskaya Bay (Fig. 1). The territory is situated in the subzone of the southern tundra excluding Khabuika related to typical tundra [Yurtsev et al., 1978].

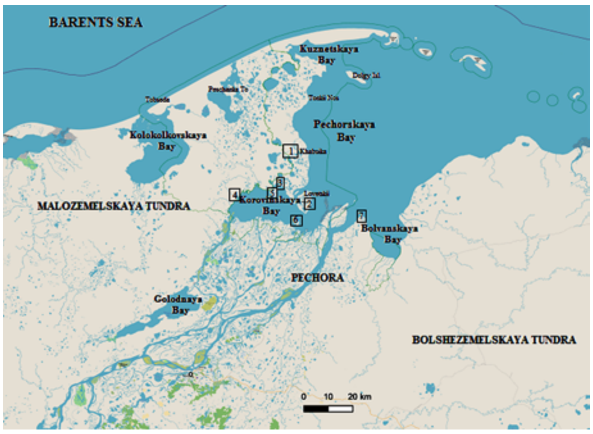

Fig. 1. Localities within the region under consideration.
Рис. 1. Изученные локалитеты региона.

Data were collected during the 1999–2000 period in the framework of a joint project "Delta Pechora" with the RIZA in Lelystad, the Netherlands and also in 2001–2003, 2010, 2019 during field works of Institute of Biology. The full sampling event dataset is published in GBIF [Taskaeva, 2020]. The following plant associations, more or less completely reflecting the diversity of vegetation were studied [Kulyugina et al., 2005]:

1. The zonal dwarf shrub-lichen tundras represent the main plant association in the study area. They form contours with large areas, situated in high points of the relief, placrusts on sandy and peat soils are characteristic of all studied points. *Empetrum hermaphroditum, Ledum decumbens, Arctous alpina* dominate in the grassy shrubby layer. The height of the moss-lichen layers 15–20 cm, where *Flavocetraria nivalis, Cladonia arbuscula, C. rangiferina, Cetraria islandica* and green mosses refer to the dominating complex.

2. Willow-yernic communities are characteristic of gentle slopes, places with sandy, loamy and peaty soils. They form small areas and presented by *Betula nana* and *Salix glauca.* In the herby-shrubby *Empetrum hermaphroditum*, *Vaccinium vitis-idaea*, *V. uliginosum*, *Ledum decumbens*, *Equisetum arvense* are most abundant. For the ground layer which is 10 cm thick *Cladonia spp.*, *Stereocaulon paschale*, *Peltigera aphthosa* prevail.

3. Grass and herbs meadows situated in flood-lands are rare. *Alopecurus pratensis, Bromopsis inermis*, *Festuca rubra, Poa pratensis* are the main dominating species.

4. The hygrophilous sedge-potentilleae communities are situated in the lowlands of the relief, swampy lowlands next to channels and along banks of lakes, in shallow waters. For them the excessive dampening, the absence of frozen earth, loamy soils are characteristic. *Carex aquatilis* is the dominant.

5. The alder communities are founding the relief lowlands along the banks of water reservoirs, in flowing narrows where they form contours with small areas. *Duschekia fruticosa, Salix lunata, S. glauca* dominate in these communities. Forbs prevails here (*Equisetum* sp., *Carex aquatilis, Ranunculus repens*) as and grasses (*Poa pratensis*).

6. The tidal strips.

Quantitative surveys of soil-dwelling microarthropods were carried out in all the above habitats (samples of 5×5×5 cm or 10×10×5, usually in 5–10-fold replicate). The springtails were extracted from the soil samples in the laboratory during 7–8 days without additional heating. In all, 135 soil samples were processed, from which over 25 thousand specimens of collembolans were extracted and identified [Fjellberg, 1998, 2007; Potapov, 2001; Kaprus et al., 2016; Babenko et al., 2017]. The quantitative surveys in sample plots were supplemented with faunistic collections using pit-fall traps. The ordination of springtails communities via nonmetric multidimensional scaling (NMDS) using the Bray-Curtis index was based upon the number of individual collembola taxa. Statistical treatment of results was carried out with the help of PAST 3.0 programm.

