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Article *in* Russian Journal of Biological Invasions · January 2021

DOI: 10.1134/S2075111721010069

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ISSN 2075-1117, Russian Journal of Biological Invasions, 2021, Vol. 12, No. 1, pp. 44–49. © Pleiades Publishing, Ltd., 2021.
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In memory of Gennady Nikolaevich Ganin (1959–2019), an outstanding researcher of the soil fauna of the Far East

Distribution of Alien Species of Woodlice (Crustacea, Isopoda, Oniscidea) in the Russian Far East

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Received May 28, 2020; revised October 9, 2020; accepted October 26, 2020

Abstract—Woodlice were not recorded in the fauna of undisturbed terrestrial ecosystems of the Russian Far East. Initially, in this region, three species of this group lived only on the littoral and were well studied by marine biologists. In the 20th century, separate records of woodlice began to appear in terrestrial ecosystems, and in recent years, the number of finding points and species has increased. Since the beginning of the 21st century, the fauna of synanthropic woodlice has already reached ten species. The only species that successively invaded untouched forest ecosystems is *Porcellio scaber*. Along with other cosmopolitan species, the alien species *Hyloniscus riparius* also penetrated here, the distribution of which in the European part of Russia became widespread. Penetration of woodlice in the territory where they never existed may cause the extinction of the indigenous saprophagous species and lead to a decrease in the level of biological diversity in the soil and the sustainability of ecosystems in the long term.

Keywords: woodlice, cartographic analysis, alien species, soil fauna
DOI: 10.1134/S2075111721010069

INTRODUCTION

An important problem of modern ecology and biogeography is the expansion of the ranges of species, and often invading species originate from other continents (Dgebuadze, 2000; Stigall, 2019). Geobotanists and vertebrate zoologists have already identified this problem for their objects for quite some time; however, the identification of the scale of migration of invertebrate species is still at an early stage (Hanski, 2005). However, soil biologists have also already faced the problem of invasions of invertebrate species (Bohlen et al., 2004; Tiunov et al., 2006). Most of the attention is focused on the colonization of soil ecosystems by alien species of earthworms, which, being ecosystem engineers, significantly transform the rate of litter destruction and the flux of carbon and nitrogen in ecosystems (Eijsackers, 2011), which leads to serious changes in their structure, up to changes in the appearance of the landscape. Many other invading species among invertebrates, which alone do not exert such a significant influence on the processes taking place in ecosystems, imperceptibly to our eyes occupy niches suitable for them in soil ecosystems, often competing with the local fauna. One of these groups is woodlice, which are undemanding to food and are capable of consuming a wide range of plant litter (Hopkin, 1991). Under favorable climatic conditions, they are able to survive in ecosystems that are significantly different in hydrothermal and soil-chemical characteristics from the original ones. It is for woodlice as nonspecialized saprophages that a sharp increase in the number of species with expanded ranges, up to cosmopolitan ones, has been noted (Schmalfuss, 2003). Invasive species were noted among woodlice in many ecosystems of Russia; in particular, an expansive broadening of the range of *Hyloniscus riparius* was shown in the center of the European part of Russia (Gongalsky et al., 2013).

A fairly large number of works have been devoted to the soil fauna of the Russian Far East (Gilyarov and Perel, 1969, 1973; Molodova, 1973), which were summarized in the catalogs of species composition (Kurcheva, 1977; Ganin, 1997), and on their basis, the patterns of distribution of communities within the region were analyzed (Ganin, 2011). None of the listed works indicates the habitation of any species of woodlice in the Far East. Nevertheless, littoral isopods were repeatedly encountered on the coasts of Primorsky

Table 1. Fauna of woodlice in the Russian Far East

Littoral species	Alien terrestrial species
Detonella papillicornis (Richardson, 1904)	*Armadillidium nasatum* Budde-Lund, 1885
Ligia cinerascens Budde-Lund, 1885	*Armadillidium versicolor* Stein, 1859
Tylos granuliferus Budde-Lund, 1885	*Cylisticus convexus* (De Geer, 1778)
	Hyloniscus riparius (Koch, 1838)
	Porcellio laevis Latreille, 1804
	Porcellio scaber Latreille, 1804
	Porcellio spinicornis Say, 1818
	Porcellionides pruinosus (Brandt, 1833)
	Protracheoniscus sp.
	Trachelipus rathkii (Brandt, 1833)

Territory, Sakhalin, and the Kuril Islands (Kusakin, 1976), but they are traditionally not included in the lists compiled by soil zoologists. Our own observations and the materials of our colleagues show that the Russian Far East is, before our very eyes, becoming an arena for the penetration of real soil-dwelling woodlice into terrestrial ecosystems.

