

**All-Russian Research Institute of Silviculture and Mechanization of Forestry
East Palearctic Regional Section
International Organization for the Biological Control of Pests and Animals**



**INVASIVE DENDROPHILOUS
ORGANISMS:
CHALLENGES AND PROTECTION
OPERATIONS**



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CHALLENGES AND PROTECTION OPERATIONS**

Pushkino 2019

Всероссийский научно-исследовательский институт лесоводства
и механизации лесного хозяйства
Восточнопалеарктическая региональная секция Международной
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**ИНВАЗИВНЫЕ ДЕНДРОФИЛЬНЫЕ ОРГАНИЗМЫ:
ПРОБЛЕМЫ И МЕРЫ ЗАЩИТЫ**

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Инвазивные дендрофильные организмы: проблемы и меры защиты : коллективная монография. – под общей редакцией Ю.И. Гниненко. – Пушкино : ВНИИЛМ, 2019. – 120 с.

Коллективная монография посвящена вопросам, связанным с проникновением в леса и озеленительные посадки древесно-кустарниковых растений новых инвазивных организмов, которые нередко наносят большой вред. Рассмотрены вопросы проникновения таких вредителей как самшитовая огневка, дубовый клоп-кружевница, уссурийский полиграф и др. на территорию России и стран Восточной Европы.

Предназначена для работников лесного хозяйства в области защиты растений и озеленения, а также для студентов высших учебных заведений.

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Invasive dendrophilous organisms: challenges and protection operations. Collective monograph. Under the general edition of Gninenko Yu.I. Pushkino: VNIILM, 2019. 120 pages.

The collective monograph is devoted to issues related to the penetration into forests and green planting of wood-shrub plants of new invasive pests, which often cause great harm. The issues of penetration of pests such as box tree moth, oak lace bug, Four-Eyed Fir Bark Beetle and others into the territory of Russia and Eastern Europe are considered.

It is intended for plant protection workers in forestry and greening, as well as students of higher education institutions.

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Editor foreword

Occurrence of new dendrophilous invaders in forests and greenery plantations of Europe and Asia is a great risk and creates new challenges for forest protection practitioners. Each new invader is not just a surprise but a protection crudity as well. People are always late as new invaders appear. It is difficult to develop protection operations against a hazardous insect or a disease agent when they are not available in the territory.

However, after invader occurrence its damage is evident but protection operations have not been developed yet and pesticide testing and registration for protection against the invader take several years.

Very often government and community do not take new invader occurrence seriously as needed. It is a clear response since people including main experts do not have comprehensive knowledge about a new invader.

The actions to eliminate the infected boxwood in the Krasnodar Territory on the Black Sea coast were carried out incorrectly. Great risk evidence for forest protection experts was not adequately assessed by society and authorities. Just after loss of natural forests with Colchis boxwood which happened 2-3 years after the pest 1st identification urgency of protection operations was clear for everybody but in fact there was nothing to protect.

Thus, each new invader occurrence should be regarded seriously and an information sharing network should be a key element of tree shrub vegetation protection package against foreign invaders. Nature conservation legislation should be adjusted so that an invader infestation of nature reserves, national parks and specially protected territories would not prevent protection operations.

The idea to prepare a joint publication to sum up tree protection experience available in Russia and neighbor states was discussed in Budapest in 2018, The idea was realized in this monograph. We believe that the presented protection experience against specific pests and diseases is valuable for specialists.

Yu.I. Gninenko

CHAPTER 1

BOX TREE MOTH: THE CONQUEST OF EUROPE AND NOT ONLY

Box tree moth *Neoglyphodes* (syn. *Cydalima*) *perspectalis* Walker, 1859 (Lepidoptera: Crambidae) is a representative of the East Asian fauna living in forests with the participation of local boxwood species. Here it is not a pest, although in cities it sometimes causes minor damage to greenery, as we were able to observe in Tianjin in 2001.

But after reaching Europe, it found such good conditions here that it quickly spread to all areas where European boxwood species grow and everywhere became a very dangerous pest.

Usually, its spread is rapid and plant protection services do not have time to take adequate measures before it sometimes causes catastrophic damage.

1.1. Box tree moth in the Russian Federation: disaster development and interim results

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Самшитовая огневка в России: развитие катастрофы и промежуточные итоги

Самшитовая огневка *Neoglyphodes* (син. *Cydalima*) *perspectalis* Walker, 1859 (Lepidoptera: Crambidae) после появления на черноморском побережье Краснодарского края в 2012 г. быстро распространилась на все территории России, где естественно произрастал колхидский самшит *Buxus sempervirens* var. *colchica* Rojark. Уже в 2014 г. Гусеницы огневки уничтожили листву в кронах самшита практически повсеместно в местах произрастания на побережье. Начавшееся изучение огневки и поиск эффективных мер защиты позволили выявить некоторых энтомофагов вредителя, испытать неспецифические вирусы, местные штаммы энтомопатогенных грибов, хищных ос, а также кукольного паразитоида *Chouioia cunea* (Hymenoptera, Eulophidae).

Ключевые слова: самшитовая огневка, самшит колхидский, биологические меры защиты.

Abstract

Box tree moth *Neoglyphodes* (syn. *Cydalima*) *perspectalis* Walker, 1859 (Lepidoptera: Crambidae), after its appearance in 2012 on the Black Sea coast of the Krasnodar region quickly spread throughout Russia, where the Colchic *Buxus sempervirens* var. *colchica* Pojark naturally grew. Already in 2014, the caterpillars of box tree moth destroyed the foliage in the crowns of box trees almost everywhere on the coast from Sochi to Novorossiysk. By 2015, its continuous range from Sochi to Grozny was formed. The beginning of the study of box tree moth and the search for effective protection measures allowed to identify some entomophages of this pest, to test non-specific viruses, predatory wasps, local strains of entomopathogenic fungi, as well as pupal parasitoid - *Chouioia cunea* (Hymenoptera, Eulophidae).

Key words: box tree moth, *Neoglyphodes* (syn. *Cydalima*) *perspectalis*, Colchic Boxwood *Buxus sempervirens* var. *colchica*, biological protection measures.

Introduction

The primary range of *Neoglyphodes* (syn. *Cydalima*) *perspectalis* Walker, 1859 (Lepidoptera: Crambidae) box tree moth includes the southern part of the Russian Far East, Japan, the Korean Peninsula and the eastern part of China.

Apparently, the reason for the pest's introduction into Europe was the delivery of the box tree moth's preimaginal stages with the box tree's planting material. Once being introduced initially in Germany, the box tree moth was spread to the box tree landings in Baden-Württemberg, Hesse, Lower Saxony, North Rhine-Westphalia in 2006 (Krüger, 2008; Straten and Muus, 2010), in Switzerland in the same year (Billen W., 2007). In 2008, the pest was recorded in France (in Alsace, later in Ile-de-France), in the Netherlands and in September of that year in the south of England (Mally, Nuss, 2010). By 2011, the pest was in Hungary and Turkey, and by 2012 – in Belgium, Austria, Italy, Slovenia, Croatia (Hizard et al., 2012) and Georgia (Kobuleti), in the last region it was probably introduced from the territory of Turkey (A.Sh. Supatashvili, personal message). A fairly full overview of the spread of box tree moth in Europe has been prepared by a team of authors (Plant *et al.*, 2019). In 2014, the box tree moth's caterpillars at 100% destroyed the foliage on the box trees in Gagra (north of Abkhazia). The box trees' damages in the same year in Sukhumi were less strong – the foliage was ragged by no more than 30%, which suggests that the box tree moth was introduced to Abkhazia from the territory of Bolchoi Sochi not earlier than 2013.

Once introduced on the south of the European part of Russia in 2012, in 2013 the box tree moth already had a continuous range from the border with Abkhazia in the south to the city of Novorossiysk on the northern Black Sea coast and two island areas in Krasnodar and in Grozny. In 2014, the box tree

moth was detected in Adygea and by 2015 the box tree moth formed its continuous range from Sochi to Grozny (Fig. 1).

In the spring of 2015, the box tree moth was officially detected in Crimea, and during 2015-2016. its caterpillars caused massive damage to the box trees in the greenery plantings of Simferopol, Yalta and Sevastopol.

According to the European authors, the box tree moth, due to its biological features, is able to master the whole territory of Europe, where its forage plants grow, from the Mediterranean countries to the south of Great Britain and Scandinavia (Nacambo *et al.*, 2013).

The spread and extensive damage caused by box tree moth to forests in Russia is a reason to discuss the main mistakes made in decision-making to carry out the necessary measures to protect the box trees.

It bears emphasizing that in this case the pest species was immediately correctly identified, and the first detection of box tree moth in 2012 was adequately evaluated by experts. In early 2013, a meeting was held in Sochi National Park to outline the scale of the issue. But the main challenge of this period was that at almost all levels of government, where protection measures were taken, they were not ready for an immediate legislative solution to these issues. The box tree moth appeared initially in the greenery plantings of the Sochi resort area and in natural box trees plantations, growing on the territory of Specially Protected Natural Areas – Sochi National Park and the Caucasus Natural Biosphere Reserve. Current environmental legislation does not allow pesticide-related activities to be carried out in such territories.

The result has led to the paradoxical situation: Specially Protected Natural Areas (SPNA) have been created to conserve natural forest communities. But after settling in these areas of an alien and dangerous organism (in this case, a box tree moth), upon its location in the SPNA territory this organism itself becomes an object of protection, and experts are powerless to protect the box tree forest communities from the pest in adequate measures.

While sporadic protective measures were carried out almost immediately in urban greenery plantings and the box tree was mostly preserved there, but the research on the possibility of the application of biological protection measures was only launched in the natural forests in 2015. (Abasov *et al.*, 2016; Agassieva *et al.*, 2016; Gninenko *et al.*, 2018). During 2015 and 2016 years the studies on the possible use of strains of entomopathogenic fungi (Borisov *et al.*, 2016) to protect the pupal parasitoid of *Chouioia cunea* (Gninenko *et al.*, 2018) have been conducted, the predatory wasps *Euodynerus posticus* Herrich-Schaeffer, 1841 (Hymenoptera: Vespidae) (Tuniev *et al.*, 2016), as well as non-specific viruses (Gninenko *et al.*, 2018). The results obtained helped to formulate the basic principles of box tree protection, which would ensure its preservation.

However, over these years, the box tree moth has inhabited all the areas where box tree grew in natural forests and in the landscaping. As a result of the

fast spread of the pest, almost all-natural forests were destroyed by the time when protection measures were developed.

One of the most affected areas on the Black Sea coast of the Krasnodar region was the Yew-tree and boxwood grove of the Caucasus Natural Biosphere Reserve (Fig. 2).

Damage and weakening of trees have been exacerbated by the fact that caterpillars in the second half of the summer 2014 and during the autumn and winter of 2014-2015, destroying the leaves, due to lack of feed significantly damaged the bark on many trees (Fig. 3). As a result, all the plants rindless of bark died in 2015.

A survey conducted in the spring of 2015 showed that in the lower part of the Yew-tree and boxwood grove, most of the box trees had already died (Table 1), although in the upper part of this grove (quarter 5 of the Hostynsky forest district) most of the trees are remained viable in the spring of 2015 (Table 2).

In the spring of 2015 the box trees, affected only defoliation, the bark that wasn't damaged, began to give a new foliage from the buds formed in the fall or from "dormant" buds (Fig. 4). However, the regenerating fresh foliage was immediately destroyed by the caterpillars of box tree moth (Fig. 5).

Table 1. The status of box trees in the low part of the Yew-tree and boxwood grove in the summer 2015

Category of the box trees status		Number of trees, pcs.	The proportion of trees in this category, the percentage (%) of the total number of trees counted
Category №	Short description		
1	No sign of damage to crowns	0	0
2	The foliage in the crowns is ragged by no more than 50%	0	0
4	The foliage in the crowns is ragged by 100%, but the bark is not damaged	5	8.06
5	The foliage in the crowns is ragged by 100%, the bark is damaged	57	91.94

Table 2. The status of box trees in forest stands, damaged by caterpillars of box tree moth during the autumn and winter feeding in 2014-2015

Survey site	Total number of surveyed trees	Box trees status, %% of the total number of surveyed trees		
		Defoliation around 100%	Defoliation from 50 till 75%	Defoliation prior 50%
Survey counting on March 25/26, 2015				
Verkhne-Sochinsky forest district, division 29	59	54.2	38.9	6.9
Hostynsky forest district, division 5	86	82.6	2.3	15.1
Dagomys forest district, division 33, forest plot 4	114	12.3	17.5	70.2
Survey counting on April 22, 2015				
Maryinsky forest district, division 41, forest plot 34	137	4.4	2.2	93.4
Maryinsky forest district, division 44, forest plot 22	119	3.3	3.3	93.4

Thus, as a result of feeding at the end of the summer season of 2014 and relatively active feeding during the winter of 2014-2015, caterpillars caused strong and dramatical damages to box trees in many forest areas, which was the beginning of the mass death of box trees.

The international practice showed (Melika, 2019; Aebi *et al.*, 2007; Melika *et al.*, 2017 *et al.*), that the only effective method of protection against the invader is the introduction of its specialized entomophages. As a result of our research, it was found that in the south of European Russia, the caterpillars of box tree moth in nature do not yet have effective entomophages. Also, to date, field observations have not noted the development among its caterpillars of mass infectious diseases. Our research has revealed the presence of two local parasitoids in the populations of box tree moth. In one case, the empty puparia of a parasitic moth was found near the remains of the deceased caterpillar (this case still remains single now).

Protapanteles mygdonia Nixon, 1973 (Hymenoptera: Braconidae) (Belokobylskij, Gninenko, 2016) plays an increasingly important role, for which we were able to establish the level of parasitization (Table 3). This *Protapanteles mygdonia* Nixon, 1973 (Hymenoptera: Braconidae) destroys the caterpillars of middle ages. It was not possible to establish when the caterpillar infestation by *Protapanteles mygdonia* Nixon, 1973 (Hymenoptera: Braconidae) occurs. The release of larvae from the body of the destroyed caterpillars of middle ages occurs on a leaf next to the remaining still alive caterpillar, but no longer feeding caterpillar, where the *Protapanteles mygdonia* spins a white spider cocoon. In the laboratory, when the imago *Protapanteles mygdonia* was placed to the foliage-eating box tree caterpillars of older age showed that they did not lead to their infection.

Table 3. *Protapanteles mygdonia* parasitization in the box tree moth population (2015)

Caterpillars' collecting place	Parasitization level of caterpillars, % of total number of counted caterpillars
Box tree bushes in the settlement Alexeyevka	7.9
Maryinsky forest district	4.1

Gatherings of pupae and pupal exuviae of box tree moth in the crowns of damaged box trees showed the absence of local parasitic entomophages, infecting pupae. Thus, in the Dagomys forest district at the 4th forest plot of the division 33 on 2 surveyed sites in the presence of pupal exuviae in the crown 336.3 ± 56.5 and 357.7 ± 37.5 and from 34 and 47 respectively, all of them were healthy.

The same results were obtained during the survey of the forest plot No.29 of the Verkhne-Sochinsky forest district (the presence of pupal exuviae in the crown 353.3 ± 19.0 : 38 were counted) and during the survey of the Kudapestinsky forest district (15 were counted).

Some of the eggs of the box tree moth turned out to be inviable (Table 7), but egg parasitoids haven't reborn of the found eggs. Apparently, the cause of death of the part of eggs could be a fungal infection, as on the surface of some dead eggs we observed the development of white or gray surface fungal disease. The rate of eggs' death for this reason amounted to 38.3% (Table 4).

Table 4. The eggs' death of box tree moth due to the entomopathogenic fungus damage (2015)

Place and time of egg masses' collecting	Total number of counted egg masses, pcs.	Eggs' proportion, died of pathogenic fungus, %
Sochi Arboretum: May	7	0
Sochi Arboretum: June	72	38.3
Maryinsky forest district, division 44	70	19.8

In the box tree moth populations, the death of caterpillars from diseases is quite rare. But analysis of the collected caterpillar's bodies showed that some caterpillars died due to the development of infection. We received a suspension of the several caterpillars died due to an infection, and we used this suspension to treat the box tree's bouquets for feeding caterpillars of III^d and IVth ages. As a result of caterpillars feeding some caterpillars died on these bouquets, but the virus in their bodies was not detected. Apparently, the box tree moth caterpillars have their own virus, which, however, is very inactively reproduced and is not able to cause outbreak.

Thus, the local entomophages and pathogens do not have a significant role in regulating the box tree moth populations on the Black Sea coast of the Krasnodar Krai. This allowed it to propagate fast and unhindered and cause catastrophic damage to the box tree in forest plantations and natural box trees.

The studies conducted in 2014-2015 have shown that the pupal parasitoid *Chouioia cunea* (Hymenoptera, Eulophidae) can be quite successfully applied in the system of box trees protection from box tree moth. Eulophid parasites, grown in the laboratory on the greater wax moth pupae (*Galleria mellonella*) and the ailanthus silkmoth pupae (*Samia cynthia ricini*), were released in several focuses of mass reproduction of box tree moths. As a result, it was possible to obtain a different mortality rate of box tree moth pupae (Table 5), which showed the key possibility of using a parasitoid in biological control programs of the number of invaders.

In 2016, the test release of eulophid parasites were carried out in the box trees of the Tsitsin forestry district of the Maikop forestry of the Republic of Adygeya. A very limited amount of entomophage was released here, but the result confirming the possibility of using this entomophage in box tree biological protection programs (the death of pupae from entomophage amounted to 6.7-9.5% of the total number of pupae and pupal exuviae found) was also obtained.

Table 5. The status of the box tree moth pupae at the *Eulophidae* release sites in August 2015 in Sochi National Park

Coordinates of survey sites	Number of collected pupal exuviae	The Status of pupal exuviae collected, %		
		Moth born	Destroyed by eulophid parasite <i>Ch. cunea</i>	Died of disease and cannibalism
43°54,35'N 39°87,14'E	19	57.90	36.84	5.26
43°54,36'N 39°87,20'E	20	60.00	40.00	0
43°54,35'N 39°87,30'E	15	62.50	37.50	0

It has to be stressed that the releases of parasitoids did not pursue aims of box tree full protection, as initially it was necessary to establish the possibility of death of the pest pupae of the released entomophage in real outbreaks. The results showed that eulophid parasites are able to successfully find and destroy the box tree moth's pupae.

In addition, we conducted the laboratory trial on the use of *Chouioia cunea* eulophid as a vector of fungal infection. With this objective in view, the *Eulophidae* imago specimens were put in the spores' powder of the entomopathogenic fungus *Beauveria bassiana* and then these imagoes were released into the boxes with caterpillars feeding on the box tree moths of the last ages. It is known that eulophid parasites can pierce the cover of caterpillars and feed on protruding drops of hemolymph. It was supposed to infect the caterpillars with a fungal infection. As a result, 50% of caterpillars died from fungal infection on the 10th day. This first trial showed the key possibility of using eulophid parasites not only as a pupal parasitoid, but also as a vector of fungal infection.

Tests of several pesticides have also shown their high effectiveness to protect against box tree moth's caterpillars, but despite all these positive results, it was not possible to stop the box tree moth's invasion and by 2016-2017 almost all-natural box tree stands have been destroyed.

After the death of natural box tree stands, the box tree moth lost its forage base. Special surveys at the sites of the outbreaks of mass reproduction of box tree moths, as well as laboratory experiments, conducted in 2014-2015, have shown that the foliage of the field maple *Acer campestre*, the colchis bladder nut *Staphylea colchica*, the shoots of *Euonymus verrucosa* and *E. europaea*, are unable to provide box tree moth's caterpillars with a necessary energy, and they all died without pupating.

Thus, in the event of the box tree death in natural forests, the box tree moth with a very high probability rate will not be able to survive here because of the inability to feed on other plants.

The box tree has survived in the Sochi greenery plantings and other cities thanks to the city authority efforts and other owners of greenery plantings, which regularly carried out the protective treatment using various pesticides,

mainly chemical ones. Despite the more or less visible effectiveness of these treatments, it is here the pest remains. The feed base of pests also remains. Moreover, the insecticide treatments occurring at random in human settlements may soon lead to the formation of pesticide-resistant pest populations in cities. As a result, if new young box trees are found during the reforestation, all of them will be destroyed again by the pest caterpillars.

To forestall such a development, only the introduction of specific entomophages is able to effectively regulate the number of box tree moths. Unfortunately, at present no research or study is carried out for such entomophages.

