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Soil Macrofauna of the South of Kunashir Island (Kuril Islands, Russia)

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Study of the soil biota organization under the conditions of minimal human influence in different soil types is one of the most important tasks for both fundamental and applied soil biology. When developing the concept of the zoological method of soil diagnostics, Gilyarov [6] considered the taxonomic diversity and the number of species of the soil macrofauna as the main parameters, characterizing soil types and soil differences. Soils of the Russian Far East were studied not so thoroughly. Notwithstanding considerably detailed earlier soil-faunistic investigations in the Russian Far East [3, 11], the problem of zoological diagnostics of the Far Eastern soils remained virtually unexplored [7]. For the majority of soil animal regional lists of species and the ecology of their communities information is still fragmentary. Particularly, this gap in knowledge about soil biota of the region is observed for island areas.

The fauna of the Kuril Islands was studied considerably often. It is also true for different groups of invertebrate animals [10, 13]; however, quantitative assessment of the soil population in Kunashir Island (the Greater Kuril Ridge) has not been conducted yet. Thereupon, the aim of our study was to investigate the number and diversity of the soil macrofauna communities from the main habitats of the southern part of Kunashir Island and preliminarily analyze their characteristics as compared with the other parts of the Far Eastern region.

MATERIAL AND METHODS

Study area. Material was collected in Kunashir Island, one of the most southern islands of the Greater Kuril Ridge. The majority of study sites were in the Kurilskii State Nature Reserve. The reserve consists of several clusters. Alekhinskii cluster, in which the majority of studies were performed, is located in the southeastern part of the island. A part of the Alekhinskii cluster is occupied by the caldera of the Golovnin Volcano (541 m above sea level) with the Sernovodskii Isthmus, which is occupied by Lake Peschanoe, adjoining to it on the north. The relief of this part of the island is smooth with soft contours of slopes of low hills. The climate is mild, monsoon; it is characterized by relatively warm winters and chilly summers with many foggy days. The average air temperature of the warmest month (August) is 15.5°C, that of the coldest month (February) is –4.6°C. The average annual precipitation is 1291 mm (www.kurilskiy.ru). In the reserve, podzolic soils are typical for coniferous forests; brown forest soils, for broad-leaved forests; sod–meadow soils, for bamboo ecosystems; and peaty–gley soils, for swamped areas. Flora is assigned to the Kuril–Sakhalin district of the Japanese–Korean oceanic province, Far Eastern conifer-broad-leaved forest region. A combination of relic subtropical and endemic temperate and boreal forests and Okhotsk species and communities is characteristic of the flora and fauna of these forests. The fauna of some groups of invertebrates in the reserve has been studied quite well (www. kurilskiy.ru; Makarov, unpublished data).

In late August 2012, eight soil samples 25 × 25 cm in size were collected in each of ten main vegetation formations down to a depth of 30 cm for estimation of the number of invertebrates. Samples were collected randomly in an area of about 0.25 ha. The depth of litter was determined for each sample. Animals were collected from samples manually. Animals were fixed in 96% ethanol and identified in the laboratory. Preliminary data on the taxonomic composition of macrofauna are presented in this study.

RESULTS

Soil macrofauna of studied localities (Fig. 1). The broad-leaved forest consisted of *Quercus crispula*, *Acer*

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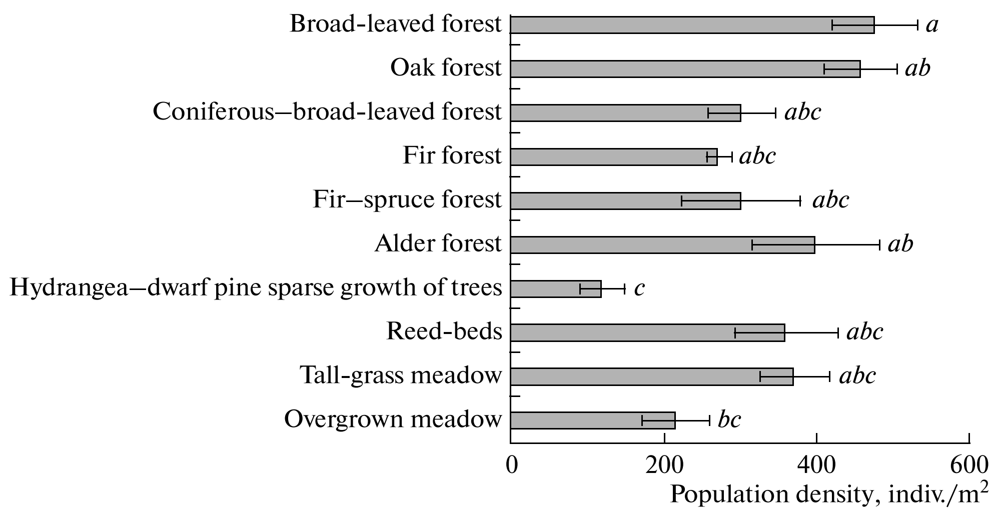

