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Insect Invasions into Terrestrial Ecosystems of the Russian Far East

V. N. Kuznetsov and S. Yu. Storozhenko

Institute of Biology and Soil Science, Far Eastern Branch, Russian Academy of Sciences, pr. 100-letiya Vladivostoka 159, Vladivostok, 690022 Russia

e-mail: storozhenko@ibiss.dvo.ru

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Abstract—The problem of insect invasions into the Russian Far East is discussed. It is proposed to develop a database on the species introduced into the region.

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In the current epoch of intense anthropogenic changes, natural ecosystems are preserved only in limited areas, where the impact of human activity is usually restrained only because of special factors, such as extreme remoteness and effective protection regime [Alimov et al., 2004]. One of the components of the process of ecosystem evolution is invasions, i.e., migration of species from one region into another, the introduction of new alien species into ecosystems, and their impact on indigenous communities. Biological invasions are understood as all the cases where living organisms are introduced into ecosystems outside the limits of their initial (usual, natural) range. The introduction of alien animal, plant, and microorganism species into natural ecosystems resulting from human activities can be viewed as biological pollution [Kolonin et al., 1992; Izhevskii, 1995]. The migration of alien species is currently global, leading to decreases in regional species diversity [Zaitsev and Reznik, 2004]. As a result of the intensification of industry and agriculture and activation of international trade, biological invasions of various organisms have led to enormous changes in ecosystems worldwide. There are well-known examples of invasions of alien species that resulted literally in national disasters (phylloxera in France, rabbits and prickly pear in Australia, water hyacinth in tropical Asia, etc.).

In Russia, fundamental and applied studies of invasion processes started not so long ago and are still conducted on a relatively low scale; the monitoring of invasive species is still poorly supplied with information; only two or three databases on all groups of invasive organisms have been created. This is very little in comparison, for instance, with the United States, where 34 databases were created exclusively on invasive plant species [Dgebuadze, 2002]. At the same time, this is a problem of extreme social and economic importance for Russia, since the number of cases where biological invasions have resulted in large-scale ecological cataclysms (ragweeds of the genus *Ambrosia*, the Colorado potato beetle, the golden nematode, the Chinese sleeper fish, etc.) is constantly growing. For instance, the area of Russia occupied by the Colorado potato beetle (*Leptinotarsa decemlineata* Say), a dangerous pest to potatoes, has increased over the last 30 years by a factor of more than 12190, reaching 3 million ha, and the area occupied by the fall webworm (*Hyphantria cunea* Drury) has increased by a factor of 832 [Izhevskii, 2002b]. Over the last 80 years, more than 100 alien species of phytophagous insects have established themselves in the territory of the former Soviet Union [Izhevskii, 1990]. Many of these species are classified as pests, and eight are dangerous quarantine species. The number of established alien insect species in some other areas of the world is considerably larger. More than 1500 insect species have been introduced to the United States, 225 of them classified as especially serious pests. In Japan, 72% of the 198 introduced insect species are classified as pests, whereas the proportion of pests among local phytophagous species is at most 7% [Izhevskii, 2002].

The notion of biological invasions includes both cases caused by human activities (introductions) and natural migrations of species beyond the limits of their usual distribution. The so-called natural expansions of ranges observed currently and resulting from long-term effects of human activities (changing habitats, global warming) should also be taken into account [Panov, 2002]. It is rather difficult to distinguish between invasions and increases in abundance of some species caused by global environmental changes, but in some cases it is possible. This can be illustrated by the example of two grasshopper species that have become abundant in southern Primorskii krai over the last decade. *Shirakiacris shirakii* Bol. in the last third of the 20th century was common only in the southern-

most areas of the Khasanskii district (42.5° N), but, at the same time, was sporadically recorded in other districts of the krai. Currently, this species is one of the most common grasshopper species in the meadows and forest clearings south of the town of Dal'nerechensk (46° N). Undoubtedly, this is a case of increasing abundance within the range of the species. By contrast, *Chorthippus caliginosus* Uv., a pest to crops and pastures in the Transbaikal region, was common in southern Amur oblast and Khabarovsk krai, and only a few specimens were collected over the years 1986–2001 in the environs of Lesozavodsk (45.5° N), while in all the other districts of Primorskii krai the species was absent. In 2007–2009, this species became common over all of Primorskii krai; its range shifted south by 400–450 km and reached Vladivostok, Nakhodka, and Lazo. This is, apparently, a case of a naturally expanding range.