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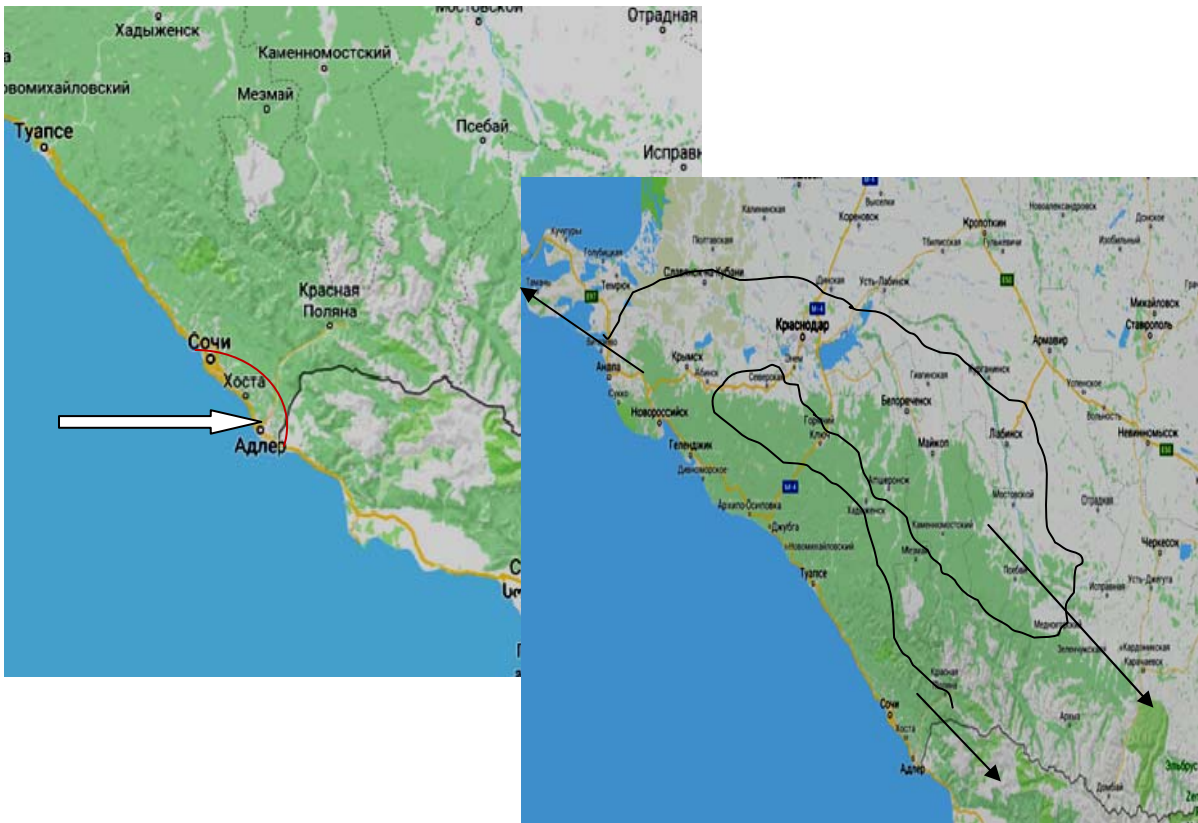


Figure 1. The box tree's invasion development on the Black Sea coast of Krasnodar region



Figure 2. Box trees, damaged by box tree moth caterpillars in the Yew-tree and boxwood grove near Sochi (2014)



Figure 3. Damage to the bark on the trunk and branches of the young box trees



Figure 4. Recovery of foliage from the buds on the branches of box trees



Figure 5. The carterpillar of box tree moth on the new box trees shoot

1.2. Invasion by the box tree moth, *Cydalima perspectalis* (Lepidoptera: Crambidae), in southeastern Europe

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Вторжение самшитовой огнёвки *Cydalima perspectalis* (Lepidoptera: Crambidae) в юго-восточную Европу

Самшитовая огнёвка *Cydalima perspectalis* (Lepidoptera: Crambidae), родиной которой является Восточная Азия, была завезена в Европу более 10 лет назад. Это привело к значительным повреждениям самшита (*Buxus* spp.) как в городских озеленительных посадках, так и в естественных лесах. Появление этого инвазивного вредителя в юго-восточной Европе еще не было достаточно подробно задокументировано. Основная цель этого исследования состояла в том, чтобы показать подробную картину распространения *C. perspectalis* в 11 европейских странах путем обобщения имеющихся данных о развитии инвазии за период с 2010 по конец 2016 года. Сбор данных в основном основывался на отчетах, полученных от граждан. Полученные результаты ясно показывают, что вредный организм был гораздо более широко распространен в этой части Европы уже в 2016 году, об этом можно судить по ранее опубликованным работам. Также были получены доказательства того, что *C. perspectalis* присутствовал в Албании, Венгрии и Косово, по крайней мере, за год до своего первого официального отчета в этих странах. Это исследование подчеркивает необходимость

использования всех сведений в мониторинге инвазивных чужеродных видов.

Ключевые слова: чужеродные виды, *Cydalima perspectalis*, самшит, распространение, юго-восточная Европа, наблюдения граждан.

Abstract

The box tree moth, *Cydalima perspectalis* (Lepidoptera: Crambidae), is native to East Asia and was introduced in Europe more than a decade ago. It causes severe damage to box trees (*Buxus* spp.) in both urban and natural habitats. The occurrence of this invasive pest in southeastern Europe has not been documented in a comprehensive way yet. The main objective of this study was to obtain a detailed picture of the spread and distribution of *C. perspectalis* in 11 countries by summarising the records of the species from 2010 to the end of 2016. Data collection was primarily based on reports received from citizens. The results, due to the involvement of citizen science, clearly indicate that the pest was much more widely distributed in this part of Europe as early as 2016 than judged from previously published works. Evidence has been obtained that *C. perspectalis* was present in Albania, Hungary, and Kosovo, at least one year before its first official record in these countries. This study highlights the utilisation of citizen science in the monitoring of invasive alien species.

Key words: alien species, *Cydalima perspectalis*, *Buxus*, distribution, southeastern Europe, citizen science.

Introduction

The current distribution of species has been shaped mostly by their natural dispersal ability, which has been ruled by several biogeographical barriers for a long time. However, these boundaries have easily been overcome by anthropogenic activities, including the intentional and unintentional transfer of living organisms. Therefore, more and more species, no longer restricted within their native range, become aliens in different biogeographical regions, where they may have a severe impact on the invaded ecosystem (Nentwig et Josefsson, 2009). The main pathway of introduction of alien pests of plants in Europe is the live plants trade (Kenis *et al.*, 2013).

The box tree moth, *Cydalima perspectalis* (Walker, 1859) (Lepidoptera: Crambidae: Spilomelinae), is native to East Asia (Mally et Nuss, 2010; Nacambo *et al.*, 2014; Bras *et al.*, 2019) and was introduced in Europe (Billen, 2007; Krüger, 2008), where it has been spreading since at least 2007 (Billen, 2007; Leuthardt *et al.*, 2010; Nacambo *et al.*, 2014). It causes severe damage to box trees (*Buxus* spp.) in both urban areas and natural *Buxus* stands. Larvae feed on leaves and can completely defoliate box trees, and they can also damage the bark. Severely affected plants may die (Kenis *et al.*, 2013; Leuthardt et Baur, 2013; Gutue *et al.*, 2014; Nacambo *et al.*, 2014; Matsiakh, 2016; Véték, personal observation). As indicated by the studies of Kenis *et al.* (2013), Matsiakh

(2016), Raineri *et al.* (2017), Matsiakh *et al.* (2018), and Mitchell *et al.* (2018), the most harmful consequences of the rapid dispersal of this invasive species within Europe may be expected in the forest ecosystems where natural populations of the box tree occur.

The native populations of *Buxus sempervirens* L. and *B. balearica* Lam. in southern Europe underwent severe reduction in the last millennia and are undergoing a process of fragmentation and isolation (Di Domenico *et al.*, 2012; Kenis *et al.*, 2013). In southeastern Europe, *B. sempervirens* occurs naturally in Albania, Greece, Kosovo, Montenegro, and North Macedonia, whereas in Croatia, Hungary, the Slovak Republic, and Slovenia only its fossil sites are documented. In Bosnia and Herzegovina, and Serbia, the historical occurrence of box trees is not verified (Di Domenico *et al.*, 2012). However, in each country, the box tree is planted frequently in historical, formal and private gardens and cemeteries as an ornamental plant or for hedging.

The spatial distribution of *C. perspectalis* in Europe by the end of 2012 was shown by Kenis *et al.* (2013). Since then, a number of further reports have confirmed the widespread occurrence of the pest in Europe (for a recent summary see CABI, 2019; but see also Hellers et Christian, 2016; Kudła and Dawidowicz, 2016; Bengtsson, 2017; Bury *et al.*, 2017; Agius, 2018; Corley *et al.*, 2018; Perez et Guillem, 2019). Although some data about the occurrence of the pest in southeastern Europe up to the end of this current research in December 2016 have already been known from the region (e.g., Jež, 2012; Koren et Črne, 2012; Matošević, 2013; Glavendekić, 2014; Kulfan *et al.*, 2014; Véték *et al.*, 2014, and references therein; Marković *et al.*, 2015; Ostojić *et al.*, 2015; Pantić *et al.*, 2015; Stojanović *et al.*, 2015; Strachinis *et al.*, 2015; Nacheski *et al.*, 2016; Szanyi *et al.*, 2016; Tüske et Marczali, 2016; Hrnčić et Radonjić, 2014, 2017; Hrnčić *et al.*, 2017; Nacheski *et al.*, 2017), a comprehensive study providing an overview of the occurrence and distribution of *C. perspectalis* from this particular region was missing. This work aims to complete information on the presence of *C. perspectalis* in this large area representing a region in some parts of which vulnerable native (natural) populations of the box tree exist and are threatened by this pest.

Materials and methods

Data about the occurrence of *C. perspectalis* were collected from 11 countries until 11 December 2016: (in alphabetical order) Albania (AL), Bosnia and Herzegovina (BA), Croatia (HR), Greece (GR), Hungary (HU), Kosovo (under the terms of UNSCR 1244) (XK), Montenegro (ME), North Macedonia (MK), Serbia (RS), the Slovak Republic (SK), and Slovenia (SI). The countries joined the study in different years in the following chronological order: 2012: HU; 2013: HR, SI, SK; 2015: AL, BA, ME, RS, XK; 2016: GR, MK. As we could not find any contact persons to participate in this study in AL, BA and XK, the

data from these countries are limited and do not represent the actual distribution of the species in these regions.

The data about the occurrence of *C. perspectalis* were collected by active search for the pest by the authors of this study (in each country except for AL and XK) at locations with expected presence of *Buxus* spp. (e.g., cemeteries, public parks, castle gardens). This was primarily based on observations of individuals (larvae, pupae and adults) and damage symptoms of the pest, but catches of the moth in light traps were also considered (in HR, HU and SI). In addition, citizen science was also involved to gather data in some of the participating countries. In this case, citizens (partly including the members of professional organisations) were requested (e.g., through specific calls uploaded to professional websites and via e-mails) to provide relevant observational data. For each observation, the following basic information was recorded: location (name and geographic coordinates); date (at least the year) of the record; and name of the recorder. If available, the data such as an elevation and a brief description of the site and environment were also recorded. Sites with different geographical coordinates but within the same settlement (location) were considered as a single record. Due to the conspicuous appearance of the larva and adult of *C. perspectalis*, and the characteristic symptoms of damage to *Buxus* plants, identification by non-professionals was considered as reliable. Besides the data received and collected actively by the authors, the presence records in the studied region known from any types of publications (see Introduction; note: not all the sources are indicated there) were also used to complete the picture of the spread and distribution of the pest in southeastern Europe by the end of 2016.

The records of the presence of *C. perspectalis* from the 11 countries were finally shown on a distribution map, where the data are displayed by the year of the earliest record for each location, to visualise the spread of the pest (ESRI ArcGIS Pro software, version 2.4.0, Coordinate system: GCS_WGS_1984, Map projection: WGS 1984 Web Mercator Auxiliary Sphere).

Results and discussion

By the end of 2016, we had collected data about the occurrence of *C. perspectalis* from a total of 685 locations in southeastern Europe. In this region, *C. perspectalis* was first recorded at Zalaegerszeg [46.8360°N, 16.8456°E], HU, in 2010 (Fig. 1). The total number of records and the year of the first record of the species in each country are shown in Table 1.

The distribution pattern of *C. perspectalis* in the studied area supports the CLIMEX map of predicted distribution and relative abundance of the species in Europe (Nacambo *et al.*, 2014). The species was recorded in the altitudes ranging from 0 m at Strunjan [45.5262°N, 13.6051°E] (adults) to 1031 m at Poljubinj [46.1905°N, 13.7822°E] (adult), both locations in SI.

Table 1. Total number of records and the year of the first record of *Cydalima perspectalis* in the 11 countries of southeastern Europe

Country	Total number of records	Year of the first record	Source of data of the year of the first record
Albania	1	2016	present study
Bosnia and Herzegovina	15	2014	Ostojić <i>et al.</i> (2015), present study
Croatia	72	2012	Koren and Črne (2012)
Greece	12	2013	Strachinis <i>et al.</i> (2015)
Hungary	404	2010	present study
Kosovo	1	2016	present study
Montenegro	21	2014	Hrnčić et Radonjić (2014), present study
North Macedonia	6	2014	Nacheski <i>et al.</i> (2016, 2017)
Serbia	53	2014	Glavendekić (2014), HabiProt (2019)
Slovak Republic	37	2012	Pastorális <i>et al.</i> (2013), present study
Slovenia	63	2011	Jež (2012), present study

Several locations in western SK, specifically Bratislava and nearby places, and the southwest of this country, a large part of western HU, mainly the northwestern region, and the area west of lake Balaton (including Zalaegerszeg, see above), northeastern SI and northwestern HR were invaded by the end of 2013. If we compare these findings with the information about heavily infested area shown in figure 3 in Kenis *et al.* (2013), it seems that *C. perspectalis* had reached the western part of the studied region (also) by active dispersal.

Considering the first published report (location and date) of the particular country combined with the data from Germany which indicate the rate of the spread of *C. perspectalis* to be approximately 5-10 km/year (Van der Straten and Muus, 2010), there were locations (with the damage by the moth) outlying from heavily invaded areas. These were, for example, the following ones: Dobrá Niva, Prešov, and Turňa nad Bodvou (SK); Budapest and Miskolc (HU); Osijek (HR); and Kifissia (GR). At least in these cases the occurrence of the species is not likely to be directly related to its first official reports from the countries concerned. Also, it may not be expected that the pest reached these sites by active spread from the known invaded areas but its arrival in outlying areas with infested planting material seems to be the most probable pathway of introduction. Human-assisted introduction, when *C. perspectalis* was introduced with plants for planting as a contaminant, following the terminology given by Rabitsch (2010), seems to be confirmed by the observations of damaged plants found in nurseries or garden centres at Dobrá Niva (*Buxus* trees introduced from Italy) and Budapest (*Buxus* plants introduced from Zala county, western HU), both as early as 2013. Moreover, damage to *Buxus* in nurseries or garden centres

were noticed at locations in other countries as well, for example at Dajç (AL), Filiria (GR), Jastrebarsko (HR), Đenovići (ME), Marena (MK) and Liplje (RS). This indicates the potential contribution of these facilities to the unintentional dispersal of the pest highlighted by Gninenko *et al.* (2014) and Plant *et al.* (2019). Passive dispersal via plant trade may largely facilitate and speed up the spread of *C. perspectalis* in those regions or countries where *Buxus* spp. are not native to and in which box trees are used only for ornamental purposes in parks and private gardens. In these cases, the transportation, even for long distances, and planting of infested plants may make formerly uninvaded locations act as stepping-stones for further invasion of the surrounding areas. The potential steppingstone role of cemeteries may also be highlighted, because *Buxus* has been a quite popular plant here even at small settlements as we found in our survey. For example, in HU, the damage by the pest was recorded in more than 40 graveyards, also on relatively old bushes. It thus seems possible that if these sites contain the appropriate host (Matošević *et al.*, 2017), they provide the moth with suitable places for oviposition, supporting the consequent development of their offspring and their further ('unaided') spread (i.e. secondary spread from the point of entry) towards native environments (Rabitsch, 2010).

Damage to *Buxus* in countries where there are no natural stands of this taxon remains only of aesthetic concern, though potentially paired with severe economic effects especially in historical and formal gardens and parks. However, the loss of native *Buxus* populations may have huge ecological impacts (Mitchell *et al.*, 2018). As indicated by Raineri *et al.* (2017) and Načeski *et al.* (2018), the pest has already reached the natural *Buxus* stands in AL and MK. Therefore, heavy damage to *Buxus*, similar to that already observed, for example, in native populations of southwestern Germany and northern Switzerland (Kenis *et al.* 2013; Véték, personal observation, 2013), northern Italy (Raineri *et al.*, 2017), and the western part of the Republic of Georgia (Matsiakh *et al.*, 2018), may also be expected in the Balkans.

This study also indicates how citizen science can contribute to the better understanding of the history of invasion of an alien insect. As both the insect and the type of damage are easy to identify by non-professionals, *C. perspectalis* is an 'ideal' target organism for further monitoring by the involvement of the public. Nevertheless, the irregular pattern of distribution across the studied region as well as the great differences in the number of presence records by country should be interpreted very carefully regarding the real occurrence of the pest, because a wide range of factors might have influenced our results. For instance, the starting date of monitoring, efforts made and area investigated, and the enthusiasm and motivation of citizens to gather and provide the data should be considered. Our study comprehensively reveals the history of the spread of *C. perspectalis* in southeastern Europe by the end of 2016. It also shows that the pest had already been present in AL (at Dajç in 2016), HU (at Zalaegerszeg in 2010) and XK (at Kosovska Kamenica in 2016) at least one year earlier than the

first known ‘official’ record from these countries (cf. Raineri *et al.*, 2017; Sáfián et Horváth, 2011; Geci et Ibrahim, 2018).

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1.3. *Neoglyphodes perspectalis* Walker, 1859 (Lepidoptera, Crambidae) – first record in Uzbekistan

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***Neoglyphodes perspectalis* Walker, 1859 (Lepidoptera, Crambidae) – первая находка в Узбекистане**

Самшитовая огнёвка *Neoglyphodes perspectalis* (syn. *Cydalima perspectalis*) впервые обнаружена в озеленительных посадках самшита *Buxus sempervirens* в г. Ташкенте. Это первое обнаружение инвайдера в регионе Средней Азии.

Ключевые слова: самшитовая огнёвка, самшит, Средняя Азия.

Abstract

The first record of *Neoglyphodes perspectalis* (Lepidoptera, Crambidae) in the Central Asian states. A special survey, conducted in mid-August 2019 found *N. perspectalis*'s pupae in several spots in Tashkent greenery plantations.

Key words: *Neoglyphodes perspectalis*, *Buxus sempervirens*, greenery plantations, Central Asia.

Introduction

The box tree moth *Neoglyphodes perspectalis* (syn. *Cydalima perspectalis*) (Walker, 1859) (Lepidoptera, Crambidae) in Europe firstly was found in Germany (Kruger, 2008) and in 2007 was included in alert list (Alert list EPPO). However, in 2007 the moth has swiftly expanded in European states that its quarantine control got doubtful and in 2011 the pest was excluded from the alert list.

In 2012 box tree moth was brought in south European Russia with boxwood seedlings from Italy (Gninenko et al 2014; Karpun *et al.*, 2014; Schurov, 2014). The moth swiftly infested natural bowdood forests and boxwood greenery plantations in the Krasnodarsky territory with serious damage everywhere and in 2015 the pest was found across the whole boxwood range, including the Stavropolie and the Crimea.

Material and methods

The special survey was conducted in the Tashkent greenery plantations in August 2019. The moth was found in pupae and pupae exuviums collected in larvae affected boxwood *Buxus sempervirens* shrubs. Larvae shrub damage was

observed visually then pupae and former generation pupae exuviums were collected from shrub branches.

The survey was done in various city areas where boxwood was available in greenery. All pupae were brought to the laboratory for its condition analysis. All pupae were opened for visual identification of larva or parasite entomophage egg availability.

Results and discussion

The search found that box tree moth in 1st half of August 2019 infested the whole city territory since it was found in various city areas (Table 1).

Table 1. Locations of box tree moth

№	Location	Geographical coordinates	Stage of development of individuals	The degree of defoliation by caterpillars' leaves, %
1	Taskent botanical garden	41.343262° 69.313051°	Pupae and former generation's pupal exuviums	Around 50% damage
2	Vakhidova street park	41.301321° 69.254996°	Same	70% damage on separate bushes
3	Abdula Kadiry street plantations	41.301676° 69.293666°	Pupae	Some pushes 30-50% eaten
4	Ulugbek, Institute greening	41.411293° 69.454659°	Pupae	10% eaten separate bushes

Fresh pupae obviously 3rd generation ones and former generation pupal exuviums on some bushes were found in the survey. Former generation pupal exuviums differ good from fresh ones in thin covers that are fragile and break when touched. Feeding caterpillars were not found.

Prevailing pupae were sound and showed no parasite entomophage features when opened (Table 2). One dead pupa was killed by bacterial infection.

Table 2. Box tree moth condition

№	Location	Collected pupae number	Pupae condition, % of total	
			Vital	Dead
1	Vakhitova str. park	15	93.3	6.7
2	Tashkent botanical garden	10	100.0	0.0

Moth emergence started in the laboratory on the 2nd day after pupae collection. One can obviously suggest that 3rd generation box tree moth emergence naturally began in Tashkent in mid-August.

In many cases obviously, on 2nd generation caterpillar damaged boxwood bushes there were no features of the moth availability except old leaf damage. Local people and specialists said that they observed 1st boxwood damage already in 2017. Right after damage identification in 2018 and 2019 all private land owners and municipal greenery city services conducted sprayings with chemical pesticides that enabled boxwood protection and death of the most caterpillars. However, pesticide application does not ensure total pest death. In addition,

even thorough spraying leaves some gaps that enable survival of some pest species. So, if boxwood is available in greenery plantations and damage minimization the moth is not only available but expands its secondary areal.

The point of 1st emergence of the moth in Tashkent and Central Asian states. The moth was brought to Russia in 2012 and by 2016-2017 it spread across all North Caucasus. Obviously, it could not reach Tashkent through non-forested desert Kazakhstan and Uzbekistan areas. Obviously, it was brought as well as in Russia in planting stock in 2015-2016.

Once available there the moth is a serious risk for boxwood greenery plantations mostly in Uzbekistan cities. From there it can infest south Kazakhstan cities as well as Kirgizstan. This invasive pest expansion needs thorough monitoring since its earlier identification enables timely planning and protection operations.