Results and discussion

The fauna

In total 81 species of springtails from 43 genera and 15 families were collected. Among them 26 species are found in the Pechorskaya Bay, 72 — in Korovinskaya Bay and 37 — in Bolvansky Nos (Table 1). For example, the local faunas of the Kolokolkova Bay (Barents Sea) and Kuznetskaya Bay (Pechora Sea) situated in typical tundra have also low diversity and include only 25 and 39 species, respectively [Babenko et al., 2017]. On the contrary, the species number of the Korovinskaya Bay is comparable with the diversity of neighboring territories. For example according to Babenko et al. [2017] in Bolvanskaya, Pakhanchenskaya and Khaipudyrskaya Guba during one season revealed 85, 90, 69 collembolan species, respectively. The fauna of one of the easternmost islands of the Barents Sea region (Dolgii Island, the Pechora Sea) also shows the high level of species diversity [Babenko, 2012]. Based on this brief comparison with the data available, one may conclude that the local fauna of the study area is not diverse. But four species, i.e. *Ballistura borealis, Isotomurus palustris, Folsomia fimetaria* and *Sminthurinus trinotatus*, are noted for the first time in East European tundra. *Ballistura borealis* is a boreal species recorded in tidal strips of the Kostyanoy Nos, previously was registered in shores of lakes and stream banks in west Finnmark, Norway [Fjellberg, 2007]. *Isotomurus palustris* usually common in damp sites with standing water is also found in tidal strips of the Kostyanoy Nos. It has been recorded all over the Holarctic and often together with most of its colour forms, but its occurrence is unknown [Potapov, 2001]. *Folsomia fimetaria* is found in shrub lichen tundra of Khabuika. It is very difficult to explain its record, as previously this species was found only in anthropogenic soils in Vorkuta and Kola Peninsula [Babenko, 2012; Kolesnikova et al., 2019]. *Sminthurinus trinotatus* is characteristic species in dry and hot places and its records in Bolvansky Nos can be explained by the thawing effect of the Pechora River [Lavrinenko et al., 2016]. Also in different plant communities situated in Bolvansky Nos a synantropic *Willowsia buski* was found with its share about 6 %. According to Babenko and Fjellberg [2006] "*A permanent presence of this species in the Arctic seems to be unreliable. The infrequent reports (also in the Antarctic) probably connect with sporadic introductions by humans*." Thus, the checklist of springtails of East European tundra including anthropogenic soils increased to 198 species [Babenko et al., 2017; Kolesnikova et al., 2019; present study].

The great majority of the species recorded in the study area are common inhabitants of the forest belt. The specificity of the fauna is primarily determined by the large fraction of exclusively or mostly littoral forms, such as *Anurida palustrus, Ballistura borealis, Folsomia sexoculata* and *Desoria breviseta.* The last species is known from sea marshes of the Spitsbergen, Kola Peninsula, Dolgii Island [Babenko et al., 2017]. In the zonal aspect, the fauna of the study area is a true boreal one. The inland (non-coastal) habitats in the environs of the Pechora Bay coast revealed only four arctic species, *Desoria tshernovi*, *Folsomia bisetosa, Pseudisotoma sensibilis* and *Oligaphorura ursi*, which were quite rare. Of the species connected to the Arctic to some extent, only *Tetracanthella wahlgreni* remains to be mentioned. All the other species recorded in the study area are typical boreal or polyzonal forms that commonly occur in the forest belt of Western and/or Eastern Europe. Some of these widespread species extend to the higher latitudes. To all appearances, collembolans are not the only group showing such composition of the fauna. Only two arctic species (6%) were found among Staphylinidae and four species (4%) among spiders [Pechora Delta, 2000]. The vascular flora of the territory has also a well-defined boreal aspect: the boreal species comprise from 39 to 49% of local floras, the hypo-arctic forms constitute 26–30%, whereas the fraction of true arctic plants is not exceed 35% [Lavrinenko et al., 2016]. The ratio of species of different latitudinal groups is determined not only by the geographical position of the territory, but also depends on the local climate and intensive migrations along the major water arteries [Lavrinenko et al., 2016].

The Specific Traits of Species Assemblages

The cenotic collembolan assemblages of the common inland habitats in the region studied are characterized by the level of species richness that is quite typical of a single survey: they include from 13 to 35 species, with the median value of 21. The zonal shrub tundra assemblages are most diverse (60 species) due to the large number of studied biotopes at all researched points. The least diverse and quite uniform assemblages are typical for alder and sedge-potentilleae associations (Table 2). Despite the somewhat impoverished local fauna, the cenotic faunas of individual habitats of the Pechora Bay ecosystems are relatively rich in species. If we consider the results of one-time surveys similar values (18–49 species) were observed in typical tundra of the Chernaya river [Konakova et al., 2017], in southern tundra of Vorkuta [Taskaeva et al., 2019] and in forest belt of Komi Republic [Taskaeva, 2006]. But the corresponding values for the southern tundra of the Padimeiskie lakes are significantly lower [Taskaeva et al., 2015].