Population density (individuals/m^2, $M \pm m$, $n = 8$) of the soil macrofauna in the main types of habitats in the south of Kunashir Island in August 2012. Identical letters indicate the values not significantly differing according to Tukey's test.

mayrii, Phellodendron sachalinense, and *Ulmus japonica*. The macrofauna population density was one of the highest (474 ± 56 individuals/m^2). Totally, 32 groups of invertebrates were found in the area, the basis of the population was comprised by spiders (27%) mainly from the families Lycosidae and Linyphiidae, earthworms (18%) and lithobiids (8%). Spiders *Pocadicnemis pumila* Blackwall 1841 were found only in this area. *Pheretima hildendorfi* Michaelsen, 1892, a species of the family Megascolecidae from the Red Data Book of the Russian Federation, was recorded among earthworms. There is also a high proportion of diplopods (mainly polydesmids *Epanerchodus orientalis* Attems, 1901) and chilopods. Characteristic of this community is the presence of amphipods of the family Talitridae, namely, *"Orchestia" kokuboi* Ueno 1929, found in Russia for the first time. Earlier, the amphipods *Traskorchestia ochotensis* Brand, 1851 [12] were found in the littoral zone, where the authors probably did not separate it from the species living in the soil and along banks of freshwater streams. The woodlice *Porcellio scaber* F., 1792 were also numerous.

In the oak (*Q. crispula*) forest the density of macrofauna was comparable with that in the previous habitat (456 ± 47 individuals/m^2). The diversity was also the highest (32 groups). Spiders of the families Linyphiidae and Nesticidae were the most abundant, with the latter family represented by one species, *Nesticella brevipes* (Yaginuma, 1970). At the same time, the proportion of earthworms among all soil animals was slightly higher than 3%. The polyzonids (*Angarozonium aduncum* (Mikkaljova, 1995)) constituted one of the most abundant groups (10% of the total abundance of macrofauna). Terrestrial leeches *Orobdella kawakatsuorum* Oka, 1895 and numerous gastropods and opiliones were also found in the area.

In the coniferous–broad-leaved forest (*Abies sachalinensis, Picea ajanensis* and *Q. crispula, A. mayrii*, and *Ph. sachalinense*, respectively) the population density (304 ± 78 individuals/m^2) and diversity (21 groups) of soil invertebrates were lower than those in broad-leaved and oak forests. Spiders of the families Salticidae and Linyphiidae (20%), amphipods (12%), and myriapods (both chilopods (17%) and diplopods (9%)) dominated in this area. The diplopod *Underwoodia kurtschevae* Golovatch, 1980 was found only here and in the broad-leaved forest. Among spiders, only *Herbiphantes cericeus* (Saito, 1934) was recorded. The density of opiliones (14 individuals/m^2) and woodlice (8) was maximal among all studied habitats.

The fir (*A. sachalinensis*) forest was characterized by the lowest population density of invertebrates among all forest habitats (278 ± 14 individuals/m^2) and a rather low taxonomic diversity (21 groups). Spiders of the families Linyphiidae and Agelenidae, geophilids, lithobiids, and staphilinid beetles dominated. The spider *Centromerus terrigenus* (Yaginuma, 1972) was found only here. In contrast to the previous areas, wireworms (5%) and beetles of the family Ptiliidae were among dominants. The finding of leeches (2 individuals/m^2) was unexpected for this type of localities.

A relatively high density (304 ± 78 individuals/m^2) but low diversity (14 groups) of the soil macrofauna has been found in fir–spruce forest (*A. sachalinensis* and *P. ajanensis*). More than a half of the population was accounted for by lithobiids and geophilids; however, the numbers of the latter were overestimated because one of the samples contained a nest with juvenile geophilids (more than 30 individuals). The rest of the macrofauna was represented by typical boreal groups (wireworms and staphilinids).

The most damped forest region, an alder (*Alnus hirsuta*) forest, was characterized by high density (398 ± 82 individuals/m^2) and average level of taxonomic diversity (23 groups) of the soil fauna. Spiders and amphipods (up to a quarter of the total macrofauna), as well as the earthworms *Dendrobaena octaedra* (Savigny, 1826) and *Lumbricus terrestris* L., 1758 (21% of total macrofauna) dominated in the area. The number of each of the rest groups did not exceed 5% of the population, except for imagoes of carabids (5.5%).