The moth biology specifics in Central Asia conditions are still unknown. Obviously, it can evolve there in not less than 4 generations per year. So, plant protection officers should understand that one or two pesticide applications over summer period does not ensure boxwood protection. Only thorough monitoring of the invader evolution will enable optimal and efficient treatments. In addition, we need to start studies of parasite entomophage applications to regulate pest population and substitute chemical pesticides with biological ones.

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CHAPTER 2

DANGEROUS INVADERS IN FORESTS AND GREENERY PLANTATIONS

Very often invasive dendrophilous organisms occur in new territories and big cities that are large transport hubs. Coincidence of 2 key conditions – suitable climate and fodder plant availability is a reason of invader quick adaptation to a new habitat; it is worth to point out that more often new invaders are found for its damage when they are fundamentally settled in new habitats. The situation in cities is strained by bans on pesticide applications while during new invader identification its biological control operations are unknown.

Special challenge is new invader occurrence in forests in specially protected territories such as nature reserves and national parks. Nature conservation legislation is aimed at total ban or sufficient limits on pesticide applications. In fact, an invader in reserve territory no matter how dangerous is a conservation target. Such nature conservation situation in Russia and many states established without due regard to invasive process build-up we encounter now. In many cases wide public is not ready to take new invader risks adequately.

Such inadequate perception example is one entomologist opinion who welcomed identification of box tree moth in Sochi saying that such new beautiful moth species would raise biodiversity of the region.

2.1. Challenges of forest ecosystem biodiversity conservation in specially protected nature territories (SPNT) as foreign organisms invade

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Проблематичность сохранения биоразнообразия лесных экосистем на ООПТ при вторжении чуждых организмов

Сочинский национальный парк – уникальный по широте биоразнообразия особо охраняемый природный объект, главная ценность которого это неповторимые по красоте и богатству растительности горные леса, в которых произрастают многие реликтовые, эндемичные и редкие растения. Существование их в настоящее время находится под угрозой в связи с появлением в них новых опасных инвазивных видов насекомых, ранее отсутствующих на территории России. Проблемы осуществления мероприятий по защите насаждений приводят к необратимым последствиям.

Ключевые слова: Сочинский национальный парк, инвазивные вредители, особо охраняемые природные территории, самшитовая огневка, восточная каштановая орехотворка.

Abstract

New for Russia species of phytophagous-invaders pose a serious danger to valuable and relic forest plantations of Sochi National Park. The current lack of reliable and effective protection measures, the legal prohibition on the use of chemical and biological insecticides, and the impossibility of protective treatments in mountain forests threaten the conservation of forest biological diversity in protected areas.

Key words: Sochi National Park, phytophage-invader expansions, specially protected territory, *Neoglyphodis perspectalis*, *Dryocosmus kuriphilus*.

Introduction

Sochi National Park is a unique due to its biodiversity specially protected nature facility with its key value mountain forests peculiar in beauty and vegetation range where many relict, endemic and rare plants grow. Now its availability is endangered due to new hazardous invasive insect species earlier absent in the Russian territory and challenges of protection operations against them that have already resulted and results in irreversible impacts.

Results and discussion

A number of factors enabled phytophage-invader expansions in Big Sochi territory: its imports from European plant nurseries without proper phytosanitary control with plants designed to green Main Olympic Village areas during preparations for XXII Olympic games 2014, uncontrolled plant imports to green private territories, environmental decline due to full scale construction during preparations for 2014 Olympics.

Initially phytophage-invaders infested urban areas. In Sochi region they found all conditions for successful adaptation – favourable climate and rich fodder base determined by a wide range of host plants.

During establishment of updated urban infrastructure before 2014 Olympics available urban green plantations were exposed to intensive man-made impacts that resulted in its stress and decline that seriously affected its resistance to new pest species.

Species with usual low initial populations after adaptation produce mass outbreaks. In its permanent habitats they do not produce sufficient commercial damage due to availability of its natural enemies entomophages. In new areals they present great risks due to lack of natural factors regulating its populations.

Invader problem became serious and dangerous for the Sochi National Park (SNP) as its territory belongs to specially protected natural federal territories. Worldwide known “Dendrarij” (“Arboretum Park”) and “Yuzhnye kultury”

("Southern cultures") arboretums incorporated in the SNP that respectively belong specially protected natural territories are located in the city. Its collection plants were subjected to invader attacks that came to the arboretums from common urban plantations and endangered some valuable species including unique and rare ones.

A vivid and specific example is a situation with the hazardous invader – box tree moth *Neoglyphodis (Cydalima) perspectalis* Walker (Lepidoptera: Crambidae) imported from Italy with evergreen boxwood *Buxus sempervirens* L. to green the Olympic Village areas. After massive urban expansion and total infestation of boxwood urban plantations and collection plants in the “Arboretum Park” and “Southern cultures” arboretums the pest moved into Colchis boxwood (*Buxus colchica*) forest stands infesting adjacent SNP areas from urban lands.

Colchis boxwood *Buxus sempervirens* var. *colchica* Pojark. is tertiary relict, a Colchis-Laziansky flora endemic listed in the Red Books of the Russian Federation (2008), the Krasnodarsky territory (1994) and the Adygeya Republic (2000), its regional populations belong to the category and the status 2 «Vulnerable» – 2, (Timukhin, Tuniev, 2007), grew in 13 forest districts of the Sochi National Park in 2342 ha.

In 2014 box tree moth outbreaks were found in all forest areas where this species grew. Over 1 month this highly aggressive invader resulted in boxwood damage ranging from singular to 90%.

The situation became grave endangering this valuable relict species availability. Urgent operations to save it were needed.

Since the Sochi National Park territory is a specially protected federal territory the Russian Federation Forest Code (article 103, para. 5) and the Chief Government Sanitary Officer resolution of 02.03.2010 № 17 «Adoption of Sanitary rules and guidelines (SabPin 1.2.2584-10) any pesticide applications there are banned. The Ministry of natural resources and ecology of the Russian Federation recommended the Sochi National Park to consider an opportunity of biological agent applications to control the pest however a permission to apply bacterial preparations was not issued.

Biological control operations tested on box tree moth caterpillars such as releases of laboratory mass reared Lepidoptera pupae parasitoid *Chouioia cunea* Yang, 1989 (Hymenoptera: Eulophidae), application of raptor wasp-entomophage *Euodynerus posticus* Herrich-Schaeffer, 1841 (Hymenoptera: Vespidae and laboratory mass reared native strains of entomophagous fungi collected in the SNP territory in its mass outbreaks were not efficient enough because all these biological protection operations are effective when they are applied to keep phytophage population at low level rather when pest population is at its peak.

Box tree moth situation seriously exposed forest protection problem in specially protected nature territories subject to mass mortality triggered by invasive organisms. A new invader infesting a specially protected territory starts to

damage protected plants meanwhile being in specially protected territory become a protection target itself. Due to a number of reasons biological plant protection operations limited by the current legislation in its “pore” application cannot check growing invader population (Shiryaeva *et al.*, 2017). We believe it is important to point out that a new invader after occurrence in the territory is always: 1) little-known by forest protection officers and 2) usually as it occurs there are no allowable protection operations against it. If invader infests forests for the 1st time usually development of protection operations against it begins shortly. However, invader occurrence in specially protected territory makes it a protected target and protection operation development is impossible.

Box tree moth invasion evolved right this way. It happened so swift that 2-3 years after the 1st identification its caterpillars managed to kill practically all-natural boxwood forests in Big Sochi region while research to develop protection operations against it was still at initial stage.

In 2016 occurrence of a new hazardous quarantine pest east chestnut gallfly chestnut woods *Dryocosmus kuriphilus* Yas. 1951 (Hymenoptera: Cynipidae) in chestnut woods was next serious problem in the Sochi National Park due to complete lack of its control operations allowable in a specially protected territory at the moment.

European chestnut *C. sativa* is the key forest forming commercially valuable species, honey plant with fruits of high food value. Russian chestnut forest area is 47,5 thousand ha. It grows only in the North Caucasus and over 75% of its area is concentrated in the Black Sea coast including the SNP (22351,2 ha).

Until recently prevailing factors of adverse impacts on European chestnut plantations were diseases: criphonectryev necrosis, vascular mycosis, phytophthora rot, root and butt rot. Insect-phytophage impacts on chestnut forest condition was assessed as insufficient. Its population stably sustained at low level and it didn't trigger chestnut wood mortality (Shiryaeva, Garshina, 2008).

First *D. kuriphilus* was found in the Sochi national Park chestnut woods in 2016 in 1175.4 ha area. The species is referred to quarantine one not available in the Russian Federation territory.

It is known that *D. kuriphilus* affects many tree species of the *Castanea* genus and there are no chestnut species resilient to it. Its natural areal covers China within Chinese chestnut *C. mollissima* range. From China this species was imported to Japan with follow-up expansion to South Korea, USA, Italy, France, Slovenia, Croatia, Netherlands, Switzerland. Any state could be a source of uncontrolled pest import to the Russian Black Sea coast to green private areas.

Due to bud and shoot mortality gallfly infested chestnut tree crowns tend to thin gradually and trees decline. Flowering and fruit-bearing capacity of affected trees drop drastically. Part of the crown dies in steps with heavy tree infestations its loss is feasible (Gninenko, Melica, 2009). The pest biology important moment is that its larvae evolve inside hard woody galls.

Rosselhoznadzor board in the Krasnodar territory and the Adygeya Republic imposed chestnut gallfly state in the Krasnodar territory and the Sochi National Park was instructed to conduct suppression operations against it with allowable applicable pesticides. However, at the moment applicable preparations against this new recent invader are not available moreover the Sochi National Park is not authorized to apply it as a specially protected territory. In addition, taking into consideration that chestnut forests grow from 200 to 800m above sea level and aged 80-200 years its treatment is practically unfeasible.

Now in Russia it is stated that there are no reliable and efficient protection operations against this gallfly as well as chemical and biological protection operations have not been tested yet.

Conclusion

The situation shaped in valuable Colchis boxwood and European chestnut forests of the Sochi National Park highlighted all challenges of forest ecosystem biodiversity conservation in specially protected territories given phytophage-invader expansions. Current nature conservation legislation shaped without due regard of growing ongoing new hazardous organism invasions and if this legislative shortcoming is not fixed loss of European chestnut woods is highly likely and boxwood will not regenerate in the Krasnodar territory Black Sea coastal natural forests.

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2.2. Heavy losses of thuja (*Thuja*, Cupressaceae) in the Sochi “Arboretum Park”

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Серьёзные потери в рядах туй (*Thuja*, Cupressaceae) Сочинского парка «Дендрарий»

Процесс появления чужеродных видов насекомых-вредителей растений на черноморском побережье Краснодарского края, в частности в районе Сочи, становится всё более и более интенсивным. Большинство инвазивных видов происходит из стран Восточной Азии и Северной Америки. Попадая в регионы, климат которых аналогичен климату ареалов их происхождения или мест культивирования, фитофаги успешно адаптируются на новых территориях.

Проникнув в последнее десятилетие и продолжая проникать на территорию Сочи, инвайдеры из городских посадок переходят на насаждения расположенного в центре города всемирно известного парка «Дендрарий», обладающего обширной растительной коллекцией растений мировой флоры, и естественные леса.

Предполагаемым источником проникновения на территорию России кипарисовой радужной златки стал посадочный материал. Появившаяся в городских насаждениях Сочи на декоративных кипарисовых и вызвавшая их массовое усыхание кипарисовая радужная златка не могла «обойти стороной» парк «Дендрарий» с его многочисленным по количеству входящих в него таксонов семейства Cupressaceae. Очередной агрессивный инвайдер продолжает осваивать новые растения этого семейства, в финале неизменно приводя их к гибели. Опасность и сложность ситуации заключаются в отсутствии на сегодняшний день эффективных мер борьбы с данным инвазивным вредителем.

Ключевые слова: Сочинский национальный парк, инвазивные организмы, радужная кипарисовая златка, кипарис.

Abstract

In the world-famous Sochi “Arboretum Park”, which has an extensive plant collection of plants from the world flora, a dangerous situation has arisen with coniferous evergreen trees. New invasive species *Lamprodila (Palmar) festiva* (L.) (Coleoptera: Bupristida) first appeared in the urban plantings of Sochi on decorative cypress trees and caused their mass drying, and since 2018 it has been found on the plants of the Cupressaceae family in the Arboretum. Representatives of the genus *Thuja* were severely affected, among which the largest number of shrunken and fallen plants were noted. Some representatives of the genera *Thujopsis* and *Chamaecyparis* also died. Another aggressive invader con-

tinues to master new plants of this family, leading them to death. Estimated source of penetration into the territory of Russia *Lamprodila (Palmar) festiva* – planting material, the country of importation – Italy.

Key words: Thuja, invasive pest, Sochi National Park.

Introduction

Process of foreign plant insect pest occurrence in the Caucasus Black Sea coast in particular in Sochi region is getting more and more intensive. Most invasive species come from subtropics and south temperate zone Infesting regions with climate similar to its native areal or propagation areas phytophages successfully adapt in new territories.

Over the last decade invaders infested and still infesting the Sochi territory move from urban plantations to the stands of the worldwide known “Arboretum Park” (“Dendrarij”) with a vast collection of world flora vegetation plants.

Materials and methods

Coniferous evergreen trees in the Sochi “Arboretum Park” collection is presented with 316 taxons of Pinaceae, Araucariaceae, Cupressaceae, Taxaceae families. According to incorporated taxons the numerous Cupressaceae family is presented by *Calocedrus*, *Chamaecyparis*, *Cryptomeria*, *Cunninghamia*, *Cupressus*, *Glyptostrobus*, *Juniperus*, *Platycladus*, *Sequoia*, *Sequoiadendron*, *Tetraclinis*, *Thuja*, *Thujopsis* genus species growing in the park.

Thuja genus is presented in the “Arboretum Park” with 5 species with its garden patterns: *Thuja koraiensis* Nakai, origin Korea (2 taxons); *Thuja occidentalis* L., origin North America (36 taxons); *Thuja plicata* Donn ex D. Don, origin North America (4 taxons); *Thuja standishii* (Gordon) Carrière, origin Japan (1 taxon); *Thuja sutchuenensis* Franch., origin China (1 taxon) and 1 hybrid *Thuja x intermedia* Gordon (garden hybrid *T. occidentalis x T. plicata*) (3 taxons) – totally 47 taxons (Soltavi *et al.*, 2016). According to U. Karpuna and S. Kriviritova data all of them are cultivated in the North Caucasus and attractive for green construction in the region.

Inventory of hazardous arthropod species and pathogenic micro-flora for the “Arboretum Park” collection plants including all thuja species was based on long-term monthly phytosanitary surveys. Our developed earlier procedures were applied in surveys of the park woods (Shiryeva, 2001).

Available hazardous arthropods and diseases triggered by pathogenic fungi were found on surveyed plants.

Surveyed plant condition categories were identified in park wood sanitary condition assessment process. Collection tree and shrub species condition identification was based on scales developed for forest stands (Shiryeva and garshina, 2000) with some adjustments due to hazardous arthropod and disease agent evolution specifics in urban conditions.

Results and discussion

Our long-term studies enabled identification of arthropod species pattern permanently available in the park (Shiryayeva, 2017). Sucking insect group dominates on thuja: *Carulaspis visci* Schr. Damages thuja needles, *Parthenolecanium fletcheri* Cockerell – needles and branches, *Cinara cupressi* Buckton – needles and shoots, *Pseudococcus maritimus* Ehrhorn. – needles and stems. *Pseudococcyx tessulatana* Staudinger regularly damages cones. Among diseases decline triggered by *Cytonaema thujae* (Sacc. et Ell.) Sutner and branch mortality on *Thuja occidentalis*, triggered by *Diplodia thujae* Sacc were observed.

Thuja hazardous arthropod and pathogenic mycoflora pattern practically did not change until 2018. Just plant pest damage rate varied slightly due to specific climate conditions of that or another year. On average it was II grade (5-25%) for phytophages and disease infection (10-20%).

First ornamental cypress decline symptoms in Russian humid subtropics for unidentified were observed since 2013 and in 2014 larval galleries and emergence holes were found on thuja in the Khostynsky district of Sochi (Karpun *et al.* 2017). Authors reported obvious cypress decline in 2016 and 1st identification on *Thuja plicata* and *Chamaecyparis lawsoniana* (A. Murr.) Parl. in Sochi central area of *Lamprodila (Palmar) festiva* (L.) (Coleoptera: Bupristida) of the Mediterranean and south Europe origin. Damaged plant list of *Juniperus*, *Cupressus*, *Cupressocyparis*, *Chamaecyparis*, *Thuja* genera in Sochi ornamental plantations is presented and it was noted that at that moment no jewel-beetle damage (Karpun *et al.* 2007) was found in the “Kuban subtropical botanical garden” (Sochi) with one of the richest collection of coniferous plants (including species of cypress family) in Russia (Karpun *et al.* 2017).

Similar situation with the cypress jewel-beetle— was noted in the “Arboretum Park”. In 2017 there was an ordinary assessment of park wood sanitary condition with evaluation of surveyed plants including *Thuja* – *T. occidentalis* and *T. plicata* species condition category.

T. occidentalis is characterized as a tree up to 20m high often multi-stem and narrow cone-shaped crown formed with short horizontal branches with same horizontal flattened twigs. Its natural species is rarely used in greenery. Normally numerous garden species various in habitat and needle nature are available in plantation (Karpun, Krivorotov, 2009). 35 garden species of *T. occidentalis* grow in the “Arboretum Park”.

In early 2018 *T. occidentalis* and its garden species distribution was as follows: 1st category (healthy) – 14% of plants, II (slightly weak) – 35, III (mean weak) – 29, IV (severely weak, declining) – 14, V category (current year dead plants) – 8%.

T. plicata is the largest species of the genus up to 50m high. It has a cone-shaped crown formed with long horizontal branches with long flat twigs covered with glittering light green needles of specific scent. It is recommended

for coastal line along the Black Sea from the Psou river in south to the Agoysky pass in north (Karpun, Krivorotov, 2009).

T. plicata plant and its garden species distribution is as follows: I category – 10%, II – 21, III – 56, IV – 7, V – 3, VI category – 3%.

The findings show that in 2017 both thuja species dead plants were found: *T. occidentalis* – 8% of current year dead plants (V category); *T. plicata* – 3% of current year dead plants (V category) and 3% of last year dead plants (VI category) – totally 6%.

Xylophage group begins to take an important place among plant damaging ecological arthropod groups from IV condition category. In 2017 this insect group species were not found even on V and VI category dead plants in identification of plant decline reasons. Specific lentil-shaped emergence holes that prove cypress jewel-beetle availability were missing on plants (Karpun, Volkovich, 2016). Practically in all cases decline was triggered by pathogenic fungi *Cytonaema thujae* and branch mortality by *Diplodia thujae*. Cypress jewel-beetle was not key factor of plant decline since in 2017 its damage of Cupressaceae family plants was not found neither in the “Arboretum Park” not in the Kuban Subtropical botanical garden.

Since 2018 evergreen coniferous tree situation undertook a dangerous development. 13 taxon species out of 36 *T. occidentalis* taxons and its garden species growing in the park died completely and dropped out of the collection (52 pcs. out of 318 growing in the park); out of 4 *T. plicata* taxons and its garden species – 3 taxon species (12 pcs. out of 65); out of *T. koraiensis* taxons (1 species and 1 garden species) – 1 taxon species (1 pc. out of 6).

A number of adverse factors among them especially 2015 summer drought that triggered decline and partial dieback of Cupressaceae family plants has likely preceded it. The idea of mass Black Sea coast introduced cypress species dieback as a result of cypress jewel-beetle damage induced by 2015 dry summer was expressed in the Karpun’s research papers (Karpun *et al.* 2016, 2017).

Below finds the list of Cupressaceae family taxon species that died and dropped out of the “Arboretum Park” collection.

List of Cupressaceae family taxon species that died and dropped out of the
“Arboretum Park” collection

Thuja koraiensis Nakai
Thuja occidentalis L. cv. *Alba*
Thuja occidentalis L. cv. *Asplenifolia* '
Thuja occidentalis L. cv. *Aurescens* '
Thuja occidentalis L. cv. *Columna*
Thuja occidentalis L. cv. *Cristata*
Thuja occidentalis L. cv. *Ellwangeriana Aurea*
Thuja occidentalis L. cv. *Ellwangeriana*
Thuja occidentalis L. cv. *Fastigiata*
Thuja occidentalis L. cv. *Lutea*
Thuja occidentalis L. cv. *Malonyana*

Thuja occidentalis L. cv. *Meldenziz*
Thuja occidentalis L. cv. *Rosenthalii*
Thuja occidentalis L. cv. *Tiny Tim*
Thuja plicata Donn ex D. Don
Thuja plicata Donn ex D. Don cv. *Dura*
Thuja plicata Donn ex D. Don cv. *Zebrina*
Thujopsis dolabrata (L.f.) Siebold & Zucc.
Thujopsis dolabrata (L.f.) Siebold & Zucc. cv. *Variiegata*
Chamaecyparis lawsoniana (A. Murray bis) Parl.
Chamaecyparis pisifera (Siebold & Zucc.) Endl. cv. *Plumosa Aurea*
Chamaecyparis pisifera (Siebold & Zucc.) Endl. cv. *Squarrosa*

The greatest number of dead and dropped out of collection plants belong to *Thuja* genus in particular *T. occidentalis* and its garden species among them *T. occidentalis* L. cv. *Ellwangeriana* (4 pcs.) and its garden species *T. occidentalis* L. cv. *Ellwangeriana Aurea* (19 pcs. and 10.7 p.m.) had the highest loss. Out of 12 *T. plicata* plants 7 belong to the species itself and 5 to its garden species, *T. plicata* Donn ex D. Don cv. *Dura* (4 pcs.) and *T. plicata* Donn ex D. Don cv. *Zebrina* (1 pc.).