The current work sets the task of identifying the composition of alien species of woodlice and the trends of its expansion in the territory of the Russian Far East.

MATERIALS AND METHODS

We have created and are updating the database of the woodlice fauna of the territory of the former Soviet Union (Kuznetsova and Gongalsky, 2012). For each point where woodlice were found, it contains the species, source of information, year, and biotope, if known. For each species, the type of range according to Schmalfuss (2003) and a list of places of finds (localities) are given. In addition, the database contains the places of finds of woodlice with an undefined taxonomic composition and points of reliable absence of woodlice in the soil mesofauna. The list of localities is available in the open international system Edaphobase (2020). For the places where woodlice were absent, only sources that indicated a detailed and, preferably, long-term study of the soil mesofauna were selected. On the basis of the database, a cadastral map of the localities of the presence of woodlice in the soil fauna of the Russian Far East was compiled for four observation periods: up to 1900 (1 observation), 1950 (2), 2000 (14), and 2020 (53 observations).

In the summer of 2019, within the framework of the Russian Geographical Society's project to study the colonization of soil invertebrates in the Russian Far East, we collected material on the distribution of woodlice, which was also included in the database. It greatly expanded our knowledge of the distribution of certain species.

We understand the Russian Far East as Yakutia and Amur Region, as well as all regions of the country lying to the east. The species identification of woodlice was carried out using specialized literature (Schmölzer, 1965; Hopkin, 1991); the taxonomy is given according to Schmalfuss (2003).

Cartographic processing was carried out using the ArcGis 10.6 software package.

RESULTS AND DISCUSSION

In the Russian Far East, 70 localities were noted where woodlice were found. In particular, three species inhabiting the littoral and supralittoral were noted—*Ligia cynerascens*, *Tylos granuliferus*, *Detonella papillicornis* (Table 1). These are local species that are not part of the communities of terrestrial ecosystems and therefore have not been noted by soil zoologists. The only alien species recorded in this area in the 19th century is *Porcellio laevis* (Table 1). From the middle of the 20th century, another alien species is noted in the fauna—*Porcellio scaber*. This species was found in the maximum number of localities (Fig. 1). It is distributed from the southern regions of Primorsky Territory to the northernmost point of finding woodlice—in the villages of Lazarev and De Kastri in Khabarovsk Territory, as well as on the islands of the Greater Kuril Chain (Kunashir, Iturup, and Urup) and the Lesser Kuril Chain (Shikotan) (Fig. 2).

From the end of the 20th century, the number of finds of alien species began to increase sharply (Fig. 3). The almost cosmopolitan *Cylisticus convexus* and *Trachelipus rathkii* were recorded first. At the beginning of the 21st century, there was a manifold increase in the number of finds of alien species, mainly in southern Primorye (Fig. 4). In Vladivostok and south of it, there are two species of the genus *Armadillidium* (*A. versicolor*, *A. nasatum*), *Porcellionides pruinosus*, representatives of the genus *Protracheoniscus* (only females were collected, which did not make it possible to reliably determine the species), and *Hyloniscus*

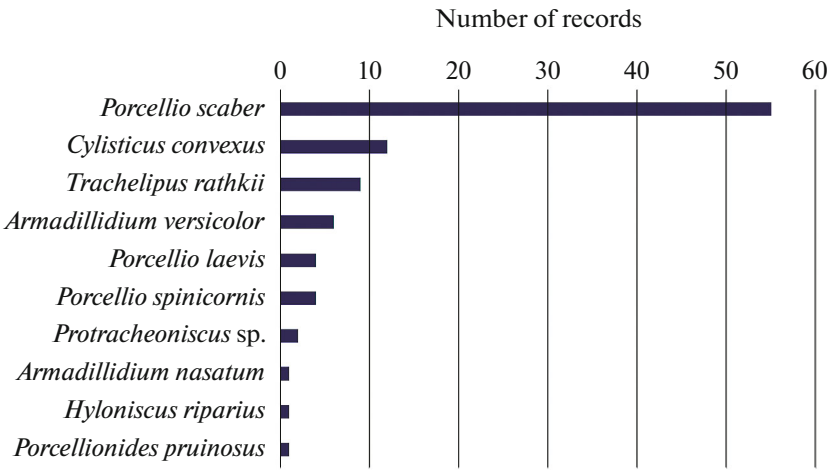

Fig. 1. The number of finds of terrestrial woodlice species in the Russian Far East.