The density of the collembolan population during the surveys was quite similar in meadows, willowyernik and zonal dwarf shrub lichen tundra, varying from 37 to 79 thous. ind./m^2. The abundance of springtails in these sites is compared with data obtained for such ecosystems both in typical and southern tundra [Konakova et al., 2017; Taskaeva et al., 2019]. The significant exceptions were the tidal strips, in which the abundance of collembolans was very high (371 thous. ind./m^2), the sedge-potentilleae and alder plant communities, in which the numbers, on the contrary, were low (Table 2). However, the total abundance is one of the

Table 1. The collembolan species composition of plant communities of the Pechora bay.
Таблица1. Видовой состав коллембол растительных сообществ побережья Печорского моря.

Family, species	Pechorskaya Bay		Korovinskaya Bay				Bolvanskaya Bay
	Khabuika	Lovetskii	Sanev	Erennoy Nos	Kostyanoy Nos	Kashin	Bolvansky Nos
Tullbergiidae							
Mesaphorura macrochaeta Rusek, 1976	+	+	+		+		
Stenaphorura quadrispina Börner, 1901					+		+
Onychiuridae							
Hymenaphorura anatolii Pomorski, 2001					+		
Oligaphorura absoloni (Börner, 1901)				+	+	+	
O. schoetti (Lie Pettersen, 1896)			+				
O. ursi (Fjellberg, 1984)	+						
Protaphorura bicampata (Gisin, 1956)			+	+	+	+	
P. boedvarssoni Pomorski, 1993	+		+	+	+	+	+
P. jacutica (Martynova, 1976)		+		+	+	+	+
P. stogovi Pomorski, 1993					+		
P. subarctica (Martynova, 1976)	+		+	+	+	+	+
P. subuliginata (Gisin, 1956) sensu Fjellberg, 1998	+						
P. tundricola (Martynova, 1976)			+	+	+	+	
Supraphorura furcifera (Börner, 1901)					+	+	+
Uralaphorura schilovi (Martynova, 1976)				+	+	+	+
Hypogastruridae							
Ceratophysella denticulata (Bagnall, 1941)		+	+	+	+	+	+
C. palustris Martynova, 1978						+	
C. succinea (Gisin, 1949)					+	+	
Hypogastrura viatica (Tullberg, 1872)		+					
Schoettella ununguiculata (Tullberg, 1869)					+		
Willemia anophthalma Börner, 1901				+	+	+	
Brachystomellidae							
Brachystomella parvula (Schäffer, 1896)				+	+		
Neanuridae							
Anurida alpina Agrell, 1939	+						
A. azurea Babenko, 1997						+	+
A. beringi Fjellberg, 1985				+			
A. ellipsoides Stach, 1949			+	+	+	+	+
A. palustris Babenko, 1997					+		
A. papillosa (Axelson, 1902)				+	+	+	
Endonura reticulata (Axelson, 1905)			+	+	+	+	+
Friesea truncata Cassagnau, 1958			+	+	+	+	+
Micranurida pygmaea Börner, 1901				+	+	+	+
Morulina gigantea (Tullberg, 1876)		+				+	
Neanura muscorum (Templeton, 1845)				+	+	+	+
Pseudachorutes sibiricus Rusek, 1991						+	+
Odontellidae							
Xenyllodes armatus Axelson, 1903	+		+	+	+	+	
Isotomidae							
Agrenia riparia Fjellberg, 1986				+	+	+	
**Ballistura borealis* (Axelson, 1905)					+		
Desoria atkasukiensis (Fjellberg, 1978)	+				+	+	
D. breviseta Potapov, 2017					+	+	
D. hiemalis (Schött, 1873)						+	
D. neglecta (Schäffer, 1900)			+	+		+	+