In addition to *Thuja* genus plants 2 plants of *Thujopsis* genus died – *Thujopsis dolabrata* (L.f.) Siebold & Zucc. And its garden species *T. dolabrata* (L.f.) Siebold & Zucc. cv. *Variiegata* as well as 5 plants of *Chamaecyparis* genus – *Chamaecyparis lawsoniana* (A. Murray bis) Parl. (3 pcs.) and *C. pisifera* (Siebold & Zucc.) Endl. cv. *Plumosa Aurea* and *C. pisifera* (Siebold & Zucc.) Endl. v. *Squarrosa* (2 pcs.).

Dead plant study and comprehensive laboratory analysis of dry branches and stems showed that its mortality reason was cypress jewel-beetle (Fig. 1, 2).

Thuja occidentalis L. was the most gamed mainly it affected very weak and declining plants of IV category that shifted to V condition category over a year.

Unfortunately, it should be stated that new invasive species occurrence process on Caucasus Black Sea coast in particular in Sochi region is getting more and more intensive. According to D. Demidko and A. Orlynsky data (2018, p. 33) “in Russia infestation rate of adventive dendrophilous insect-phytophages has bursted dangerously in the 2000-es (2,3 species per year) and especially in the 2010-es (4,3 species per year) due to growing intensity of cross-border trade and movement of people”. According to the authors most of these species’ come from subtropics and south moderate zone.

In urban greenery wide use of decorative introduced species from various natural areals as well as foreign nurseries in particular Italian ones where plants are widely produced for sale (Fig. 3) and supplied as planting stock to new regions enables infestations of phytophages associated with these plants.

We illustrated this process using an example of the specific invader supplier to the Caucasus Black Sea coast – Italy with the climate similar to the Russian Black Sea coast one in particular Sochi. Italy is located in subtropical; Mediterranean climate zone whereby the Alps buildup sea impacts as a barrier for

north and west winds. Sochi is in subtropical climate zone surrounded with the Caucasus mountains serving as a barrier for cold air from northern regions.

Analysis of new phytophage invasion sources in Sochi territory found that:

a) all phytophage invader species are available in Italy;

b) in the “Arboretum Park” the phytophage invaders infested vegetation taxons or species of the same (or close) genus similar to the ones imported from Italian nurseries before the 2014 Olympics to green the Main Olympic Village areas and buildings and facilities to accomodate the Olympic Family and the International Para-Olympic committee (Shiryeva, 2017a).

In process of pre-Olympic delivery of various ornamental plant species from Italian nurseries to green the city the insect dendrophages associated with these plants with the striking hazardous aggressive invader box tree moth *Cydalima perspectalis* Walker have been “shipped” to Sochi territory (Gninenko et al, 2014).

Foreign species invade city territory in ornamental plant deliveries to green private areas.

D. Demidko and A. Orlynsky (2018) showing possible ways of adventives dendrophilous insect invasions in Russia primarily specify its delivery with planting stock as well as seeds, fruits and raw timber.

Invasive species can gradually expand to new areals due to not only various man-made factors but natural dispersal provided by specific species biological specifics its long flight ability.

Once in regions with climate similar to its origin or successful cultivation area one they easily adapt there finding fodder resources needed for its growth and evolution.

Over the last decade new foreign phytophage species have already repeatedly invaded and go on attacks of the “Arboretum Park” park with a wide collection of world flora vegetation plants from Sochi urban plantations. An example of this is *Lamprodila (Palmar) festiva* that goes on using and inclusion of new coniferous Cupressaceae family species in its fodder plant range. Another 10 genera of this family are endangered with this invader infestation.

Conclusion

Planting stock was a proposed cypress jewel-beetle source of Russian territory invasion. After infestation of ornamental cypress species in Sochi urban plantations and its follow-up decline cypress jewel-beetle could not “leave out” the “Arboretum Park” with its numerous Cupressaceae family. Another aggressive invader goes on using new plants of this family that finally results in its mortality. The situation risk and complexity are in lack of efficient control operations against this invasive pest at the moment.

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Figure 1. Exterior view of *Thuja occidentalis* L., damaged by cypress jewel-beetle *Lamprodila (Palmar) festiva* (L.) (Sochi “Arboretum Park”, January 2019)



Figure 2. Branch damage of *Thuja occidentalis* L. by cypress jewel-beetle *Lamprodila (Palmar) festiva* (L.) – emergence holes and larvae galleries



Figure 3. Decorative plant nurseries in Italy located along Rome-Florence highway (author's photo, May 2017)

2.3. Horse chestnut condition in Moscow territory

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Состояние конского каштана на территории Москвы

Конский каштан обыкновенный *Aesculus hippocastanum* Linneaus, 1758 – популярное древесное растение в озеленительных посадках во многих городах России. Конский каштан является инвайдером для территории нашей страны и нигде не произрастает в естественных лесах.

Долгое время это древесное растение сколько-нибудь серьезно не повреждали никакие местные насекомые или болезни. В начале XXI века на территорию России проник охридский минёр, или каштановая минирующая моль (*Cameraia ochridella* Dëshka et Dimic, 1986). Почти сразу же после того, как на каштане появился новый вредитель, резко возросло поражение листвы патогенным грибом *Guignardia aesculi* (Peck) Steward, 1916. Ранее этот гриб не был столь заметен в качестве возбудителя опасного заболевания листвы.

В начале XXI века в Европе, а затем и в России, появился гриб *Erysiphe flexuosa* (Peck) Braun et Takam., 2000, являющийся возбудителем мучнистой росы конского каштана.

Эти три вредных организма стали оказывать очень сильное влияние на состояние каштана во многих городах Европы и России.

Ключевые слова: конский каштан, озеленительные посадки, охридский минёр, патогенные грибы.

Abstract

Horse chestnut is a popular decorative tree, widely used in landscaping in Moscow. The features of chestnut damage in different urban planning elements of the city are studied. It is shown that where the foliage is regularly removed from the beginning of leaf fall damage to the crowns for the next year is significantly less.

Key words: *Aesculus hippocastanum*, horse-chestnut leaf miner, greenery plantations.

Introduction

Common horse chestnut *Aesculus hippocastanum* Linneaus, 1758 is one of rather popular tree species in greenery plantation of many Russian cities. Horse chestnut is an invader in our country territory and does not anywhere in our natural forests.

For a long time, this tree plant had not been seriously damaged by any local insects or diseases. In early XX1 century the horse-chestnut leaf miner or horse chestnut leaf miner (*Cameraia ochridella* Deshka et Dimic, 1986) invaded the Russian territory (Gninenko, Shepelev, 2004; Golosova et al, 2008). Almost right after new pest occurrence on chestnut Foliage damage with the pathogenic fungus *Guignardia aesculi* (Peck) Steward, 1916 has grown drastically. Earlier this fungus had never been identified as a dangerous foliage disease.

In early XX1 century the fungus *Erysiphe flexuosa* (Peck) Braun et Takam., 2000 emerged in Europe (Adamska, 2002) and then in Russia it is an agent of horse chestnut mildew.

These 3 hazardous organisms began to impact chestnut condition in many cities in Europe (Gninenko et al, 2003; Rakov, 2011) and Russia (Golosova et al, 2008) seriously.

Material and methods

The work has been done in Moscow greenery plantations in 2014-2018. Chestnut condition and foliage damage rate with the horse-chestnut leaf miner mines were evaluated in various habitats such as garden squares, parks, forest parks, street linear plantations and other urban design components. In any component unlimited sample plots were established each one designed to cover at least 50 trees if less then 50 all horse chestnut species there. Mine number per a leaf was evaluated by leaves collection (normally around 100 pcs.) from lower tree branches its herbarization and follow-up laboratory count of mines per each compound leaf.

To assess foliage damage rate in crowns all trees were visually surveyed for mine availability using infestation rate scale that classifies trees into the following categories: 1 – no mines; 2 – mines are rare and available on less than 25% leaves; 3 – mines are numerous and available on 26-50% leaves; 4 – mines are numerous and available on 51-75% leaves, 5 – mines are available on more than 75% leaves.

Counts were done in 3 various periods (2nd half and late July, late July and mid-October) that enabled miner foliage damage rate dynamics identification.

During counts survey areas were selected to cover all Moscow territory at maximum (Fig. 1).

Results and discussion

The horse-chestnut leaf miner moth emergence starts as chestnut flowering period commences. Eggs are laid on full open leaves and an emerged caterpillar gnaws through epidermis and shapes a mine in photosynthesis tissues between fibers (Fig. 2).

Caterpillar feeding results in cavity (mine) formation between upper and lower leaf surfaces where a caterpillar eats green tissues that results in a leaf defoliation due to photosynthesis surface reduction and plant decline.

The more mines are shaped by the miner on a leaf the bigger share of photosynthesis surface is ruined by the pest the stronger is its impact on trees.

Thus, it is important to assess foliage damage rate in various chestnut growing conditions and try to identify the conditions and horse chestnut species with the most severe damage.

Therefore, in 2018 and 2019 there were special surveys of horse chestnut plantations in various urban design components as well as plantations of various horse chestnut species. 2018 common horse chestnut plantation survey resulted in identification of the horse-chestnut leaf miner foliage damage rate dynamics (Table 1).

Table 1. Leaf damage dynamics in chestnut crowns growing in various urban green spaces

Urban green spaces	Total number of surveyed trees, pcs.	Condition average category in various survey periods		
		mid-July	July	Early October
Square	100	1.6±0.02	1.8±0.03	2.0±0.03
Linear plantations along main roads	140	1.8±0.02	2.1±0.02	2.6±0.02
Plantations along avenues	107	1.1±0.02	1.2±0.023	1.4±0.03
Garden plantations	54	1.2±0.05	1.3±0.05	1.7±0.07
Plantations in microdistrict	23	1.9±0.09	2.2±0.09	2.5±0.13
Plantings in forest parks	104	1.6±0.02	1.7±0.02	2.0±0.03
Street linear plantations	29	1.8±0.07	2.2±0.11	2.9±0.11
Courtyard plantations	147	1.9±0.02	2.4±0.03	2.7±0.03

By commence of intensive leaf fall as well as in mid-summer the best foliage condition was in linear plantations in linear plantations in avenues and gardens as well. The worst foliage condition was in street linear plantations and plantations along main roads and in courtyards.

Good foliage condition in squares, gardens and forest parks is quite expected since trees there are less exposed to urban stress impacts. Heavy foliage damage in linear plantation along streets and roads is also quite characteristic. Heavy foliage damage in courtyard plantations was not anticipated at all. Likely it can be explained that soil around trees is too thick, air is too polluted with gas and foliage is not removed after leaf fall.

We already stressed great importance of foliage removal to reduce leaf damage rate. However, growing conditions are of similar importance. Thus, in gardens their soil is not so thick and air pollution is minimal foliage is comparatively low miner infested. In forest parks with rather low air pollution foliage miner damage is higher compared to gardens likely due to the fact that horse chestnut does not grow in forest communities and was planted along trails their soil is too thick.

Less insufficient foliage damage dynamics rate was in squares. Average miner foliage damage category in mid-summer was 1.6 and by vegetation period

end it grew to 1.8, that is only 1.12 times. While in greenery plantation in city avenues in early summer it was 1.9 and by autumn grew to 2.3 or 2.1 times.

In 2019 the horse-chestnut leaf miner leaf infestation dynamics was studied in several specially selected Moscow areas. These areas were selected to enable comparison of foliage condition in areas where foliage is never removed (Educational research and consulting center Forest Experimental Dacha of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy (FED of the RSAU – MTAA), where foliage is removed completely (Exhibition of Achievements of National Economy (VDNH) and where foliage is removed sometimes and not completely (other areas) (Table 2).

Table 2. Average number of mines per a common horse chestnut leaf in various Moscow growing areas in 2019

Leaf collection area in Moscow	Average mine number per 1 leaf in various count periods		
	June	July	September
RAS The Main Botanical garden (MBG)	1.28±0.09	1.28±0.09	12.73±0.05
FED of the RSAU – MTAA	4.87±1.17	10.5±2.69	52.62±0.02
Building №28 of the RSAU – MTAA campus	2.13±1.05	4.92±1.13	16.37±0.04
Bld. №1 of the RSAU – MTAA campus	1.21±0.23	3.83±0.72	13.61±0.03
Bld. №12 of the RSAU – MTAA campus	0.47±0.07	1.32±0.82	9.58±0.04
Central Scientific Library named after N.I. Zheleznov	0.56±0.15	1.14±0.65	7.10±0.07
VDNH	0	0	0.87±0.02

The findings clearly show that the greatest number of mines per a leaf was found at Forest experiment summer cottage where foliage is never removed while the least was at VDNH where foliage is carefully removed carefully during the whole leaf fall period.

Average number of mines according to autumn count on chestnuts at the Forest experiment summer cottage was 60 times more than on chestnuts growing at the VDNH. Over summer average number of mines per leaf grew by 10.8 times. In other areas number of mines grew by 6.4-22.6 times.

Leaf number counts in various areas where chestnut grows showed that average mine number per leaf in street linear plantations was 13.44 times more than at the VDNH and in areas that can be referred to parks it 37.9 times higher (Table 3).

Such sufficient difference is because at the VDNH falling leaves were carefully removed since leaf fall commenced while in park plantations such as forest experiment summer cottage and main botanical garden plantations foliage practically was not removed. It explains why chestnuts at the VDNH were very poorly infested with the miner even at vegetation period end while at the forest experiment summer cottage chestnuts have almost completely reddish-brown foliage that falls in early September.

Table 3. Average mine number per horse chestnut leaf according to autumn 2019 counts

Location of leaf collection	Total leaf number in analysis, pcs.	Total number of counted mines, pcs.	Average mine number per 1 leaf, pcs.
Street linear plantations			
Central Scientific Library named after N.I. Zheleznov	30	213	7.10±0.07
Building № 28	32	524	16.37±0.04
Bld. № 1	31	422	13.61±0.03
Bld. № 12	34	326	9.58±0.04
Average	127	1485	11.69±0.04
Park plantations			
FED of the RSAU – MTAA	35	1842	52.62±0.02
MBG	34	433	12.73±0.05
Average	69	2275	32.97±0.04
Square plantations			
VDNH	33	29	0.87±0.02

The horse-chestnut leaf miner variously damage foliage of different horse chestnut species. Most readily it infests common horse chestnut which is the most popular in greenery Other chestnut species that can successfully grow in Moscow and match it in ornamentality are infested by the miner less readily (Table 4).

Table 4. Dynamics of various chestnut species foliage infestation by the horse-chestnut leaf miner

Location of leaf collection	Average mine number per 1 leaf per collection period, pcs.		
	June	July	September
<i>Aesculus hippocastanum</i>			
MBG	1.28±0.09	2.14±0.09	52.62±0.02
FED of the RSAU – MTAA	4.87±1.17	10.5±2.69	12.73±0.05
<i>Aesculus pavia</i>			
MBG	0.02±0.01	0.07±0.02	
FED of the RSAU – MTAA	0.36±0.12	0.77±0.37	
<i>Aesculus glabra</i>			
MBG	0.0	0.02±0.01	

The findings show that the horse-chestnut leaf miner population and its adverse impacts on greenery plantations can be sufficiently reduced by using other horse chestnut species in greening.

Conclusion

Conducted studies showed that all fallen foliage should be collected and utilized carefully every autumn as leaf fall starts as well as practice of the only horse chestnut species use should be abandoned to reduce The horse-chestnut leaf miner impacts on greenery plantations sufficiently.

These operations will enable sufficient reduction of The horse-chestnut leaf miner population and its adverse impacts on urban greenery plantation condition.

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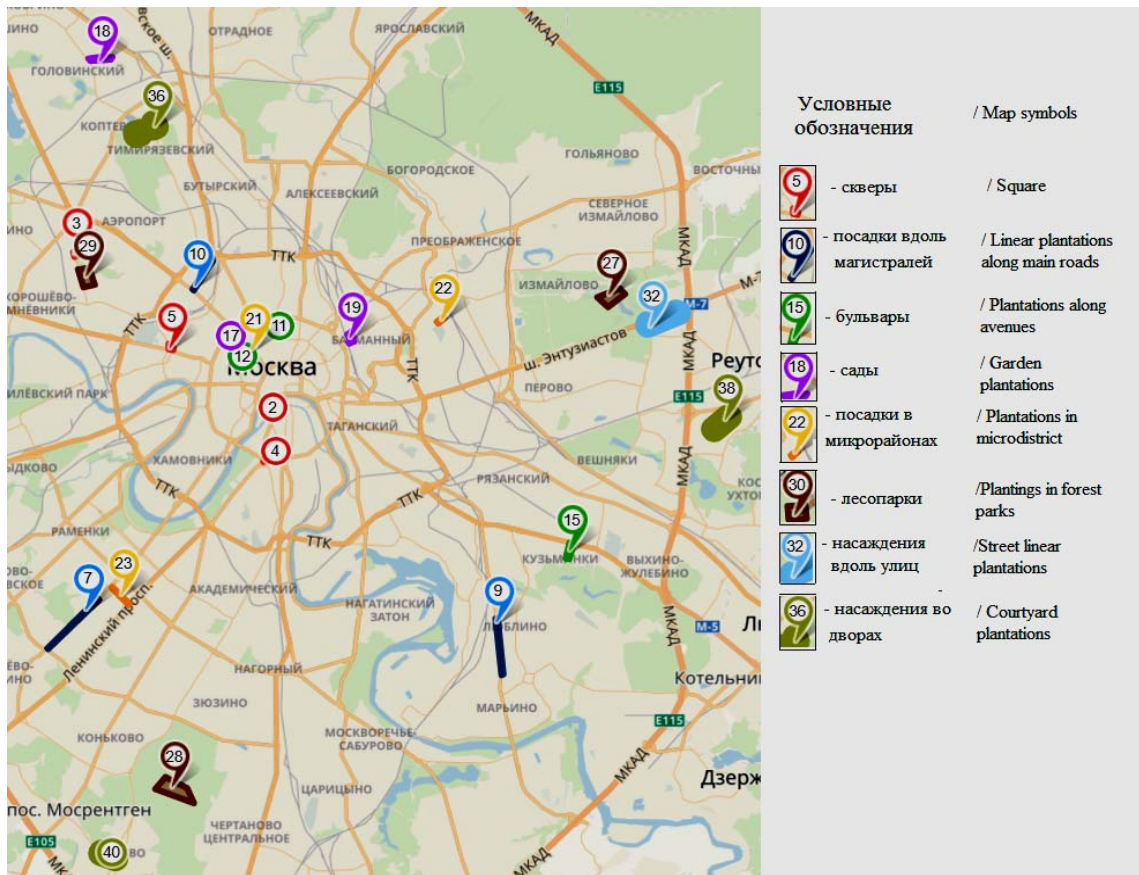


Figure 1. Location of count areas in Moscow territory



Figure 2. Chestnut leaves with the horse-chestnut leaf miner mines

2.4. Some biological features of the oak lace bug in the oak forests in the Caucasus region

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Некоторые данные биологии дубового клопа-кружевницы на Северном Кавказе

Дубовый клоп-кружевница *Corythucha arcuata* Say, 1832 (Hemiptera, Heteroptera: Tingidae) впервые был обнаружен в России в 2016 г., в Краснодарском крае по нанесенным повреждениям. Уже к концу летнего сезона 2016 г. по данным Краснодарского центра защиты леса общая площадь поврежденных дубрав составила около 1.2 млн. га. С этого времени началось расширение ареала инвайдера и в настоящее время он уже заселил и вредит дубравам всего Северного Кавказа.

Приведены сведения о современном распространении клопа в дубовых лесах юга России и некоторые данные о его биологии.

Ключевые слова: дубовый клоп-кружевница, дубравы, очаги массового размножения.

Abstract

This article presents information about formation of the secondary area of *C. arcuata* in the Northern Caucasus region. Other objectives of the study included the new data on the sex ratio in populations of oak lace bug, fertility of its females, counting of the size and placement of egg clusters on the crown. Some of the factors of mortality of the bug and the state of oak in the centers of mass reproduction of the bug were analyzed. Also, the area of necrotic spots on the leaves was counted.

Key words: alien species, *Corythucha arcuata*, Northern Caucasus region.

Introduction

The oak lace bug *Corythucha arcuata* Say, 1832 (Hemiptera, Heteroptera: Tingidae) is a native to North America. For the first time in Europe, it appeared in Italy in 1999 (Bernardinelli, 2000; Bernardinelli, Zandigiacomo, 2000), and almost at the same time was identified in Turkey in 2000 (Mutun, 2003; Ibrahim, 2014), In 2002, the species was found in southern Switzerland, in France in 2006 and later in other countries (Forster et al., 2005; European, 2001).

It was first detected in Russia in 2016 in the Krasnodar region because of leaves damage (Gninenko *et al.*, 2017; Internet resource, 2016). According to

the Krasnodar Center for Forest Protection the total area of severe infected oak trees was about 1.2 million hectares at the end of the summer season in 2016. Since that time, it was the beginning of the range expansion of the invader and now it's already spread in and damaged the oak forests in Northern Caucasus.

Therefore, it was extremely necessary for us to develop protection measures against the bug with the use of modern pesticides (Gninenko *et al.*, 2018a).

The work has begun to study the biology of the bug in new habitats (Gninenko *et al.*, 2018b). However, the main features of the biology of this new invader remain unknown for the oak forests of the region.