The hydrangea–dwarf pine sparse growth of trees (*Hydrangea paniculata* and *Pinus pumila*, respectively), the most swampy region in our study, was characterized by the lowest population density and diversity of invertebrate groups. Spiders (49%) were represented here by seven families, as well as lithobiids, staphilinids, and copepods dominated in this area.

Reed-beds (*Phragmites australis*) located near the previous area on the bank of Lake Goryachee were characterized by relatively high macrofauna density (368 ± 68 specimens/m^2) and diversity (19 groups). Spiders of the families Lycosidae and Linyphiidae (38%) had the highest proportion in the macrofauna, but among dominants there were exceptionally beetles, including staphilinids, carabids, and nitidulids.

Two grassy areas, a tall-grass meadow (*Reynoutria sachalinensis*, *Filipendula camtschatica*, *Heracleum lanatum*, *Cacalia robusta*) and ruderal forb–grass–bamboo (*Lilium pennsylvanicum*, *Thermopsis lupinoides*, *Leymus mollis*, *Poa macrocalyx*, and *Sasa* sp.) meadow, differed both in population density (400 and 214 individuals/m^2) and diversity (26 and 19 taxa, respectively) of soil macrofauna. However, the structure of communities was similar: earthworms of the family Lumbricidae, spiders, and staphilinids dominated in both areas. Geophilids and amphipods were also found to be co-dominants in tall-grass communities; leafhoppers and polydesmids (mainly, *Uniramidesmus septimus* (Mikhailjova, 1990)), in meadow communities. Woodlice *P. scaber* (10 individuals/m^2) were recorded in the meadow.

DISCUSSION

According to the data on the composition of soil animals, it is possible to distinguish the major groups of habitats of the southern part of the island: forest, open habitats and semi-aquatic. Forest communities are represented by an association typical for boreal ecosystems: earthworms, chilopods, spiders, wireworms, and staphilinids. In similar forests of the Russian Far East, the abundances of these groups of soil macrofauna are about the same [4]. In broad-leaved forests of the Lazovskii State Nature Reserve, e.g., lithobiids (122 individuals/m^2), julid millepedes (106), and spiders (104) were the most abundant [8]. Total number of earthworms in the Suputinskii State Nature Reserve (now, Komarov Ussuriiskii State Nature Reserve) (32–53 individuals/m^2) reported by Gilyarov and Perel' [5, 7], is lower than that in our data obtained in the south of Kunashir Island. According to own and literature data, a common regional feature of soil fauna of the Russian Far East is the presence of amphipods, leeches, and earthworms of the family Magascolecidae [2, 4, 7].

Our data allow assuming that geological factors, including the age of islands of the Greater Kuril Ridge, play a considerable role in the formation of the diversity of soil macrofauna of Kunashir Island. The terrestrial leech *O. kawakatsuorum* [14], which is a relic of the tertiary fauna with the most northern finding known on Hokkaido Island, was found in soils of the Kurilskii Nature Reserve for the first time. Species diversity and abundance of leeches in Japanese islands are higher by an order of magnitude, although they occur throughout the southern Russian Far East. In the Suputinskii Nature Reserve, *Orobdella whitmani* (Oka, 1895) was found in one-third of the locations studied, its population density was 2 individuals/m^2 [7]. This agrees with the geological history of the formation of the region. In the beginning of the Holocene (11 000–12 000 years ago), the post-glacial sea transgression started, temperature increased, which became clear after the discovery of the La Pérouse Strait which allowed the penetration of a warm current into the Sea of Okhotsk [9]. As a result, the connection between islands of Kunashir and Hokkaido (7500 years ago) was lost, and Sakhalin Island was separated from Primorye (7000 years ago) [1]. Findings of some species of terrestrial talitrids and spiders, described in Japan confirm the similarity of the faunas of Kunashir and the Japanese Archipelago.

The spread of the woodlice *P. scaber* in Kunashir Island is probably connected with the appearance of people: they were the first terrestrial woodlice that appeared in the island and distributed, having found numerous suitable habitats. Almost worldwide distribution of this species is the evidence for this assumption [15]. Autochthonous species of woodlice were not found, except for inhabitants of the littoral zone (*Detonella papillicornis* Richardson 1904, *Tylos granuliferus* Budde-Lund 1885, and *Ligia cinerascens* Budde-Lund 1885), which are species with trans-Pacific or north-Pacific ranges [15].

In conclusion, the following characteristics of soils of Kunashir Island may be noted: relatively high, for the Far East, numbers and diversity of macrofauna, the presence of amphipods and leeches in the macrofauna, and a high abundance of opiliones.

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