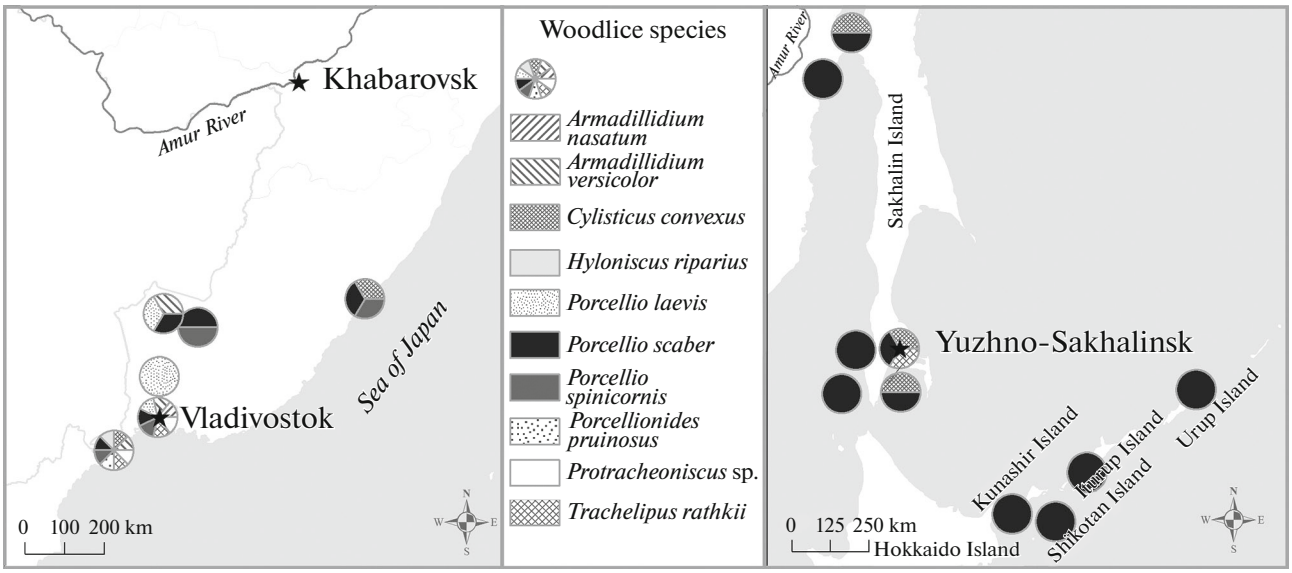

Fig. 2. Fauna of alien species of woodlice in the Russian Far East.

riparius; therefore, it seems likely that these species are found in many other similar habitats on the territory of southern Primorye. The set of species within localities appears to be random. In each locality to the south of Vladivostok, two or three species were found, and in villages located on the shores of Posiet Bay, sometimes up to six species at a time were found (Fig. 4).

Despite the poor knowledge of woodlice in our country and a low density of points of their findings on maps, it seems obvious that woodlice are increasingly spreading in the Russian Far East. Our analysis has a fairly large set of limitations, primarily in the number of points related to different periods of research. It is impossible to establish reliably whether before 1950 there were only single finds of species, or they were simply not recorded in collections. After 1950, information becomes quantitative with the development of large-scale soil zoological research begun by Acad. M.S. Gilyarov all over the country. An exhaustive review of soil biological research carried out by the end of the 1970s published by Kurcheva (1977) indicates the absence of woodlice in the lists of the fauna of the Far East. At the same time, such reviews usually do not touch upon single finds of woodlice, data on which are stored only in zoological collections and archives. We have previously shown (Gongalsky et al., 2012) that eight localities are sufficient to identify the woodlice fauna within a biome. In this regard, the excess (more than 50) points after 2000 could not proportionally increase the number of species found.