Material and methods

The oak lace bug (abbreviated as «OLB» further on) began forming its habitat in Russia in 2016. It was able to spread rapidly through oak forests, so in 2018 a special survey was undertaken, in which we examined the planted oak trees in cities along the route from Rostov-on-don to Makhachkala (Fig. 1). At the same time, a survey of oak plantations in the settlements of the Belgorod and Voronezh regions was inspected. This made it possible to establish the boundaries of the area occupied by the bug.

The study of the main features of the biology of OLB was carried out in the foci of its mass reproduction in artificial plantations of *Quercus robur* and *Q. castaneifolia* in the area of Gelendzhik town, Krasnodar Krai. Here, during 2018 – 2019, the number of bugs on the foliage of oak trees of different species was recorded. At the same time, several branches in the lower part of the crown were cut. We checked at least 30 leaves of each infected tree for present adults, larvae and egg clusters (in our earlier researchers and publications we used a term «oviposition», but it is sometimes impossible to separate visually one oviposition from another, we will use the term «egg clusters»).

Special surveys were carried out in different types of tree and shrub plants, which allowed to establish these plant species as suitable hosts.

In addition, we counted the egg clusters separately on oak trees to determine which oak species females prefer for egg-laying sites. Also, we counted the number of eggs in each cluster and at the same time visually determined the condition of the eggs, which can be infected by parasites.

In the wintering areas of adult individuals in the bug foci in the territory of the Republic of Adygea in the middle of winter (in February 2018) were collected some wintering adults. They were divided on the basis of sex and condition, separately taking into account the healthy, parasitic and dead ones from diseases.

In the spring, when adults were registered in the crowns of oak trees, they were collected, fixed in alcohol and divided by sex in the laboratory. Females were cut and the number of eggs in the egg tubes was counted using a microscope.

The state of oak trees in bug foci was taken into account by 6 categories of condition. We categorized:

1 – no symptoms of discoloration of the upper surface of the leaves or barely noticeable;

2 – symptoms of chlorosis are noticeable on single leaves and usually occupy a small part of the leaf blade;

3 – chlorosis is noticeable on a significant part of the leaves in the crown of the oak;

4 – chlorosis is noted on most leaves in the crown, some leaves have necrotic brown spots;

5 – crown oak become brown-green colour due to the strong development of chlorosis and necrotic leaf lesions;

6 – the most part of the leaves in the crown dies, all the leaves have numerous brown spots of necrosis, often occupying the most part of the leaf blade.

Field studies accompanied by photography were conducted on *Quercus robur* and *Q. castaneifolia* growing in the area of Gelendzhik town, Krasnodar Krai in alley plantings; also, were fixed the geographical coordinates of the studied areas.

Results and discussion

Formation of the secondary area of C. arcuata in Russia

A survey conducted in 2018 showed that by the autumn of this year the bug had mastered the entire territory from the Northern Caucasus to Dagestan (Table 1).

Table 1. Results of detection of individuals of *C. arcuata* in the cities in the North of Caucasus

№	Location of the survey (city)	Coordinates	Type of urban landscape	Number of individuals per 1 running meter of a branch, pcs.		
				accounted trees	adults	egg clusters
1	Rostov-on-Don	47°13'47"N 39°44'43"E	Park	3	1	1
2	Stavropol	45°2'49"N 41°58'34"E	Park and street planted	20	3	1
3	Cherkessk	44°14'6"N 42°2'9"E	Park	2	2	2
4	Mineralnye Vody	44°12'36"N 43°7'50"E	Park	5	2	2
5	Nalchik	43°30'35"N 43°38'22"E	Park	3	108	38
6	Vladikavkaz	43°2'58"N 44°39'52"E	Park	4	2	2
7	Grozny	43°19'8"N 45°41'55"E	Park	7	2	1
8	Makhachkala	42°58'54"N 47°30'7"E	Park	6	3	1

Thus, since its discovery in the Krasnodar Krai in 2016, OLB mastered the entire territory in the North of Caucasus and appeared on the coast of the Caspian Sea (Fig.1).

At the moment its greatest number and visible damage is only in the Krasnodar Krai, the Republic of Adygea and the Republic of Kabardino-Balkaria. In other regions of the Northern Caucasus, the bug caused severe damage to oak forests in 2018.

Conducted in 2018, surveys of urban oak plantations in Belgorod and Voronezh cities showed that a bug was not found here. Thus, it can be confirmed that the bug by the end of 2018 had completely mastered the entire territory of Northern Caucasus region (Fig. 2).

The bug expansion of the secondary range on the territory of Russia is continuing, and in 2019 its appearance can be expected in oak forests of Chernozem zone in Russia, and from the territory of Dagestan it can penetrate into Azerbaijan.

Plant hosts of C. arcuata in the Northern Caucasus region

During our research, adult individuals and larvae of the bug were observed on many deciduous trees and shrubs. We did not consider a tree species as a host if only adults were found on it. However, the presence of adults or even larvae on a particular plant cannot serve as a convincing evidence of their nutrition on them. The known host records within its native range are based on the following literature sources (Bernardinelli, Zandigiacomo, 2000; ERO, 2001; Drake, Ruhoff, 1965).

According to the recently obtained data, collected in the Krasnodar region and the Republic of Adygea (Borisov et al., 2018), the OLB has much more host plants than it has been known from foreign publications, but we can not verify this information yet. In the Northern Caucasus region, we managed to find all stages from egg to adult on many species of oak leaves (Table 2).

Table 2. Species of oak on which individuals of the bug have been found

№	Plant species	Location of the survey	Found stages of development
1	<i>Quercus robur</i>	Gelendzhik	Adults, larvae, egg clusters
2	<i>Q. castaneifolia</i>	Gelendzhik, Sochi	Adults, larvae, egg clusters
3	<i>Q. glauca</i>	Sochi	Adults, larvae, egg clusters
4	<i>Q. hartwissiana</i>	Sochi	Adults, larvae, egg clusters
5	<i>Q. iberica</i>	Sochi	Adults, larvae, egg clusters
6	<i>Q. pubescens</i>	Gelendzhik	Adults, larvae, egg clusters
7	<i>Q. macranthera</i>	Gelendzhik	Adults, larvae, egg clusters

Some differences in the degree of presence the bug on the leaves among different species of oak were found. The calculations of the presence the foliage in the crowns of two species of oak (*Q. robur* and *Q. castaneifolia*), carried out at the end of July, 2019 showed that the differences between them were not very significant (Table 3).

The conducted surveys showed that at the beginning of the growing season in the crowns of *Q. robur* mastered by bug 13.72% of leaves, whereas in the crowns of *Q. castaneifolia* mastered 11.21%. This level of foliage presence gives a reason to believe that the bug damages petiolate oak to a greater extent than chestnut.

Table 3. The presence of the foliage OLB in the crowns of *Q. robur* and *Q. castaneifolia*

№	Location of the survey (Gelendzhik)	Coordinates	Approximate quantity of leaves		
			total on the tree, pcs.	with bugs, pcs.	with bugs, %
<i>Q. robur</i>					
1	Guest House "Lesnik"	N 44.590018 E 38.060346	29160	1620	5.56
2			60000	6800	3.40
3	Odesskaya str.	N 44.590018 E 38.060346	5700	240	4.21
4			15120	324	2.14
5	Park them. Admiral Wrungel	N 44.588643 E 38.062792	2640	1056	40.00
6	Park them. Admiral Wrungel	N 44.58649 E 38.06082	4860	72	1.48
7			3150	30	0.95
8			3000	120	4.00
9			1080	144	13.33
10	Gelendzhik forestry, compartment 70	N 44.592371 E 38.065309	11000	4200	38.18
11			4440	1554	32.81
12		N 44.594060 E 38.068396	6545	850	13.00
13			5120	1024	19.05
14			16640	3328	21.05
15	Stop "Avtostancia"	N 44.566390 E 38.081239	10800	3240	60.00
Average			11950.3±4097.1	1640.1±483.6	13.72±4.2
<i>Q. castaneifolia</i>					
16	Park them. Admiral Wrungel	N 44.58649 E 38.06082	5720	78	1.36
17			4560	76	1.66
18			3360	360	10.71
19			6048	768	12.69
20			6825	1365	20.00
21			2800	640	22.85
Average			4885.5±805.0	547.8±257.8	11.21±4.4

The sex ratio in populations of C. arcuata

Sex ratio in bug populations collected in wintering areas (winter 2018/2019) was studied according to data from four locations of the Republic of Adygea (Table 4).

Table 4. Sex ratio in populations of OLB during wintering in the Republic of Adygea

№ Locations	Number of adults	Proportion of males and females in the population, %	
		♂	♀
1	285	36.8	63.2
2	2373	32.6	67.4
3	595	30.2	69.8
4	846	33.6	66.4
Average	1024.7	32.8	67.2

The obtained data indicate that the average sex ratio of bug during wintering in the Republic of Adygea was equal to 1 / 2.05, so, the number of females in wintering areas is slightly more than 2 times the number of males.

In summer, the sex ratio in bug populations is unstable. Thus, in August 2018, the conducted collections in the area of Gelendzhik (Krasnodar region) showed that there were practically no males in the populations. 1,000 individuals of the bug were collected, among which no males were found. To explain such an unusual phenomenon as the absence of males in the population and whether this phenomenon is temporary, we have not succeeded yet. But in spite of that our data are completely the same with the data about sex ratio from an article published recently by Shchurov V.I. (Shchurov V.I. et al 2019).

Fertility of females

In August 2018 we collected about 1.0 thousand females and three hundred of them were cut and counted the number of eggs in their egg tubes with a help of microscope. The number of eggs ranged from 1 to 17 (Fig. 3). The average number of eggs was 6.59 ± 0.05 PCs. This number of eggs does not correspond to the fertility of the female, it only shows how many eggs are in a female and how many can be laid by them in the nearest future.

Thus, the calculations carried out in August 2018 showed that on average a female can lay about 6-7 eggs during August.

The size and placement of egg clusters on the crown

Female bugs lay eggs in groups only on the low surface of the leaves. The number of egg clusters on one leaf of some species of oak annually varies from 1 to 4, and in the vast majority of cases significantly it is more often to see one cluster on a leaf (Table 5).

Table 5. Number of egg clusters of *C. arcuata* on one leaf of oak species

Number of egg clusters on one leaf	Number of cases	The proportion of the total number, %
<i>Quercus robur</i> , 2018		
1	58	72.5
2	16	20.0
3	5	6.2
4	1	1.3
total	80	100.0
<i>Q. robur</i> , 2019		
1	36	63.2
2	17	29.8
3	4	7.0
total	57	100.0
<i>Q. costaneifolia</i> , 2019		
1	46	74.2
2	11	17.7
3	4	6.5
4	1	1.6
total	62	100.0
<i>Q. pubescens</i> , 2019		
1	62	79.5
2	13	16.7
3	2	2.5
4	1	1.3
total	78	100.0

Thus, more than in a half of the cases on the oak leaf can be found a single egg-laying bug, but in more than 92% of cases on the leaf there is one or two clusters.

On average, the differences between oak species in the number of egg clusters on one leaf are not very large (Table 6).

Table 6. The average number of egg clusters on one leaf in the crowns of three species of oak

Plant species (oak names)	Survey year	Average number of egg clusters per leaf in a crown
<i>Q. robur</i>	2018	1.36±0.04
<i>Q. robur</i>	2019	1.44±0.05
<i>Q. costaneifolia</i>	2019	1.52±0.05
<i>Q. pubescens</i>	2019	1.26±0.04

Counting the number of eggs in egg clusters was made in several places of Gelendzhik (Table. 7).

Table 7. Number of eggs in the egg clusters of the oak lace bug

Location of the survey (Gelendzhik)	Coordinates	Number of egg clusters	Total number of eggs, pcs.	Average number in 1 egg cluster
Guest House "Lesnik", 2018	N 44.589717 E 38.060664	54	1895	35.1±2.7
Odesskaya str., 2018	N 44.588033 E 38.05720	44	527	12.0±1.3
Gelendzhik forestry, compartment 70, 2018	N 44.586484 E 38.066200	12	406	33.8±8.8
Total in 2018		110	2828	25.7±1.3
Park them. Admiral Wrungel, 2019	N 44.58649 E 38.06082	70	2185	31.5±3.4

On average, 110 egg clusters were counted and one egg cluster consists of more than 25 eggs. The maximum number of eggs in an egg cluster is 145 eggs, the minimum is one egg.

The factors of mortality of the bug

Conducted analyses of the state of individuals of OLB in the wintering areas, as well as the state of eggs in egg clusters on oak leaves, show that local entomophages and pathogens have no effect on the number of invaders, but we observed high overwintering mortality of the bug. One of the important factors of mortality for the bug is precipitation in the form of intense rainfall of a torrential nature. We could not quantify the degree of death of individuals during heavy rains, but visually we noted that after a heavy rain in the crowns of trees adults and larvae of the bug are absent, but egg clusters are preserved.

In fact, we observed a huge number of dead adults and larvae in the sea, that swam near the shore (Fig.4).

It is interesting to notice that the summer of 2019 in the Northern Caucasus was characterized by a large number of days with heavy rainfall, which

could be one of the reasons why the overall level of crown damage in the oak forests of the Krasnodar region in 2019 was lower than in 2018.

Thus, it can be considered that effective local entomophages of the bug in the forests of Northern Caucasus region do not significantly affect on the level of its population, while some weather events can reduce the number of the pest.

The state of oak in the centers of mass reproduction of the bug

Our observations show that despite the annually inflicted severe damage to the foliage for 3 years, since 2016, in most oak forests, the overall sanitary condition of the oak has not deteriorated significantly. However, the distribution of trees according to the degree of damage foliage in the crowns by phytophagous shows that more from the bug suffers petiolate oak (Table 8).

Table 8. The state of foliage in the crowns of oaks

Plant species	Number of trees counted	Share of trees of different status categories, %			
		1	2	3	4
<i>Q. robur</i>	51	29.41	56.86	11.76	1.96
<i>Q. costaneifolia</i>	52	69.23	25.00	1.92	3.85

The received data show that the condition of *Q. costaneifolia* trees is slightly better than that of *Q. robur* after four years of OLB damage.

We have made calculations (with program ImageJ) of the area of necrotic spots that are formed on damaged leaves *Q. costaneifolia* as a result of feeding symptoms (Table 9).

Table 9. Counting the area of necrotic spots on the leaves of *Q. costaneifolia*

№ leaf	Total leaf area, mm ²	Damage area, mm ²	Share of necrotic tissues on the leaf, % of the total leaf area
1	3054.9	1073.6	35.14
2	13712.0	6065.0	44.23
3	9746.9	3437.4	35.27
4	6925.5	3037.7	43.86
5	12189.4	4138.4	33.95
6	8926.4	4881.3	54.68
7	7057.4	1681.0	23.82
8	7489.4	2428.6	32.43
9	11984.5	4221.5	35.22
10	10849.0	703.8	6.49
11	4759.2	1069.5	22.47
12	8938.1	3362.2	37.62
13	2683.8	599.6	22.34
14	6919.1	1263.9	18.27
15	6334.3	1051.3	16.60
Average	8104.7±787.7	3008.3±390.4	33.4±3.44

The average area of damage that led to the death of the part of leaf was equal to 33.4 %, the minimum – 6.49%, the maximum – 54.68%. Thus, in Au-

gust 2018, a third of the photosynthetic surface of leaves was destroyed in the plantings of *Q. costaneifolia* in the area of Gelendzhik, Krasnodar Krai as a result of feeding of OLB in the crowns. By the end of the growing season, the proportion of defoliation (destruction of the photosynthetic surface of the leaves) reached, most likely, 50%. This indicates a high degree of damage leaves *Q. costaneifolia* that causes bug. Special accounts of defoliation level in crowns of other oak species were not carried out, but visually it was possible to estimate that the level of defoliation of crowns of *Q. robur* was slightly higher than that of *Q. costaneifolia*.

Conclusion

Summed up, the studies have shown that oak lace bug after 4 years since the first discovery in the Krasnodar region has fully mastered the oaks in the Northern Caucasus and began the process of spreading on oak forests of Chernozem zone of the European part in Russia.

As a result of feeding of bug individuals by August there is a destruction not less than 50% of a photosynthetic surface of leaves, that leads to progressive weakening of oaks. However, during the harmful activities of the bug in the Krasnodar region, the state of oak forests has not yet become critical. The long-period influence of the *C. arcuata* damage has not yet known, but there are positive reasons to confirm the constantly infections will have huge negative effect on the growth, health status and fecundity of the oak stands. There is still time to take all necessary measures to protect oak forests from this invasive pest.

No pathogens and entomophages are capable of effectively regulating its number have been found in the populations of the oak lace-bug in the Northern Caucasus region.

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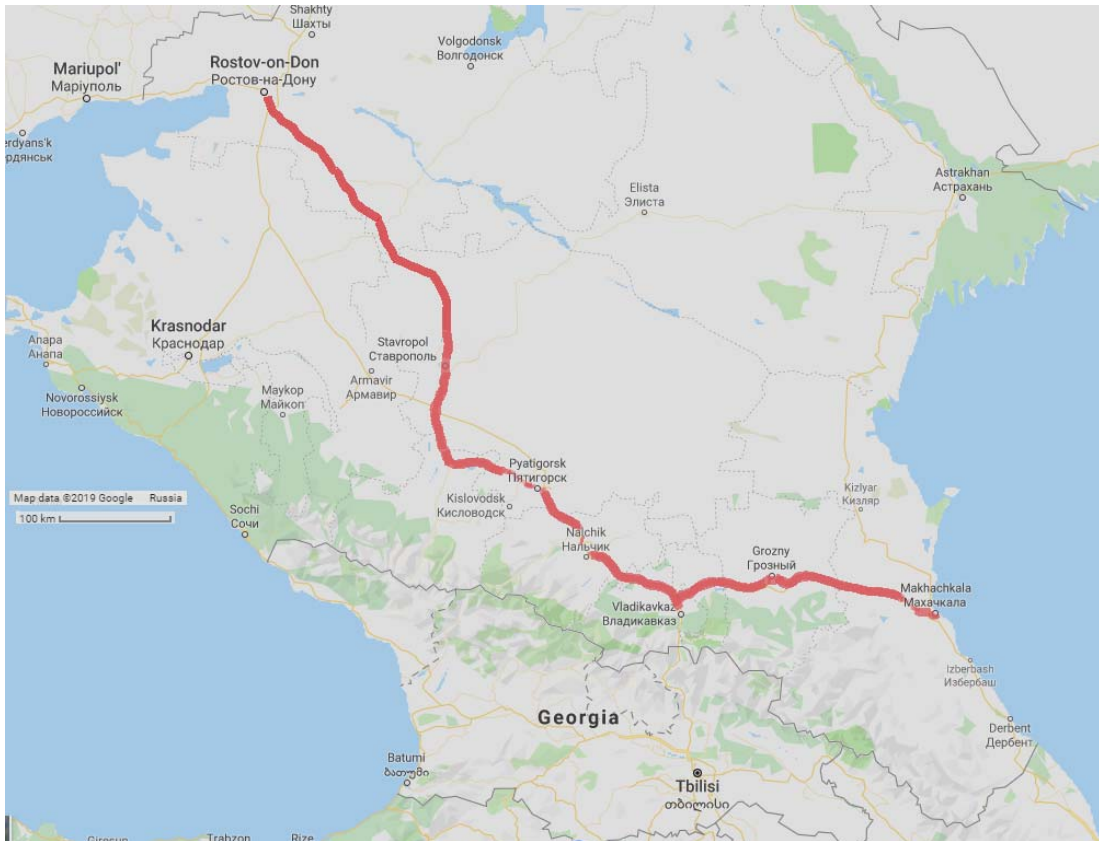


Figure 1. Survey route



Figure 2. Range of *C. arcuata* in Russia in 2018

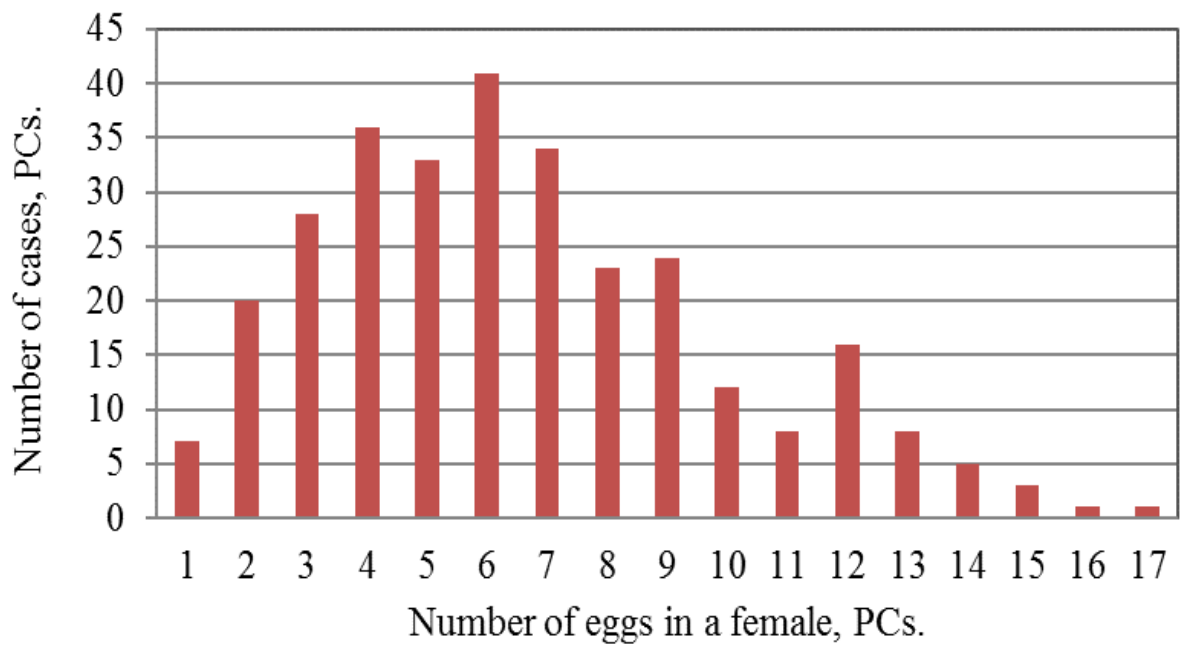


Figure 3. Frequency of occurrence of the recorded number of eggs in a female, pcs.