Family, species	Khabuika	Lovetskii	Sanev	Erennoy Nos	Kostyanoy Nos	Kashin	Bolvansky Nos
D. propinqua (Axelson, 1902)					+		
D. tshernovi (Martynova, 1974)					+	+	
D. violacea (Tullberg, 1876)				+	+	+	
Folsomia amplissima Potapov et Babenko, 2000	+		+	+	+	+	
F. bisetosa Gisin, 1953			+		+	+	+
F. ciliata Babenko et Bulavintsev, 1993				+			
F. fimetaria (Linnaeus, 1758)	+						
F. longidens Potapov et Babenko, 2000				+			
F. manolachei Bagnall, 1939		+	+		+	+	
F. palaearctica Potapov et Babenko, 2000			+		+	+	+
F. quadrioculata (Tullberg, 1871)	+	+	+	+	+	+	+
F. rossica Potapov et Dunger, 2000				+		+	+
F. sexoculata (Tullberg, 1871)					+		
Isotoma anglicana Lubbock, 1873						+	
I. gorodkovi Martynova, 1970		+		+		+	+
I. riparia (Nicolet, 1842)	+		+		+	+	
I. viridis Bourlet, 1839		+	+	+	+	+	+
Isotomiella minor (Schäffer, 1896)		+	+		+	+	+
Isotomodella alticola (Bagnall, 1949)					+		
**Isotomurus palustris* (Müller, 1776)					+	+	
I. stuxbergi (Tullberg, 1876)						+	
Pachyotoma crassicauda (Tullberg, 1871)						+	
P. miserabilis Potapov, 2017	+	+	+	+	+	+	+
Parisotoma ekmani (Fjellberg, 1977)			+	+	+		+
P. notabilis (Schäffer, 1896)		+	+	+	+	+	+
P. reducta (Rusek, 1984)						+	
Pseudisotoma sensibilis (Tullberg, 1876)		+		+	+	+	+
Tetracanthella wahlgreni Axelson, 1907	+	+	+	+	+	+	+
Tomoceridae							
Tomocerina minuta (Tullberg, 1876)				+	+	+	
Entomobryidae							
Entomobrya nivalis (Linnaeus, 1758)		+			+	+	+
L. lignorum (Fabricius, 1793)			+	+	+	+	+
LWillowsia buski (Lubbock, 1870)							+
Neelidae							
Megalothorax sp.1				+			
Sminthurididae							
Sphaeridia pumilis (Krausbauer, 1898)			+		+	+	+
Katiannidae							
Sminthurinus aureus (Lubbock, 1862)						+	+
S. igniceps (Reuter, 1881)							+
**S. trinotatus* Axelson, 1905							+
Arrhopalitidae							
Pygmarrhopalites principalis (Stach, 1945)						+	+
Bourletiellidae							
Heterosminthurus claviger (Gisin, 1958)							+
Dicyrtomidae							
Ptenothrix atra (Linnaeus, 1758)							+
Number of species	15	15	26	36	52	54	37
Number of biotops / samples	1 / 6	3 / traps	1 / 10	3 / 15	7 / 39	6 / 51	4 / 14

NOTE. The eudominants and dominants are shown in bold; “+” indicates the presence of a species with the relative density of less than 1%.
ПРИМЕЧАНИЕ. Эудоминанты и доминанты выделены жирным шрифтом; “+”обозначено присутствие вида с долей менее 1%.

Table 2. Relative abundance (% of the total abundance) of mass collembolan species in the main plant associations.
Таблица 2. Относительное обилие (% от общей численности) массовых видов ногохвосток в основных растительных ассоциациях.

Species	Zonal tundra (n = 12)	Willow-yernik (n = 5)	Meadows (n = 2)	Sedge-potentilleae (n = 1)	Alder (n = 1)	Tidal strips (n = 1)
Folsomia quadrioculata	**25.0**	**23.1**	**72.2**	**28.2**	**33.7**	+
Tetracanthella wahlgreni	**37.5**	**17.7**	4.2	11.3	2.6	+
Parisotoma notabilis	1.1	**16.4**	3.6	–	**25.5**	+
Pseudisotoma sensibilis	7.8	5.5	–	–	–	–
Pachyotoma miserabilis	2.4	9.7	–	–	–	–
Protaphorura boedvarssoni	1.5	1.1	7.1	–	–	–
Ceratophysella palustris	–	–	–	**25.0**	–	–
Desoria neglecta	+	–	–	8.9	3.7	–
Protaphorura subarctica	1.2	1.0	–	–	9.7	+
Isotomiella minor	+	2.8	1.6	–	9.4	–
Ceratophysella succinea	–	–	–	–	+	**66.3**
Anurida palustris	–	–	–	–	–	10.4
Desoria breviseta	+	–	–	–	–	6.7
Folsomia sexoculata	–	–	–	–	–	6.4
Mean density, thous.ind./m^2	79.3±19.1	37.7±9.2	48.2±24.0	9.9±1.1	17.8±7.8	370.9±81.1
D_{BP}	0.5	0.3	0.6	0.3	0.3	0.7
S (number of species)	60	47	23	16	16	24

NOTE. The eudominants and dominants are shown in bold; "+" indicates the presence of a species with the relative density of less than 1%.
ПРИМЕЧАНИЕ. Эудоминанты и доминанты выделены жирным шрифтом; "+"обозначено присутствие вида с долей менее 1%.