The second limitation is due to the fact that, in the second half of the 20th century, most soil zoological

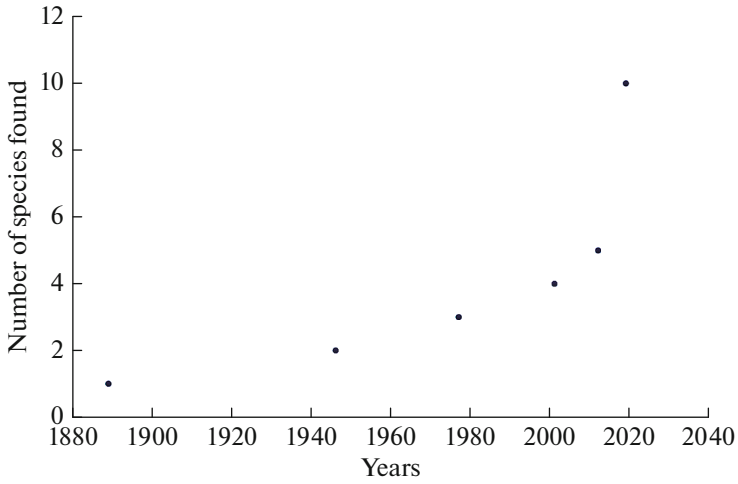

Fig. 3. Cumulative number of alien woodlice species in terrestrial habitats of the Russian Far East.

studies were carried out in undisturbed terrestrial ecosystems. As a rule, the soil fauna was studied in reserves and other reference conditions, where there are few alien species of woodlice even at the present time. So, according to studies by Ganin (2011) and by us (Gongalsky et al., 2014), only one species penetrated into such habitats, *Porcellio scaber*. Most of the locations of the finds of alien species belong to residential areas, parks, and forest park zones. During the work of M.S. Gilyarov and his students, much less attention was paid to these ecosystems, and therefore many species might not have been identified earlier. Unfortunately, our attempt to divide all localities into natural and synanthropic ones was unsuccessful, since this information is practically inaccessible in old collections.

Nevertheless, despite the forced limitations in the methodological part of the work, one can note a tendency for the appearance of alien species exclusively in synanthropic habitats (within urban and rural settlements), only sometimes in disturbed forests around settlements.

While working on the study of soil mesofauna of Kunashir Island, we were able to trace the distribution of the only terrestrial species of woodlice on the island—*Porcellio scaber*. On Kunashir Island, the habitat *P. scaber* was noted both in the littoral area and in terrestrial ecosystems (Gongalsky et al., 2014). Among 11 points of sampling quantitative soil zoological samples of woodlice, *P. scaber* were featured in four. The number has always been low: from 2 to 10 individuals/m^2; however, locally it was possible to find clusters where these woodlice are found in the hundreds: under the bark of fallen trees, under stones, etc. *P. scaber* in the Russian Far East is associated with the presence or former activities of humans, since the species was encountered on the seacoasts and in the forests in the vicinity of residential or abandoned villages. It was also found on the territory of the Kuril Nature Reserve, for example, on the Ozerny cordon in the caldera of Golovnin volcano, while in the other studied habitats in the caldera and along the Ozernoye stream, woodlice were not recorded. We assume that its distribution on Kunashir is associated with the location of settlements during the time that the island belonged to Japan, when the density of the population and buildings was much higher. The compiled map of woodlice distribution (Kuznetsova and Gongalsky, 2012) showed the potential suitability of Kunashir for woodlice habitat. Our field studies have confirmed the validity of this assumption. According to our data, not only extrazonal habitats (marine littoral, basements of houses) are inhabited by woodlice, but also natural habitats support stable populations of woodlice as a natural component of the soil population. However, *P. scaber* is so far the only species in the Far East found in natural terrestrial habitats. Its participation in ecosystems is consistent with the theory of a successful colonist (Mayr, 1965), which states that the first to find suitable conditions settled all possible habitats. Why other synanthropic species do not yet inhabit these ecosystems favorable for wood lice remains unknown. The reason for the absence of endemic woodlice species on the Kuril Islands is probably their young geological age since the last uplift. At this time, the main variety of wood lice on the planet had already been formed, and only existing species could have been brought here, which during their habitation had not yet had time to give new species owing to geographical isolation. The penetration of tropical species from the Japanese islands could have been expected. However, for such dynamic territories of the Cenozoic age, regularly covered with volcanic ash, the level of endemism in soil communities was generally low. In addition, acidification of soils and cold winters do not contribute to the high diversity of woodlice. Why there were no local woodlice species on the territory of the