Figure 4. Masses of bugs in the sea on the next day after a downpour

2.5. *Polygraphus proximus* in European Russia

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Уссурийский полиграф в европейской части России

Очаги массового размножения уссурийского полиграфа *Polygraphus proximus* (Coleoptera: Curculionidae) были обнаружены в пихтовых лесах Сибири в конце XX века, и он стал предметом пристального изучения.

Впервые уссурийский полиграф был обнаружен в европейской части России в 1999 г. Но это была единичная находка, которая впоследствии не была подтверждена новыми обнаружениями. С тех пор вредитель широко распространился по регионам Сибири и стал там одним из наиболее опасных стволовых вредителей. Приведены сведения о новых обнаружениях полиграфа в Москве и в пихтовых лесах Удмуртии.

Ключевые слова: уссурийский полиграф, пихтовые леса, европейская часть России.

Abstract

The ussuri polygraph, or four-eyed fir bark beetle was first discovered in natural forests on the territory of the European part of Russia in the Republic of Udmurtia. New foci of it were also found in artificial plantings in Moscow. The invader continues to expand its range in the European part of Russia, moving West through forests that contain fir and artificial plantings in cities.

Key words: *Polygraphus proximus*, fir, European part of Russia.

Introduction

Four-eyed fir bark beetle, or ussury bark beetle *Polygraphus proximus* Blandford (Coleoptera: Curculionidae) mass outbreaks were found in Siberian fir forests in late XX century (Baranchikov et al 2011; Gninenko *et al.*, 2010a, 2010) and it became a target of thorough studies (Krivets et al 2014; 2015; Chernova, 2014; Krivets *et al.*, 2015).

For the 1st time in European Russia ussury bark beetle was found in 1999. (Maldelstam, Popovichev, 2000). However, it was the only founding that has not been proved by new ones.

Afterwards the pest widely expanded in Siberian regions and became one of the most hazardous stem pests.

Material and methods

Surveys of fir forests and fir greenery plantations were done visually. In cases resin leak find on bark in these surveys identification of resin leak source was done. In such case upper part of the bark in place where tar leaked was cut off with a knife where we found either a turpentine embedded beetle or a necrotic spot shaped as a result of *G. aoshimae* development.

To identify condition of firs and its beetle damage rate circular 10 m diameter sample plots were established where condition of all available fir trees was inspected. Tree condition categories were estimated with the standard scale (Sanitary rules, 1998) specially updated for fir exposed to the Ussury bark beetle attacks (Gninenko et al, 2016). Beetle species identification was done at the VNIILM laboratory (All-Russian Research Institute of Silviculture and Mechanization of Forestry) or in field conditions by specific galleries under bark.

Review of the Ussury bark beetle expansion in European Russia

For the 1st time in European Russia *Polygraphus proximus* was found in 1999 on spruce in the vicinity of Tosno-2 township in the Leningrad region. The spruce where the bark beetle was found grew near railway tracks thus it was suggested that the find was connected with the xylophage's delivery by railway (Mandelstam, Popovichev, 2000). Afterwards the ussury bark beetle has never been found in the Leningrad region despite special surveys and eventually this species was excluded from the list of xylophages living in the Leningrad region (Mandelstam, Khairtdinov, 2017).

This finding did not draw any sufficient attention of entomologists to this Far East invader. Discovery authors suggested that the bark beetle was delivered accidentally and it would not be able to acclimatize successfully.

It is likely happened and the ussury bark beetle could not settle in the Leningrad region spruce woods which is proved by lack of its new finds in this region over the next 20 years.

For the 1st time in the Moscow region *Polygraphus proximus* was found in summer 2006 in fir plantations along the Kurkinskoe highway (Khimkinsky district, Novogorsk) where a local outbreak shaped and 34 trees of Siberian fir and balsam fir died (Chilikhsaeva, 2008).

Almost at the same time in June 2006 singular ussury bark beetle species were found in Pervomaisky housing complex (Korolev, Moscow region) under bark of a fallen spruce tree affected by root rot. That year singular polygraph beetles were found in some areas of Moscow vicinity and some beetles were collected under bark of a fallen Siberian fir upper stem in Shishkin les township and Mikhailovskoe village in the Podolsky district on August 29, 2006. In December in the Oditsovo district near Agafonovo village *P. proximus* beetles were found under bark of a fallen spruce affected by the bark beetle, in fact all these finds were done in close vicinity of Moscow (Fig. 1).

Next 2007 year the bark beetle was found in the Odintsovo district 1 km from the Moscow ring road "MKAD" along the Skolkovskoe highway in the Zarechje township on 1 fir tree (*Abies sp.*). Then in May 2008 in the Podolsky district in the country estate park in the Mikhailovskoe village (Shishkin les) active Siberian fir beetle infestations and tree decline were observed. It is likely that the ussury bark beetle successful evolution near this area since 2006 commenced this small local outbreak.

In July 2008 *P. proximus* was caught in a window trap in Bykovo township suburbs in the Ramensky district. In June 2011 in Serpukhov 1 ussury bark beetle infested Siberian fir tree was found. Until 2013 due to lack of a good fodder base the ussury bark beetle damages had a singular pattern.

In 2013 *Polygraphus proximus* was found in the RAS N. Tsitsin Main Botanical Garden on 2 fir species: *A. balsamea* and *A. sibirica* (Mukhina *et al.* 2014). In the follow-up *P. Proximus* mass outbreak shaped here. Siberian fir trees planted in 1950-1980-es in "Siberia" display of the flora department by the time of the bark beetle introduction were too dense and weak due to root rots and became a suitable base area for the invader population build-up. By autumn 2013 in the flora department 67 trees died and were cut down more 41 dead trees were removed during 2014 and 5 trees were taken away in early spring 2015. In 2012 tree mortality in the fir collection of the dendrology department. It was observed in plantations of *A. balsamea* (L.) Mill., *A. lasiocarpa* Nutt., *A. nephrolepis* Maxim., *A. sibirica*, *A. veitchii* Lindl. In 2012 mortality was 9 pieces in 2013 – 31 pieces and in 2014 – 10 pieces (Seraya *et al.*, 2018).

In 2013-2014 fir infestation commenced across the whole territory of Moscow and Moscow vicinity towns. Thus, the only fir aged around 50 years growing in a private house yard in Uchinskaya street in Pushkino died in 2013. In 2014 resin bleeding started on 5 fir stems in the Educational research and consulting center Forest Experimental Dacha of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy and one of them died. At the same time rather heavy resin bleeding of fir trees in Pushkino at the VNIILM arboretum and in greenery plantation in Naberezhnaya street near building № 17. Everywhere in these areas development of necrosis spots triggered by the bark beetle transmitted phytopathogenic fungus *Grosmannia aoshima* was observed. However, this fungus infection intensity was low everywhere. Only 1 the most retarded and weak tree in the Forest summer cottage territory was not ringed with necrotic spots thus trees did not die. Firs at the Forest summer cottage were experimentally injected with the limitrin preparation probably it saved the trees.

In 2015 in the Main Botanical Garden (MBG) there were industrial treatments against the Ussury bark beetle with the Kliper preparation to protect stems of affected species *A. sibirica* and *A. lasiocarpa* against bark beetle infestation. 270 trees were treated. It enabled to slow down early spring fir infestation. Attack traces as resin bleedings were observed on individual Siberian fir trees 30

days after the treatment. Nevertheless, no single tree of *A. sibirica* and *A. lasiocarpa* was removed in 2015 in the arboretum (Mukhina *et al.* 2016). Treatment continued in 2016 and 2017 mortality was not observed. In 2018 treatments terminated (Seraya *et al.* 2018) since outbreak evolution stopped. There is no signal on new decline cases in areas where fir grows in Moscow vicinity towns since 2016.

In areas where we managed to observe fir condition, we noted termination of resin bleeding on stems and visually all fir trees looked quite healthy.

Thus, the polygraphus intensive mass outbreak that evolved in fir plantations in the MBG in early XX century was the area polygraphus beetles dispersed covering rather long distances and tried to infest all available firs.

However relatively small number of beetles managed to fly long distances and trying to infest firs brought the pathogen in stems but these infestation efforts were relatively rare and necroses could not ring stems. *G. aoshimae* is not a dangerous infection mycomycete individually able to trigger fast infected tree destruction. Tree mortality needs that the beetles carrying it regularly buildup infection load. Only in this case the infested tree will be weakened slowly and will be unable to resist polygraphus attacks and overwhelmed with it and killed.

It shows that successful polygraphus infestations in new areas are feasible provided availability of some declining for some reason fir trees in a newly infested area or its infestation efforts will be supported with new beetle flights from a nearby outbreak.

After polygraphus outbreak elimination in the MBG fir plantations the invasion evolution suspended and there were no new invader finds in Moscow and Moscow vicinity territories from 2016 to 2019. It was clear that the conducted treatments did not kill the polygraphus completely but for some time its outbreaks were suspended in Moscow region.

However, a new report about mass fir decline came from the “Biruljevo” arboretum in 2019. After survey of these plantations it was clear that a new strong source had shaped in Moscow territory and beetle emergence will start there in the nearest future and risks for remaining fir trees in Moscow and Moscow vicinity towns will arise again (Table 1).

Table 1. Siberian fir condition in the “Biruljevo” arboretum (Moscow)

Location	Total number of surveyed trees, pcs.	Fir condition according to condition categories, % of total inspected number					
		1	2	3	4	5	6
Fir alley	92	0	0	66.3	32.6	1.1	0
Spruce alley	21	0	0	90.5	0	0	8.5
Firs between linden tree and birch tree alleys	35	0	0	0	62.9	0	37.1

The ussury bark beetle infested fir trees are available across the whole arboretum territory. According to fir decline pattern mortality process there started no less than 3 years ago and at the moment the outbreak needs urgent elimination operations.

Thus, after some years of lack of the ussury bark beetle and fir *Grosmannia oashimae* further evolution features in 2019 the invasion renewed further development.

During all invasion evolution main polygraph and *G.oashimae* outbreaks were active in Asian part of Russia. There both invaders infested vast area of fir forests from the Tomskaya to the Irkutskaya region from mountain fir woods in the Altay Republic to the Mid-Enisey areas in the Krasnoyarsk territory. However, for the 1st time both invader outbreaks were found in 2019 in Udmurtia forests on fir. These were the earliest outbreaks in European Russian territory.

Across the Udmurtia fir is relatively rare and grows in its natural range boundary (Fig. 2).

When *Dendrolimus sibiricus* mass outbreaks were active in 1957 in the Nygliksky forest district the growing stock had stand composition with a predominance of fir and Siberian fir, density 0,6-0,7 and was around 120 years old. After *Dendrolimus sibiricus* caterpillar damage in 1957 sufficient part of fir died and its share in forest composition decreased. The Siberian firs attacked by the bark beetle had characteristic streaks of soft resin on the bark and under the bark of the xylophage passages (Fig. 3).

During our surveys more often, forests had relatively young fir trees (Table 2) that obviously recovered after disastrous damages of fir component in the 50-es of XX century.

Table 2. Fir condition in the ussury bark beetle mass outbreaks in Udmurtia

Survey location	Coordinates	Brief inventory characteristics	Mean fir condition category	Polygraphus infestation rate
Yaganskoe forest district, compartment 243, stratum 20	N 56.568266 E 53.093415	10A+P, aged 50-60 years, density 0.6	4.4±0.6	severe
Yaganskoe forest district, compartment 243, stratum 27	N 56.559722 E 53/104718	10A+P, aged 50-60 years, density 0.6	4.0±0.2	severe
Zavyalovskoe forest district, compartment 65, stratum 8	N 56.674093 E 53.320864	7A3P, aged 50 years, density 0.7	3.3±0.3	average
Zavyalovskoe forest district, compartment 72, stratum 31	N 56.696813 E 53.322576	4P3A2L1Ac	3.5±0.8	average
Vavozhskoe forest district	N 56.471379 E 51.531124	6P2A2Ac	2.5±0.3	very poor, there few dead trees killed earlier

Note. A – Abies; P – Picea, Ac – Acer; L – Larix

In the Udmurt territory fir damage by the ussury bark beetle was found in 3 areas (Fig. 4) that proves its rather wide expansion in forests of the republic.

Thus in 1st identified mass outbreaks of the ussury bark beetle and fir *Grosmannia oashimae* in Udmurt forests with Siberian fir share the pest activity resulted in commence of mass fir decline that promotes risk of forest fir component loss in south-east boundary of Siberian fir natural range.

Identification of these invader outbreaks may be an evidence that the ussury bark beetle and the grosmaina carried by it started an active expansion of its secondary areal in fir woods in European Russia. Only special search surveys of forests with fir share in the Urals and North European Russia will enable to find out if the outbreak identified in the Udmurtia is insular or outbreaks began to shape all over from the Tomsk region to the Udmurtia.

Conclusion

The ussury bark beetle and fir *Grosmannia oashimae* invasion is on-going in European Russia, Identification of new outbreaks in Moscow region endangers fir existence in greenery and collection plantations. However, identification was done of first outbreaks in forests with fir share endangers Siberian fir in European part of its natural areal.

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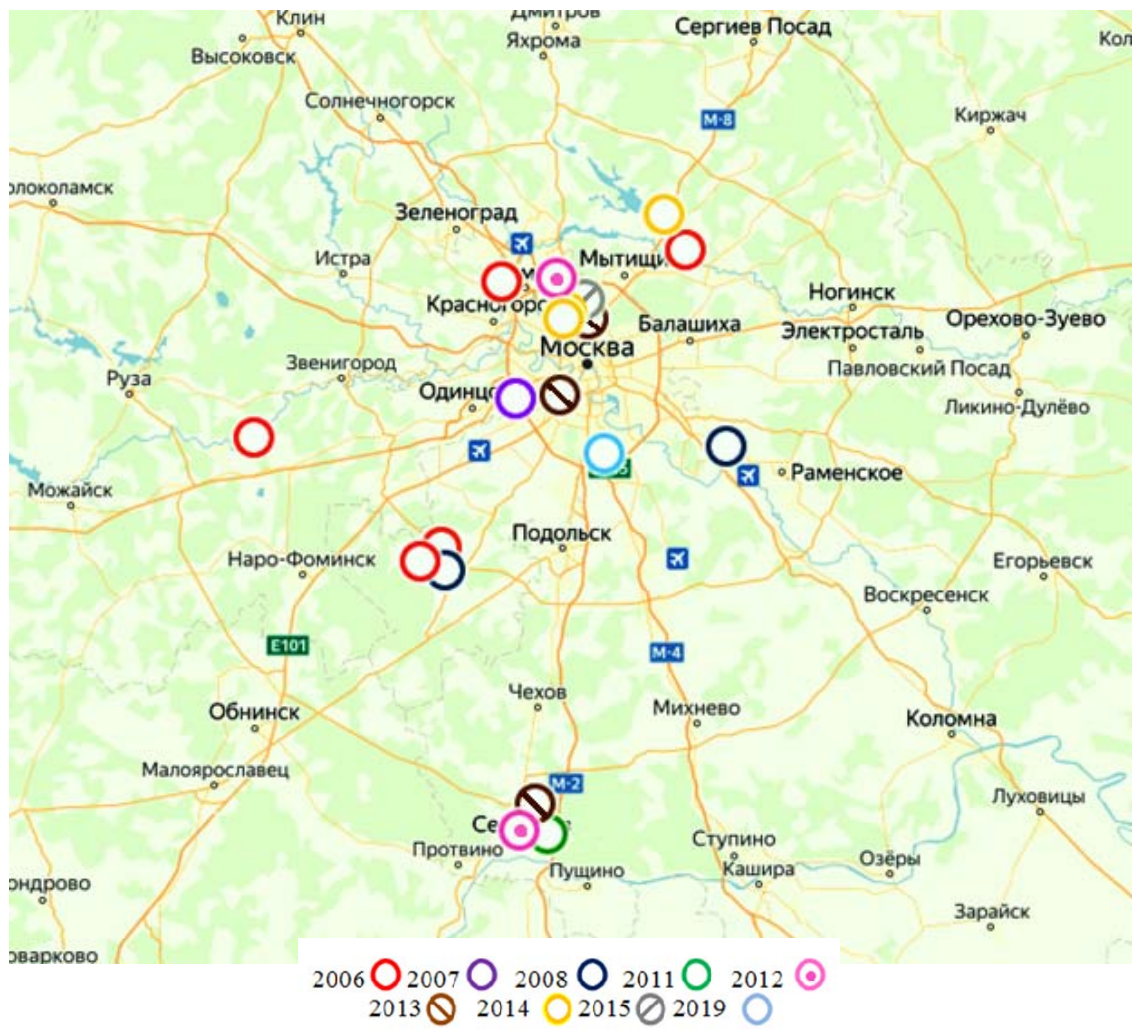
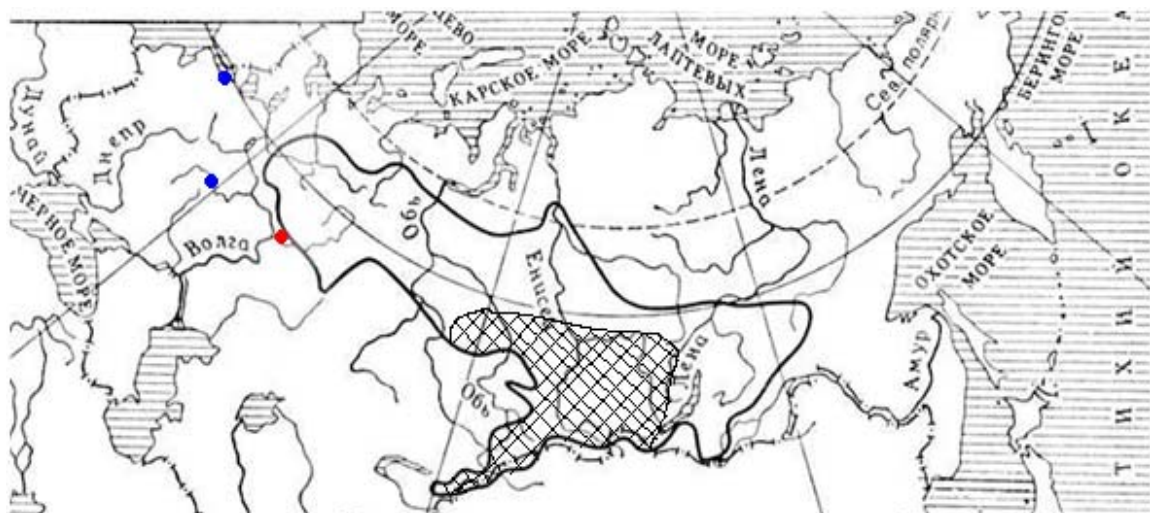


Figure 1. Locations of the ussury bark beetle finds in Moscow and Moscow vicinity



Note: Hatchure – Ussury bark beetle secondary areal in Siberia
 ♦ – identified outbreak in Udmurtia
 ● – identification areas in European Russia

Figure 2. Siberian fir areal (Malyshev, 2008)



Figure 3. Ussury bark beetle galleries on fir stem in the Vavozhskoe forest district

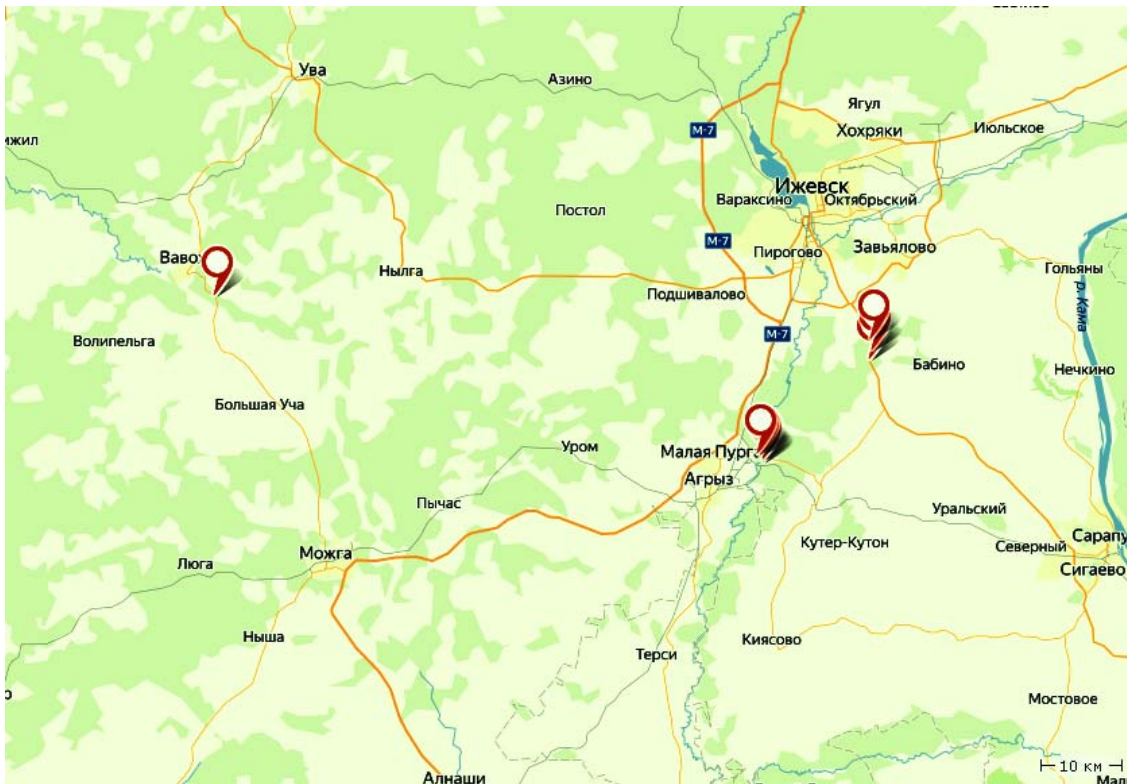


Figure 4. Ussury bark beetle identification locations in the Udmurtia territory

2.6. *Phylonorycter issikii* (Lepidoptera, Gracilliidae) in Moscow

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Липовая моль-пестрянка *Phylonorycter issikii* (Lepidoptera, Gracilliidae) в Москве

Липа *Tilia cordata* Mill., 1768 является широко распространенной лесообразующей породой в России. Площадь лесов, в составе которых она принимает участие, составляет примерно 2,0 млн га.