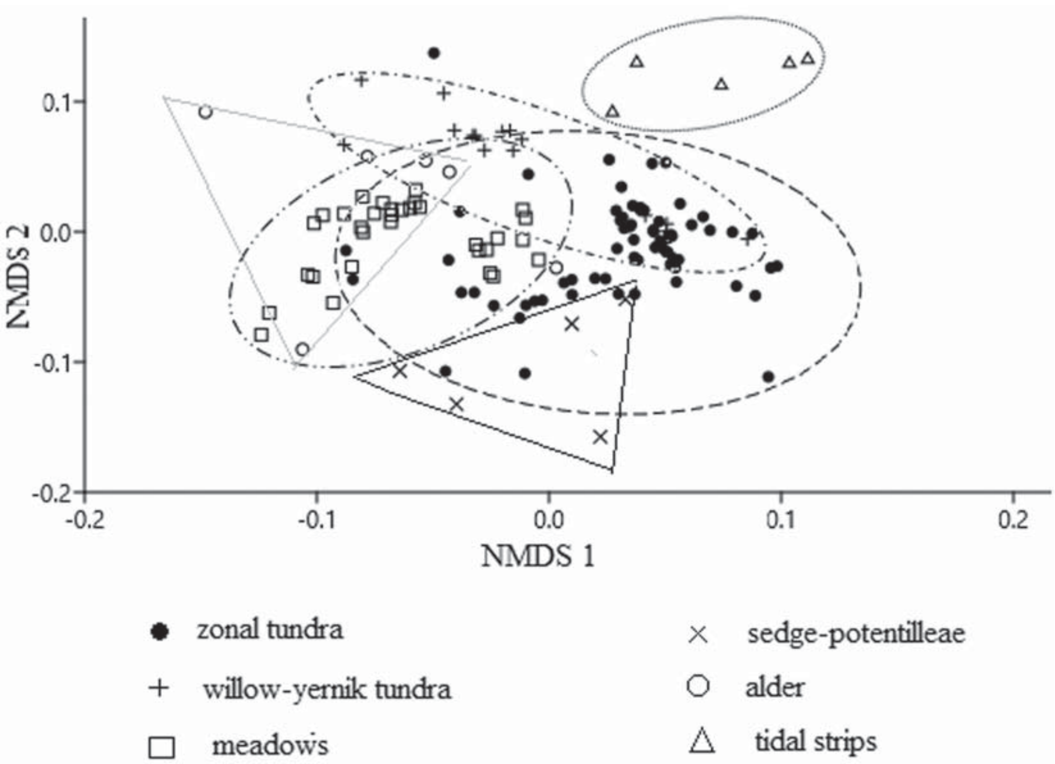

Fig. 2. Multidimensional scaling of springtails communities in the studied plots. Samples from the same phytocenoses are outlined.
Рис. 2. NMDS ординация сообществ коллембол на исследованных участках. Пробы из одних и тех же фитоценозов обведены линией.

most dynamic parameters of the soil assemblages [Kuznetsova, 2005], which strongly depends not only on the natural dynamics in a particular community but also on the method used.

A characteristic feature of most of the examined assemblages of the Pechora Bay ecosystems is a very high level of dominance of a few species (Table 2), often considerably exceeding the eudominant level (39.4%) on the scale of Engelmann [1978]. In meadows the eudominant was the widespread ubiquitous *Folsomia quadrioculata*, a very common form in the East European tundra; *Ceratophysella succinea* was the eudominant in the tidal sprips. A more uniform distribution of species with respect to abundance were observed in the willow-yernik, alder and sedge-potentilleae associations ($D = 0.3$), though in the latter cases this may have been the result of low general population density. Moreover, all the tundra habitats showed a high abundance of *Tetracanthella wahlgreni* which was also found in a number of other communities in the study area. As can be expected from the high similarity of the main dominants (often also subdominants) of the assemblages studied, most of the samples overlap extensively and form a single cluster in the multidimensional scaling plot (Fig. 2). Three collembolan assemblages are the most clearly distinguished: those of the tidal strips, alder and sedge-pottentilleae associations. These communities are indeed very distinct in the landscape due to their peculiar vegetation, therefore it is quite natural that their soil complexes differ from those of the background tundra habitats.

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