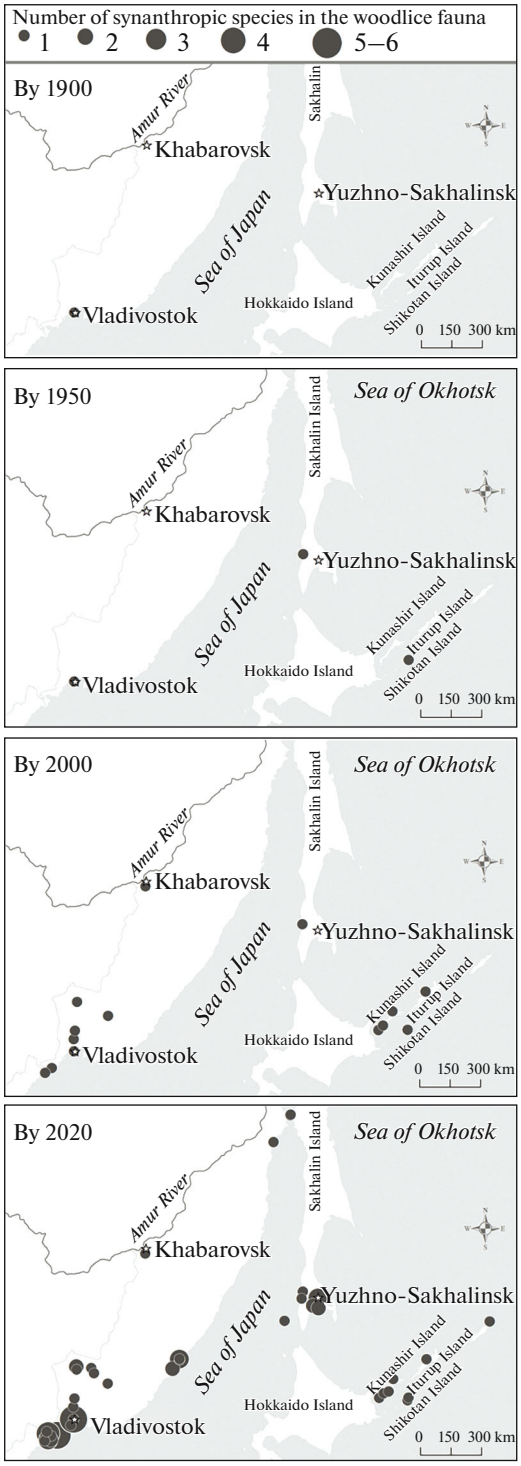

Fig. 4. The number of alien species of woodlice in terrestrial habitats of the Russian Far East by 1900, 1950, 2000, and 2020 (top down).

continental Far East, despite the rather rich fauna of Japan and Korea (Schmalfuss, 2003), remains to be clarified in the future.

It is also worth noting the appearance in the Far East of one of the most actively spreading species of woodlice in the world—*Hyloniscus riparius* (see (Gongalsky et al., 2013) and references therein). The appearance of this massive species in the forests in the vicinity of the settlements of the European part of Russia has already caused alarm, since the species may well displace the local species of saprophages.

Thus, the Russian Far East seems to be a unique natural laboratory where woodlice are actively introduced. Moreover, if at the first stage the development of natural territories was carried out by the only active species that inhabited many suitable habitats over several decades, then in recent years there has been a tendency for many other species to penetrate into this territory, which are still in the first stages of settling this territory.

ACKNOWLEDGMENTS

We express our gratitude to the administration and staff of the Kuril Nature Reserve for their help in organizing field work on Kunashir Island, especially M.A. Antipin, the deputy director for scientific work of the reserve. We are grateful to the woodlice collectors in the Far East who provided their materials, especially L.A. Prozorova. We are grateful to A.S. Zaitsev for valuable comments on the manuscript.

FUNDING

The research on Kunashir Island was supported by the Russian Foundation for Basic Research, grants 11-04-00245-a and 12-04-10148-k, and the research on the mainland of the Russian Far East was supported by the Russian Geographical Society, grant 13-2019-R.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflict of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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