На территории европейской части России липовая минирующая моль-пестрянка была обнаружена в 1987 г. в окрестностях п. Рамонь (Воронежская область). С этого времени она широко распространилась в лесах и озеленительных посадках липы мелколистной в европейской части России и в Сибири.

Проведено изучение масштабов повреждения листвы лип этим минером в озеленительных посадках Москвы и показана степень изъятия фотосинтезирующей поверхности листвы гусеницами вредителя.

Ключевые слова: липовая минирующая моль-пестрянка, инвазивные организмы, повреждения листвы.

Abstract

Lime leaf miner inhabits all stands of common Linden in the landscaping plantings of Moscow. The study of the degree of population of Linden in different urban planning elements. It is established that the greatest damage is caused by the pest to trees growing in forest or close to forest conditions. Less damaged foliage on trees in squares and in protective strips, where the trees are most strongly and evenly lit. This confirms the opinion that the lime leaf miner prefers to settle in more shaded conditions.

The level of removal of the photosynthetic surface of foliage in the crowns during the study did not exceed 30% everywhere, which may indicate that the moth caused generally quite weak damage to the crowns of trees and trees.

Key words: *Phylonorycter issikii*, lime, damaged foliage, landscaping planting.

Introduction

Lime tree *Tilia cordata* Mill., 1768 (or linden tree) is a wide spread forest forming species in Russia. Area of forests with linden share is around 2,0 million ha.

In European Russia lime leaf miner was in 1987 in suburbs of Ramon township (Voronezhskaya region) when up to 70% of leaves were already damaged (Kozlov, 1991), This author also pointed out that the moth was not found in urban plantations in Voronezh located 40 km south of Ramon township. By 1991 lime leaf miner was observed in Samara and Ufa cities (Kozlov, 1991; Kozlov, Koricheva, 1991) as well in the Uljanovsk region. In 1992 the miner was found in Ryazansk and Leningrad regions (Mischenko, Zolotukhin, 2003). In 1995 lime leaf miner was identified in the Yaroslavskaya region (Efremova, Mischenko, 2003) in 1999 species *Ph. issikii* was found in the Udmurdszkaya Republic (Ermolaev, Motoshkova, 2008). In 2000 the miner was found in the Foresttechnical Academy park in Saint Petersburg (Mischenko, Zolotukhin, 2003).

By 2002 lime leaf miner affected linden trees in Saratovsk and Penzensk regions and Tatarstan Republic as well. In the same year low populations of miner were found in the Nizhegorod region in the “Kerzhensky” reserve territory (Anufriev, Baynov, 2016) and in Yoshkar-Ola city (Ermolaev, Motoshkova, 2008). In 2003 the moth was found in the Kaliningrad region (Gninenko, Kozlova, 2008) and in Belgorod (Struchaev, 2011) in 2004 in Tusk (Baryshnikova, Bolshakov, 2004), Tver and Kaluga regions in 2005 the miner was identified in the Smolenskaya region (Shmytova, 2005), Tumen and Kurgan towns as well. In 2008 *Ph. issikii* caterpillars were caught in a light trap near Lash-Taijab village in the Yalchicksky district of the Chuvashia Republic (Lastukhin, 2009). Same year the miner was found in the Central Siberian Botanical Garden arboretum of the Russian Academy of Science Siberian Branch in Novosibirsk (Kirichenko *et al.*, 2009). Meanwhile leaf share with mines did not exceed 10%. In 2010 lime leaf miner sufficient populations were found in the arboretum of the M. Lisavenko Siberian Horticulture Research Institute (Barnaul). In 2012 individual small-leaf linden damage was observed in the Kuzedevskay linden groove (Kemerovo region) (Kirichenko, 2013).

Bednova O. and Belov D. point out that for the 1st time in Moscow (Kuntsevsky forest park, Sokolniki park and a square in the Lublinskaya street the miner was observed already in 1985. It is noteworthy that in the Voronezh region M. Kozlov found the moth at its high population levels while O. Bednova and D. Belov reported identification of single mines in 1985 and these authors wrote “in the following years the number of its identification locations as well as lime leaf miner population grew gradually”.

Material and methods

Tilia cordata Mill. and *Tilia platyphyllos* Scop. leaf blades affected by *Ph. issikii* caterpillars were collected in Moscow and Moscow region greenery plantations during 2018-2019 field seasons.

Linden condition studies were conducted in plantations in various urban planning elements (squares, parks, linear street plantations etc.) The material col-

lected in each record plot was herborized and tagged using classical leaf blade drying operations (Forman, Breedson, 1995).

In each of 8 sample plots established for stationary studies 10 model linden trees were selected by random sampling and lower branch leaves (up to 2 m high) in period of the 2nd generation caterpillar completion.

Then all collected leaves were dried in a botanical press. Then all leaves with mines were scanned with Canon Pixma MP230 scanner with fixed 300 dpi resolution. To estimate area of both a leaf itself and *Ph. issikii* caterpillar damage the weight method was applied. Resulting leaf images were printed with printer on uniformly thick A4 paper and clipped along the profiles of leaf plate and damages on it. Then its mass was weighted with high accuracy analytical scales "SE 224-S SARTOGOSM" with a special precision class under GOST 53228-2008. At the same time an 85 sm² (9,2x9,2 sm) quadrate of similar paper was cut and its mass weighted (Tretjakov, 1990). Area of a studied leaf and lime leaf miner mines was calculated using the following formula:

$$S = \frac{a \times C}{b}$$

where:

a – leaf profile mass, mg;

b – paper quadrate mass, mg;

C – paper quadrate area, sm²

Thus, each collected leaf area and total area of mines on leaf plates were estimated.

To estimate pest damage impact rate on affected tree, condition a specially developed scale of leaves miner damage categories was applied (Table 1).

Table 1. Scale of *Ph. Issikii* lime leaf miner damage categories

Damage category	Feature
I	Low damage of linden leaves. Pest mine affected area is from 1 to 25 % of total leaf area
II	Average damage of linden leaves. Pest mine affected area is from 26 to 50 % of total leaf area
III	Severe damage of linden leaves. Pest mine affected area is from 51 to 75 % of total leaf area
IV	Very severe damage of linden leaves. Pest mine affected area is from 76 to 100 % of total leaf area

Results and discusion

To study number of mines per a linden leaf and lime leaf miner leaf destruction rate we picked some linden plantation areas in various urban green spaces (Table 2).

In each area lower branch leaves were collected and available mines counted. Finally, it was found that the highest number of mines per leaf was in

the VNIILM park plantations and in the woods of the FED of the RSAU – MTAA (Table 3). In both areas' linden trees grow in rather dense stocking conditions close to natural forest communities.

Table 2. Linden plantations chosen for studies

Urban green spaces	Area	Location coordinates
Parks, arboretums and similar plantations	Educational research and consulting center Forest Experimental Dacha of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy (FED of the RSAU – MTAA)	55.830712 37.616910
	Exhibition of Achievements of National Economy (VDNH)	55.832028 37.515225
	All-Russian Research Institute of Silviculture and Mechanization of Forestry (VNIILM)	56.014619 37.857836
	RAS The Main Botanical garden named after N.V. Tsitsin (MBG)	55.841054 37.601084
Squares	Dzerzhinets str., Pushkino, Moscow region	56.011921 37.862222
Urban linear plantations	Pushkino, Moscow region	56.004676 37.842863
Courtyard plantations	Pushkino, Moscow region	1)56.015183; 37.848117 2)56.009251; 37.847524 3)56.008069; 37.846229 4)56.008228; 37.844730 5)56.004751; 37.843947
Shelterbelt	micro-district “Novoe Pushkino”, Pushkino, Moscow region	56.027529 37.863815

Table 3. Mine occurrence per linden leaf at various survey points in 2018/2019

Survey point name	Average mine number per leaf, pcs.	
	2018	2019
FED of the RSAU – MTAA	6.02±0.01	13.74±0.4
VDNH	3.87±0.00	0.52±0.02
VNIILM arboretum	10.09±0.01	8.08±0.14
MBG	1.35±0.00	0.65±0.03
Squares	0.65±0.00	0.37±0.03
Urban linear plantations	8.04±0.01	1.50±0.07
Courtyard plantations	1.78±0.00	0.87±0.04
Shelterbelt	0.65±0.00	0.10±0.01

The lowest mine occurrence rate was observed in squares and on shelterbelt linden trees where trees grow un linear plantations exposed to sufficient light not overshadowed by other trees. In urban linear street plantations mine number per leaf is higher than in squares and shelterbelts. It is because greenery plantations along streets are more or less overshadowed with buildings that

sometimes are rather high. Plantations in courtyards, VDNH and the MBG collections keep mid-position according to mine number per leaf.

Measurements of leaf and mine area show that leaf plate damage rate in 2019 was slightly higher compared to 2018 (Table 4).

In 2018 the most severe leaf damage was in the VDNH territory when moth caterpillars destructed slightly over 10% of leaf surface.

In 2019 the most severe leaf damage was in the VDNH territory as well however damage rate was 3 times higher than in 2018.

Over 20% of a leaf plate was destructed on linden trees at Forest experiment summer cottage.

However overall linden crown defoliation level by lime leaf miner was relatively low and did not exceed 30% (Table 4). Such damage is not crucial for linden and it recovers easily. The previous year defoliation level in the VDNH territory was 10.9%. Such crown defoliation cannot trigger visible tree weakness.

Table 4. Share of linden leaf photosynthesizing surface severed by lime leaf miner in 2018-2019

Survey point name	2018			2019		
	Leaf area, sm ²	Damage area, sm ²	Damage area, sm ²	Leaf area, sm ²	Damage area, sm ²	Damage area, %
FED of the RSAU – MTAA	47.28±2.39	1.92±0.21	4.06	54.71±2.25	11.84±0.70	21.63
VDNH	40.63±2.52	4.43±0.62	10.91	41.79±2.42	12.76±0.90	30.53
VNIILM arboretum	33.58±1.93	1.30±0.12	3.86	36.27±1.66	1.68±0.13	4.64
MBG	35.37±1.40	1.46±0.17	4.13	32.22±1.81	1.67±0.14	5.18
Squares	47.39±2.10	2.62±0.30	5.53	35.01±1.49	2.13±0.17	6.09
Urban linear plantations	43.44±2.13	0.96±0.09	2.22	35.51±1.41	2.35±0.22	6.62
Courtyard plantations	40.24±1.36	1.00±0.09	2.49	36.64±2.19	1.03±0.05	2.80
Shelterbelt	48.62±1.86	0.74±0.08	1.52	36.70±1.78	1.64±0.13	4.48

Mine number was counted and linden undergrowth defoliation rate studies in the FED of the RSAU – MTAA. On average there were around 4 mines per leaf on most undergrowth plants (Table 5).

Table 5. Mine number per leaf of linden undergrowth in compartment 7 in the FED of the RSAU – MTAA

№ of count area	Mine number, pcs.		
	Average per 1 leaf	mode	Maximum mine number
1	3.44±0.60	5	7
2	3.44±0.50	3	7
3	3.92±0.45	4	7
4	4.33±0.30	4	7
5	4.50±0.25	4	7

The conducted survey showed that all small-leaf linden undergrowth plants in the FED of the RSAU – MTAA woods were infested with the linden miner. Average mine number per leaf varies from 3.44 to 4.5 which proves high foliage infestation intensity.

The conducted studies showed that average area of 1 linden leaf in the FED of the RSAU – MTAA undergrowth was $44.84 \pm 1.52 \text{ sm}^2$ and average area of 1 mine was $1.32 \pm 0.21 \text{ sm}^2$.

This data shows that average undergrowth leaf and average mine areas are practically equal to adult tree ones.

During the studies undergrowth defoliation level was around 10-13% that as for adult trees does not sufficiently affect plant condition (Table 6).

Table 6. Lime leaf miner defoliation rate of undergrowth

№ of count area	Average mine number per 1 leaf, pcs.	Leaf area severed by the miner, sm^2	Defoliation rate, %
1	3.44	4.54	10.12
2	3.44	4.54	10.12
3	3.92	5.17	11.53
4	4.33	5.75	12.82
5	4.5	5.95	13.27

Conclusion

Study of small-leaf linden foliage colonization with lime leaf miner caterpillars shows that the pest most severely damage trees growing in forest or close to forest conditions. Less affected is tree foliage in squares and shelterbelts where trees are exposed to strong or uniform light. It proves the stated opinion that lime leaf miner prefers infestations in shadier conditions.

During the studies crown foliage photosynthesizing surface destruction level was under 30% that may be an indicator of rather poor tree crown and undergrowth damage.

Obviously, the lime leaf miner despite long-term damage everywhere in its secondary areal poorly affects tree condition. As a result, there is no need to plan and conduct operations to protect linden against this pest.

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CHAPTER 3

DENDROPHILOUS INVADERS IN SIBERIA AND RUSSIAN FAR EAST

Siberia with its vast taiga tracts for a long time was not aware of foreign organism invasions. Record losses in European Russian forests caused by such dendrophilous invaders as Dutch elm disease (agents *Ophiostoma ulmi* and *O. novo-ulmi*), American white moth *Hyphantria cunea*, oak mildew (agent *Microsphaera alphitoides*) and some others had not affected Siberian forests.

However the situation changed fundamentally in late XX century. *Polygraphus proximus* and carried by it *Grosmannia oashimae* penetrated Siberian taiga forests from Far East forests. Another Far east forest resident – linden miner moth came to South Siberian linden woods from west. Recently *Ips amitinus* invaded the taiga forests and already became an evident pest.

Even robinia-related leaf gall midge managed to invade greenery plantation in Far East cities where robinia is a rather rare introducent.

3.1. Robinia gall midge *Obolodiplosis robiniea* in the island of Sakhalin

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Белоакациевая листовая галлица *Obolodiplosis robiniea* на Сахалине

Белоакациевая листовая галлица была впервые обнаружена в озеленительных посадках в г. Южно-Сахалинске, где она нанесла существенный вред белой акации. Показано ее распространение в городе и численность особей.

Ключевые слова: белоакациевая листовая галлица, Сахалин, озеленительные посадки.

Abstract

Robinia gall midge was first detected in landscaping plantings of *Robinia pseudoacacia* in the city of Yuzhno-Sakhalinsk. Apparently, it appeared here in the second half of 2009, but then it was small and it was not identified. Only in 2010 the number of phytophages increased and it was discovered.

Key words: *Obolodiplosis robiniea*, the island of Sakhalin, *Robinia pseudoacacia*.

Introduction

Robinia gall midge *Obolodiplosis robiniea* Hald., 1847 (Diptera: Cecidomyiidae) after move from North America to Asia is rather widely spread in Japan, China and Korea (Kodoi et al., 2003; Uechi et al. 2005; Yang Zhong-Qi et al., 2006). For the first time in Russian Far East it was found in 2005 in south Primorsky territory. At the moment the phytophage have already infested sufficient territory in the Primorje and its range in the Fa East is extending. Special surveys in 2008 enabled identification of the gall midge everywhere in Vladivostok, Ussurijsk in Pogranichny and Zarubino townships right in south Primorsky territory (Gninenko, Yurchenko, 2009). Gall midge find in the Khasansky district proves the idea that it has already infested the whole North Korea territory. Thus, at the moment the gall midge has shaped a rather vast areal over the short period since its 1st identification till now.

Material and methods

This work has been done in greenery plantations in Uzhno-Sakhalinsk. Robinia plantation survey was a visual inspection of all identified trees. The whole crown was inspected however more thoroughly its lower and middle parts. Galls are easily found visually so its identification during these surveys is not difficult.

During the survey we cut some branches for laboratory count of number of leaves with galls, galls per leaf and larvae and pupae per gall. At the same time, we identified if larvae and pupae were infected with parasitoids.

Results and discussion

In 2009 we did not find it in the Sakhalin but the 2nd survey in early September 2010 identified this phytophage in Uzhno-Sakhalinsk. It implies that the gall midge likely invaded Uzhno-Sakhalinsk in 2009 but its population was extremely low to enable its identification and only in 2010 the population grew drastically and it was found.

Robinia is not a popular tree species in urban greenery. Its trees are quite rare in urban plantations and do not shape numerous groups anywhere. However, in 2010 the gall was available everywhere in urban greenery plantations (Table 1) where robinia grows.

Gall number was very high usually most of simple leaves on 1 compound leaf had galls (Table 2).

Table 1. Robinia gall midge availability in Uzhno-Sakhalinsk

Survey location	Survey results in 2009		Survey results in 2010	
	Number of inspected trees	Gall infested tree share, %	Number of inspected trees	Gall infested tree share, %
Square around the Drama theater	10	0.0	10	50.0
Khabarovskaya str.	15	0.0	14	100.0
Pobedy avenue	21	0.0	21	100.0

Number of galls per 1 simple leaf varied from 1 to 5 but more often were 1 or 2 galls per leaf while 4 or 5 galls per simple leaf were quite rare (Table 3).

Table 2. Share of simple leaves with galls

Leaf collection area	Total number of compound leaves, pcs.	Average number of simple leaves per compound leaf, pcs.	Average number of simple leaves with galls, pcs.	Share of simple leaves with galls, %
Mira avenue	13	17.30±0.17	11.20±1.25	64.74
Khabarovskaya str.	18	19.72±0.65	12.33±1.18	64.55
Pobedy avenue	13	19.70±1.08	9.62±1.25	48.83

Galls are located at various distances from leaf base. Most of them present a leaf edge turned down and just singular galls are formed with a turned-up leaf edge. Gall tissues compared to unaffected leaf parts have paler colour and its structure is thickened swollen tissue of a leaf plate.

Table 3. Gall number per 1 simple leaf

Leaf collection area	Counted gall number, pcs.	Leaf share (%) wuth gall number				
		1	2	3	4	5
Mira avenue	136	50.74	38.24	10.28	0.74	0.00
Khabarovskaya str.	236	37.71	42.37	13.56	4.24	2.12
Pobedy avenue	118	60.17	25.44	10.17	2.54	1.69

More often galls occur on young leaflets in shoot tops. They were more numerous on younger leaves. It is quite natural with regard to sharp gall population growth over 1 season. It relates to the fact that in early summer season the phytophage population level was low and during summer its population grew which by autumn enabled infestation of many young leaves while leaves shaped in early summer were inaccessible for the gall oviposit.

More often there was 1 larva in a gall. However often there were more than 1 larva in galls and sometimes gall dissection found not a single larva. The most larva number per gall 5 we observed in 2010.

Average larva number per 1 gall varies. We could not find any link between gall number on 1 simple leaf and larva number in a gall (Table 4).

In late September survey we could not find any parasitoid infected larva. *Platygaster robiniae* Buhl et Duso (Hymenoptera, Platygasteridae) first found in 2007 and described as a new for science species (Buhl, Duso, 2008; Wermelinger, Skuhrava 2007) at the moment has not been identified in the Sakhalin.

Table 4. Average larva number in a gall

Leaf collection area	Gall number on a simple leaf, pcs.	Average larva number in a gall, pcs.
Khabarovskaya str.	1	1.40±0.53
	2	1.73±0.44
	3	1.90±0.49
	4	1.76±0.44
	5	1.50±0.55
Pobedy avenue	1	1.49±0.67
	2	1.56±0.55
	3	1.42±0.45
	4	1.64±0.54
	5	2.11±0.33
Mira avenue	1	1.46±0.63
	2	1.28±0.72
	3	1.08±0.77
	4	1.08±0.67

Conclusion

Conducted surveys for the 1st time found robinia gall midge availability in the south of Sakhalin. Obviously, it came there in 2nd half of 2009 but then it was few so we could not find it. Just in 2010 the phytophage population grew and it was identified.

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3.2. *Polygraphus proximus* - invasion of Siberia

Polygraphus proximus occurrence in Siberian fir forests was a kind of dramatic. First reports on adverse condition of fir woods in the Kemerovaskaya region started since the end of XX century. However originally it did not raise any concern among forest pathologists since *Xylechinus pilosus* (Ratzeburg, 1837) (Coleoptera, Curculionidae) was named as an “originator” of this event. True reason of fir forest mortality was found only several years after this wrong statement.

But time was lost irreversibly and the pest commenced wide scale attack of Siberian taiga fir woods.