The process of migration of insects beyond the limits of their natural ranges is continuous. Successful introduction of phytophagous insects into terrestrial ecosystems beyond the limits of their ranges is largely determined by both abiotic factors, especially climatic conditions, and biotic factors, above all the presence of food resources and the absence of specialized predators, parasites, and entomopathogenic fungi and microorganisms. Some invasive species, failing to find sufficient food supplies in the new area, do not reach high levels of abundance and cause no significant damage, while species that find plentiful food supplies dramatically increase in abundance and rapidly occupy large areas. It is during this phase that the highest economic damage is usually observed, and attempts are made at decreasing the abundance of the introduced species by chemical methods. However, a biocenosis is a self-regulatory and relatively stable system. Sooner or later, many alien species fall prey to local insectivorous and other predatory species, and the abundance of their populations decreases from natural causes. Chemical control of introduced species often causes more damage than the species itself. Abstention from chemical pest control measures in many cases allows unfavorable effects of pesticide usage on biocenoses to be avoided and, thus, the indigenous fauna of insectivorous species to be preserved.

The results of introductions of alien species into terrestrial ecosystems in different regions are sometimes diametrically opposite. For instance, in the 1980s, the American phytophagous insect *Zygogramma suturalis* F. (ragweed leaf beetle) was intentionally introduced to Russia for biological control of the alien ragweed *Ambrosia artemisifolia* L. The leaf beetle rapidly multiplied in the North Caucasus over the first few years, and then its abundance decreased, so that currently this species cannot be found even in the areas where it was released. In southern Primorskii krai, no rapid increases in abundance were observed after the release of this beetle, but currently this species has successfully naturalized in several districts of the krai.

Tropical and subtropical zones are especially susceptible to invasions of alien insects. But the number of insect species introduced into areas with a temperate climate is also growing every year. The large area of the Russian Far East is no exception to this rule. In this region, invasions of phytophagous species from other regions of Russia and other countries, especially from Southeast Asia, are currently observed. The impact of alien species on the structure and diversity of insects in biocenoses of the Russian Far East still remains to be estimated.

Introductions of species can be either intentional, with species specially released beyond the limits of their natural range, or unintentional, resulting from some other cause related to human activities.

Some insects were intentionally introduced to Primorskii krai for biological control of pest species. For instance, the insectivorous species of tropical origin *Encarsia formosa* Gahan, a specialized parasite of the dangerous pest the greenhouse whitefly (*Trialeurodes vaporariorum* Westw.), successfully reproduces in greenhouse farms and reduces the abundance of this pest. The predatory lady beetles *Lemnia biplagiata* Swartz and *Leis demidiata* F. were introduced from South China into the greenhouses of Primorskii krai in 1990 for biological control of aphids. The ragweed leaf beetle was intentionally introduced into Primorskii krai as a measure against weeds.

Examples of insects unintentionally introduced into the Russian Far East are considerably more numerous. For instance, the quarantine species *Leptinotarsa decemlineata* Say (Colorado potato beetle) was introduced into Primorskii krai. By 2004, it occupied an area of 150 ha on private farmlands and is currently living in seven districts: Spasskii, Chernigovskii, Mikhailovskii, Ussuriiskii, Yakovlevskii, Kirovskii, and Chuguevskii [*Prognoz...*, 2004]. Although the Colorado potato beetle causes considerable damage, and the urgency of taking measures to eliminate its foci is obvious, since it was excluded from the list of quarantine pests of Russia, no special measures are taken for controlling this beetle in Primorskii krai. Some dangerous pests from European Russia and Siberia are introduced into the Russian Far East with agricultural plant products. For instance, the large white butterfly (*Pieris brassicae* L.) was introduced into Primorskii krai in 1991–1992 and caused considerable damage. Potentially dangerous species are usually introduced accidentally with various products and goods, in (or on) transportation facilities, with personal luggage of passengers, as a result of ill-conceived delivery with the purpose of study, and even by smuggling. In rare cases, alien species come from adjacent countries by themselves, in the course of migrations or borne by wind and water [Mironova and Izhevskii, 2002]. Increased amounts of imported plant products, including seeds and planting stock, especially from

countries with poorly known quarantine behavior (Korea, China, Vietnam), create preconditions for introducing into the Russian Far East several new particularly dangerous quarantine insects. Thousands of tons of fruits and vegetables are delivered daily into Primorskii krai through checkpoints at the border with China. In summer, the delivered products are fumigated, but in winter, they are usually stored without such treatment. Furthermore, dry plants, soil, etc., are regularly found in passenger compartments and bodies of cars imported from Japan, posing a real threat of introducing dangerous insect pests. Around ten new dangerous greenhouse plant pests, including the Oriental leafworm moth (*Spodoptera litura* F.) and the western flower thrips (*Frankliniella occidentalis* Perg.), were introduced from the American continent to Europe and the Far East with flowers [Izhevskii, 1992]. These species, now widespread in Russia, are serious pests to greenhouse crops. It should be noted that the export of flowers from China has greatly increased recently and poses a considerable threat of the introduction of dangerous unknown species of thrips, leaf-miner flies, aphids, and other insects into the Russian Far East. The problem of introduction of insects resistant to pesticides is also growing. Invasions of such species from China, where chemical methods of pest control are widely used, may lead to dramatic increases in their abundance in Russia, and multiple chemical treatments will be required for their suppression.

It should be noted that insects easily penetrate into anthropogenic ecosystems, but the gravest consequences result from the introduction of alien species into natural ecosystems, for instance, into forest communities. The possible invasion of the pine needle gall midge (*Thecodiplosis japonensis* Uchida & Inouye), a dangerous pest to pine trees, is a real threat to forest communities of the Russian Far East. The introduction of the fall webworm (*Hyphantria cunea* Drury) into deciduous forests of Russia required conducting protective chemical treatments over large areas; currently this species has already been found in Primorskii krai as well.

The insect fauna of the Far East is peculiar and includes a great number of species distributed in East Asia [Lelei et al., 2006]; therefore, many Far Eastern pests are potentially very dangerous to the forests and agriculture of Russia and foreign countries. For instance, the Siberian silkmoth (*Dendrolimus sibiricus sibiricus* Tschetv.) adapts in the west to the coniferous forests of central European Russia [Gninenko, 2002]. Without a doubt, we may already predict the further expansion of this species into many countries of Europe. After the introduction of the gypsy moth (*Limantria dispar* L.) into North America, this species dispersed over an area of 18 million ha and established itself as the main forest pest [Grigor'ev, 1997]. The annual damage caused by this moth is estimated at hundreds of millions of dollars. In Russia, Primorskii krai is a potential source of the following dangerous quarantine species: the fall webworm (*Hyphantria cunea* Drury), the Oriental leafworm moth (*Spodoptera litura* F.), the pear fruit moth (*Numonia pyrivorella* Mats.), the San Jose scale (*Quadraspidiotus perniciosus* Comstock), the peach fruit moth (*Carposina niponensis* Wlsm.), the apple wood borer (*Agrilis mali* Mats.), etc. [*Spravochnik*..., 1995; Shvydkaya et al., 1995].

On the other hand, the Russian Far East is a very promising potential source of insectivorous insects for introduction into other regions for pest control. For instance, the emerald ash borer (*Agrilus planipennis* Fair.) was recently introduced into the United States and European Russia, where it caused considerable damage to different species of ash. The study of the natural habitats of this beetle in Primorskii krai has revealed that the low population density of this species here is determined by the monsoon climate and the high degree of canopy closure, as well as by the presence of two braconid parasitic wasp species [Yurchenko et al., 2007], which can be used for developing biological methods of control for this pest.

Thus, the Russian Far East, owing to its peculiar fauna and its position on routes of transportation of goods from Asia to Europe, is an important link in the chain of dispersal of alien insect species. While the most important pests are known and their movement across the border is controlled by the quarantine service, and while intentional introduction can also be, at least to some extent, controlled, unintentional introduction of insects is virtually beyond control. It is very likely that the number of insect species introduced into the Russian Far East will steadily grow with the intensification of the exchange of goods. It is impossible to predict whether the introduction of particular alien species into natural or anthropogenic biocenoses of the Russian Far East will be successful. Therefore, one of the top priorities should be the development of a unified database that would include all the data on the insects coming into the region, whether they are quarantine species or not.

The development of measures that would prevent invasions, weaken their impact, and monitor their course in the Russian Far East requires the combined efforts of the quarantine service and plant protection service and experts from academia, departmental institutes, and research institutes of the Russian Academy of Sciences. An important component of this work at the early stage would be the development of a unified database on all the alien insect species of the Russian Far East.

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