3.2.1. Four-eyed fir bark beetle *Polygraphus proximus* Blandford, 1894 (Coleoptera, Curculionidae: Scolytinae) in Western Siberia: review of a ten years of research of the invasion

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Уссурийский полиграф *Polygraphus proximus* Blandford, 1894 (Coleoptera, Curculionidae: Scolytinae) в Западной Сибири: обзор результатов десятилетнего изучения

В статье приведены результаты десятилетних исследований агрессивного чужеродного короеда – уссурийского полиграфа *Polygraphus proximus* в Западносибирском регионе инвазии. Дана характеристика общего распространения в регионе, основных местообитаний, биологии, сезонного развития, связей с кормовыми растениями и естественными врагами, демографических особенностей инвайдера, динамики отмирания деревьев в поврежденных насаждениях пихты сибирской и комплексного воздействия на компоненты темнохвойных экосистем.

Ключевые слова: уссурийский полиграф, Западная Сибирь, пихта, инвазия, энтомофаги и патогены.

Abstract

The results of a ten years study of an aggressive alien bark beetle *Polygraphus proximus* in the Western Siberian invasion region are presented in the article. Its distribution, basic habitats, biology, seasonal development, trophic links, demographic feature, dynamics of tree mortality in the Siberian fir stands, and complex effect on the components of dark coniferous ecosystems are established.

Key words: *Polygraphus proximus*, Western Siberia, fir, natural enemies and fungal pathogens.

Introduction

Four-eyed fir bark beetle (abbreviation FFBB) *Polygraphus proximus* Blandford, 1894 is the invasive species of Far Eastern origin that introduced into South Siberia and European part of Russia. FFBB has become one of the most aggressive pests in term of the recent large-scale degradation of Siberian fir forests (Krivets *et al.*, 2013).

Presumably, the primary donor region of the invasion of FFBB was the Khabarovsk Krai, the invasion corridor was the Trans-Siberian Railway. The primary recipients of the invasion were fir stands adjacent to the Trans-Siberian Railway in the Krasnoyarsk Krai and the Kemerovo Region (Baranchikov, 2010; Gninenko and Klyukin, 2011), from where the bark beetle independently settled in adjacent regions. Such a way of expansion of new territory is confirmed by molecular genetic analysis of regional bark beetle populations (Kononov *et al.*, 2016).

In connection with the hidden intrusion in the Siberian dark-coniferous ecosystems after an accidental drift with timber, FFBB has been identified in the territory of Southern Siberia only at the end of the first decade of this century (Baranchikov, 2010; Baranchikov *et al.*, 2011). The first 30–40 years after emergence of FFBB its population underwent adaptation under new conditions, and only at the beginning of the 2000s the outbreak foci were formed (Baranchikov *et al.*, 2014).

In the coniferous forests of Siberia, FFBB was first identified in the Tomsk Region in 2008 (Baranchikov and Krivets, 2010), then in 2009 in the Krasnoyarsk Krai (Baranchikov *et al.*, 2010), and in 2010 in the Kemerovo Region (Gninenko and Klyukin, 2011). Currently, the invasive area of FFBB in Siberia covers the territory of 8 administrative subjects of the Russian Federation in Siberia (Irkutsk, Kemerovo, Tomsk, and Novosibirsk Region's, Altai and Krasnoyarsk Krai, Republics of Khakassiya and Altai) (Krivets *et al.*, 2015a; Bystrov and Antonov, 2019). This pest of Siberian fir leads to large economic losses and negative environmental consequences. Recently, its value has been increasing due to the weakening of fir forests as a result of the new pandemic outbreak of Siberian moth *Dendrolimus sibiricus* Tschetv.

The invasion of FFBB was comprehensively studied by Russian scientists. Data were obtained on the biology and ecology of *P. proximus* in the secondary area, including the bark beetle lifecycle and mating behavior, relationships with the new host plant and biota in general, association with phytopathogenic fungi, seasonal development, population characteristics of the invader and its effect on various components of Siberian forest ecosystems. The most important results of these studies in Western Siberia, one of the regions of invasion FFBB, are given in this review.

Distribution and habitats of FFBB in Western Siberia

By 2019, in Western Siberia, FFBB was found in the dark coniferous forests of the Tomsk, Kemerovo, Novosibirsk Regions, Altai Krai and the Altai Republic.

In secondary area, it moves towards its host tree species up to the extreme borders where the latter grows, and occurs there in the territory with extreme geographic coordinates N 59°00'21.7", E 080°54'10.5" in the north, N 51°03'36.9", E 087°24'44.2" in the south, N 57°15'31.2", E 088°23'21.8" in the east, N 58°59'00.9", E 080°39'21.6 in the west, from the southern part of middle taiga in the plain to the upper limit of the fir distribution in the Altai mountains (Krivets *et al.*, 2015a; Krivets *et al.*, 2018). On the West Siberian Plain, it was discovered in the taiga ecosystems at the average altitude of 100–200 m a.s.l. In mountainous areas, its habitats are identified at an altitude of 300 to 1490 m a.s.l. (Kerchev, 2014a).

In the Tomsk Region, FFBB has now spread over almost the entire territory, except the north, in the subzone subtaiga, southern taiga and middle taiga. In the Kemerovo Region, it is found both in the forests of the southeastern part of the West Siberian Plain, and in the mountain forests of the Kuznetsk Alatau and Mountain Shoria. In the Novosibirsk Region, area of FFBB is located in the extreme eastern part, from the southern taiga lowland forests in the north to the low-mountain forests of the Prislairye in the south of the region. In the Altai Krai, FFBB is distributed in the eastern and southeastern parts of the region, in the forests of the Salair Ridge and Altai foothills. In the Altai Republic, it was identified in the mountain forests of the north-eastern part of the region.

The habitats of FFBB in Western Siberia are pure fir forests, polydominant fir-Siberian pine-spruce forests with an admixture of aspen and birch, with different participation and age of fir in the stands, low-mountain dark coniferous forests, mountain-taiga Siberian pine-fir forests, Siberian-pine forests with fir undergrowth near villages, and also fir plantations in settlements. The highest abundance and frequency of FFBB is observed in monotonous fir stands, but it is, however, able to increase its numbers, allowing it to attack externally healthy trees, even in stands where firs are found as solitary trees (Kerchev, 2014a).

Biology and seasonal development of FFBB

FFBB is monogynous species (Kerchev, 2014b). Its family is formed by one male and one female. Both male and female can gnaw entry hole in the bark. The female is attracted to the pheromone secreted by the male. Laboratory and field observations showed that aggregation pheromone can be secreted by male and female of FFBB (Kerchev and Pousheva, 2016; Kerchev, 2019a). The behavior of bark beetles is determined not only by semiochemicals. Acoustic signals in *P. proximus* produced during stress, rivalry behavior, and courtship

chirps are distinguishable according to temporal parameters. During courtship males produce two types of chirps. The first type was produced in all three contexts mentioned earlier. The second chirp type was registered only in male-female interactions just before copulation. Pre-copulation signals produced by rubbing of the tibia against the elytral margin, were registered for the first time in a bark beetle (Kerchev, 2019b). After mating, the female makes two or, somewhat less frequently, one, three or four egg galleries (Fig. 1). On standing trees and at a low colony density of bark beetle, the galleries have a predominantly transverse direction, but at high density they are located in different directions in order to reduce intraspecific competition. The mean fecundity of female is 45 ± 15 eggs.

In Western Siberia, under favorable conditions, FFBB can form two generations. In laboratory conditions, at a temperature 22°C and humidity 85% it takes about 50 days to fully develop one generation. In natural conditions, wintering takes place under the bark of the tree on which the development took place. The adults mostly winter, fewer larvae and pupae.

The general scheme of the seasonal development of the polygraph is shown in the Table 1.

Table 1. Seasonal occurrence of the stages of development of FFBB under fir bark in Siberia (Baranchikov *et al.*, 2012)

Stage	Months					
	April	May	June	July	August	September
Adult	+++	+++	+	+	++	+++
Pupa	◆	◆	◆◆	◆◆◆	◆◆	◆
Larva	–	–	---	–	–	–
Egg		●●●	●	●		

The onset of spring dispersal flight of FFBB depends on microclimatic habitat conditions and its duration and intensity is determined by weather conditions in this period for each particular year. The most favorable days for the dispersal flight of beetles are those with sunny and calm weather and air temperature above $+15^{\circ}\text{C}$. Such negative factors as wind, cloudiness, and precipitation may temporarily interrupt the dispersal flight of beetles and, in the whole, prolong or shift its dates. For example, in 2008, FFBB in Tomsk Region was captured by pheromone traps from mid-May to early of June (Krivets, 2012). This bursting flight of beetles is explained by the low precipitation rate during the described period and the high temperature. From May 7 until the end of the month, there were 12 days without precipitation and the daytime temperature exceeding $+15^{\circ}\text{C}$. For comparison, data of 2013 show that the intense swarming of beetles began much later owing to the unfavorable weather conditions (Kerchev, 2014a). In May of this year, only two days were marked by suitable weather, however there were still solitary burrowing beetles that used this time period to fly and find a tree for colonization. Intense flight of FFBB began only at the end

of the first ten days of June, when the days became warm enough and sunny, and lasted for several weeks. For this reason, if years with a warm spring are marked by development of the second generation in August, this period in 2013 within the fir forest of Tomsk Region was characterized by the intense pupation of larvae from the first generation, which points to the presence of phenological shift in the development of families by whole month.

Host plants of FFBB in Western Siberia

In the native area in the Russian Far East, main host plants of FFBB are aboriginal species of the genus *Abies*: *A. nephrolepis* (Trautv. ex Maxim.) Maxim., *A. holophylla* Maxim., and *A. sachalinensis* Mast. Less commonly, it colonized the Far Eastern species of coniferous from genera *Pinus*, *Picea*, *Larix*, and *Tsuga* (Kurentzov, 1941; Krivolutskaya, 1958, 1973, 1996).

The main host of FFBB in Siberia is *Abies sibirica* Ledeb. According to the laboratory experiment performed in 2011 when the logs wood of such coniferous species as Siberian pine *Pinus sibirica* Du Tour, Siberian spruce *Picea obovata* Ledeb., and Siberian larch *Larix sibirica* Ledeb. were populated by beetles, it was revealed that these trees can be colonized by FFBB, which is able to feed on these plants and produce prolific offspring. The most favorable for the development of FFBB, after Siberian fir, is Siberian larch. The least favorable tree for FFBB nutrition is Siberian pine (Kerchev, 2012a).

During the field studies carried out in 2012 within in the outbreak focus of FFBB in Tomsk Region, sporadic colonies of this invader were found on wind-fallen tree of Siberian spruce and on large storm-damaged branches and the bole of a dying tree of Siberian pine, as well as on a storm-damaged branch of Scotch pine *Pinus sylvestris* L. (Kerchev, 2014a).

Phytopathogenic fungal associates of FFBB in Western Siberia

From the Far East to the invasion areas in Siberia FFBB brought ophiostomatoid fungi that infect the vascular tissues of conifers and facilitate the colonization of living trees by the pest (Pashenova *et al.*, 2012).

In Western Siberia, the complex of ophiostomatoid fungi found on Siberian fir trees inhabited by FFBB includes species such as *Grosmannia aoshimae* (Ohtaka et Masuya) Mas. et Yamaoka, *Graphilbum microcarpum* Yamaoka et Masuya, *Gra. rectangulosporium* Ohtaka, Masuya et Yamaoka, *Ophiostoma nikkoense* Yamaoka et Masuya, *O. picea* (Munch) H. and P. Syd., and *O. subalpinum* Ohtaka et Masuya (Pashenova *et al.*, 2018). The highest frequency of occurrence (17–90%) and phytopathogenic activity is characterized by the fungus *G. aoshimae*. This species is the main and specific associate of FFBB. Due to the widespread distribution and high frequency of occurrence in invasive populations of FFBB, it is *G. aoshimae* that claims to be the most dangerous phytopathogen in the new area of the bark beetle. *Gra. microcarpum*, *Gra. rectangulosporium* and *O. subalpinum* are also constant components of the

complex of ophiostomatoid fungi distributed by the FFBB in the invasive area (Pashenova *et al.*, 2018).

Natural enemies and fungal pathogens of FFBB in Western Siberia

Now, FFBB established stable relationships with predatory and parasitic insects and entomopathogenic fungi in its new habitats in Siberia.

In Western Siberia, in the galleries of FFBB, there have been found 27 species of predatory insects (Kerchev, 2012b; Krivets and Kerchev, 2015, 2016; Krivosheina *et al.*, 2018): Coleoptera, such as *Thanasimus femoralis* (Zett.), *T. formicarius* (L.) (Cleridae), *Lasconotus jelskii* (Wank.) (Colydiidae), *Plegaderus vulneratus* (Panz.), *Paromalus parallelepipedus* (Hbst.) (Histeridae), *Leptophloeus alternans* (Er.) (Laemophloeidae), *Epuraea longipennis* Sjöberg, *E. pallescens* (Steph.), *Glischrochilus quadripunctatus* (L.) (Nitidulidae), *Rhizophagus dispar* (Pk.) (Monotomidae), *Nudobius lentus* (Grav.), *Placusa depressa* Maekl., *Phloeopora testacea* (Mannh.), *Phloeonomus lapponicus* Zett. (Staphylinidae), *Corticeus fraxini* (Kug.), *C. suturalis* (Pk.), *C. linearis* (F.) (Tenebrionidae), and *Denticollis varians* (Germ.) (Elateridae); Diptera, such as *Medetera penicillata* Neg., *M. excellens* Frey, *M. pinicola* (Kow.) (Dolichopodidae), *Xylophagus cinctus* Deg. (Xylophagidae); *Lonchaea collini* Hack. (Lonchaeidae), and *Toxoneura ephippium* (Zett.) (Pallopteridae); the bug *Scoloposcelis pulchella* Zett. (Hemiptera, Anthocoridae); the ants *Formica rufa* L. and *Lasius niger* L. (Hymenoptera, Formicidae).

The most abundant of the predators is *M. penicillata* (Fig. 2) which most likely inhabited Siberia as a result of a joint invasion with FFBB from the Russian Far East (Kerchev and Negrobov, 2012; Kerchev, 2013). This species is found in 50% of the nests of the four-eyed fir bark beetle and can kill from 30 to 75% of its offspring.

Two species of Hymenoptera (Pteromalidae) parasitize on the larvae of FFBB: *Dinotiscus eupterus* (Walk.) and *Roptrocerus mirus* (Walk.) in Western Siberia. Only *D. eupterus* reaches high numbers – up to 6 larvae in the host family, consuming approximately 13% of its larvae in particular years.

The population of FFBB from Western Siberia was examined for the presence of insect pathogenic ascomycetes (Kerchev *et al.*, 2017a). Four species of insect pathogenic fungi, *Beauveria bassiana*, *B. pseudobassiana*, *Lecanicillium attenuatum* and *Isaria farinosa*, were detected basing on morphological characteristics and/or sequencing data. Bioassays using conidia of fungi *B. bassiana* and *I. farinosa* from collection of ISEA SB RAS were performed against adults of FFBB under different temperatures (15 °C and 5 °C) and 100% RH. The mortality of FFBB reached 80–100% within 45 days. The fungus *B. bassiana* was more effective at the 15 °C as compared to 5 °C. Contrarily, *I. farinosa* was more virulent at 5 °C. The most prominent part in the reduction of the number of FFBB is played by *B. bassiana* and *Isaria farinosa*. The fre-

quency of occurrence of *B. bassiana* among other fungal infections in samples picked at the outbreak foci of the four-eyed fir bark beetle is almost 90%. The mortality of FFBB caused by fungal pathogens in declining foci in some trees may reach 41.6%, mainly its larvae (Krivets and Kerchev, 2015).

It has been established that in Western Siberia at least 4 species of entomoparasitic nematodes from the genera *Protorhabditis* (Osche) Doug (Rhabditidae), *Rhabditolaimus* Fuchs and *Pristionchus* Kreis (Diplogasteridae), and *Sychnotylenchus* Rühm (Anguinidae) are associated with FFBB. Nematode infection of the genera *Sychnotylenchus* and *Pristionchus* leads to immunosuppression of the hosts, which causes quantitative and qualitative changes in the immune system of the infected insect and its susceptibility to *Beauveria bassiana* (Kerchev *et al.*, 2017b).

Demographic characteristics of FFBB in Western Siberia

The values of demographic characteristics of FFBB vary greatly between regions of invasion and in the stands within each region (Table 2). These differences may be due to the different duration of the outbreak foci, their heterogeneous forest pathological conditions, as well as differences in the natural and climatic conditions of the regions and weather features during the development of the populations.

Table 2. Absolute minimum and maximum values of demographic features of FFBB per tree registered in different regions in Western Siberia

Feature	Regions			
	Tomsk Region	Novosibirsk Region	Kemerovo Region	Republic of Altai
Occurrence (% colonized trees in the stand)	76.2-100	26.7-45.8	4.6-100	1.7-36.9
Number of families (per dm ²)	2.2-6.5	1.9-6.3	2.1-4.8	3.7-15.0
Number of bark beetle of parent generation (per tree)	5136-26190	1108-8208	–	712-6269
Number of bark beetle of daughter generation (per dm ²)	37-90	1.8-30	7-70	8.8-64.7
Propagation energy	2.7-13.4	0.9-5.5	1.2-9.7	2.5-4.8

Dynamics of the state of Siberian fir tree stands damaged by FFBB in Tomsk Region

In Tomsk Region the earliest cases of death of trees of *Abies sibirica* Ledeb. from FFBB are dated in 2000, according to dendrochronological data. It is supposed that penetration of an invader on the territory of Tomsk Region happened in the mid 1990s (Demidko, 2014). Since 2010, unusually strong drying of a fir in the south of Tomsk Region was noted by forest pathologists of Tomsk Forest Health Centre (Krivets *et al.*, 2011).

In 2012–2017 the studies were carried out in southern taiga forests in Tomsk Region (southeast of the West Siberian Plain) suffered from invasion of FFBB (Bisirova and Krivets, 2018). State dynamics of the damaged stands were

analyzed on seven sample plots that were located on three model ground for the purpose of long-term monitoring (Table 3).

To assess tree condition, a scale of condition categories was used. This scale was developed taking into consideration interaction of a Siberian fir and FFBB. Healthy trees (without signs of weakening, not attacked by FFBB) are referred to the 1st category of state. The 2nd category includes the weakened trees (attacked by FFBB, but not colonization, with single or moderate drips of resin from places of attack, with the resin-soaked entrances of beetles). The 3rd category comprises heavily weakened trees (with plentiful drips of resin, attacked by FFBB, there are non resin-soaked entrances on a trunk, without successful colonization of beetles on a tree). Trees of 1st, 2nd and 3rd categories are viable. The 4th category includes the drying trees (colonized by FFBB). The 5th category comprises the trees which died in the current year (the recent dead tree killed by FFBB). The 6th category includes the trees which died in last years (an old dead tree). Average weighted categories of a tree condition, stand vitality index, degradation level, and vitality structure of a stand were used as integral indicators. The 7th category includes "fallen trees" is added for reference to the speed of windthrown and wind-broken trees formation in the stands damaged by FFBB over a period of observation.

Table 3. Inventory data of Siberian fir stands in the sample plots (M±m)

No. of sample plot	Stand composition	Tree stands of fir forest elements	Average fir tree diameter, cm	Average fir tree height, m	Average fir tree age, year	Stand density	Quality class	Forest type
1	8A1Pns1P+Pn		28.6±0.9	24.1±0.9	90	1.1	II	phb
2	6A3Pns1P		18.6±0.8	17.6±0.7	55	0.9	II	phb
3	5P3A _I 1A _{II} 1Pns+Pn	I generation	30.5±1.3	22.7±0.7	95	1.2	II	vhb
		II generation	13.3±0.5	13.6±0.4	55			
4	6A _I 1A _{II} 2Pns1P+Pt	I generation	30.2±1.1	26.5±0.6	95	1.0	I	phb
		II generation	12.7±0.5	13.3±0.6	50			
5	10A+P, single Pns, Pt, B		27.9±0.8	24.7±0.7	60	1.0	I	vhb
6	5A3P2Pns		27.9±1.5	20.1±1.2	70	1.2	II	ms
7	5Pns3A2P+Pn		22.1±0.8	20.5±2.6	115	0.6	III	vhb

Note. A – *Abies sibirica* Ledeb., Pns – *Pinus sibirica* Du Tour, P – *Picea sibirica* Ledeb., Pn – *Pinus sylvestris* L., Pt – *Populus tremula* L., B – *Betula pendula* Roth. Arabic numerals denote the share of the species in the stand composition. A_I, A_{II} – first and second generation of fir. Forest type: phb – parviherbetum, vhb – variiherbetum, ms – mosses (forest types are indicated before the emergence of FEFBB).

Initial condition of fir stands in 2012 varied on different sample plots as a result of extension of FFBB invasion in previous years under specific stand conditions. Differences in disturbance of forest stands are due to various factors of weakening of Siberian fir: intraspecific (competitive suppression of the second generation in multiple-aged stands), interspecific (root and stem fungal pathogens) and anthropogenic (change in illumination when laying power lines), which determined the qualitative and quantitative state of the host plants of FFBB and its numbers.

Changes in distribution of the trees by condition categories on the sample plots were found during the six-year studies (Fig. 3).

All the stands were characterized by negative dynamics of vitality index connected with activities of FFBB. General trends for the studied stands are as following: a consistent decrease of healthy fir trees, an increase of weakened, extremely weakened and dead trees, and massive number of fallen trees in 2015–2017. Differences in degree and speed of degradation of tree stands are caused by peculiarities of stands (mainly, amount and vitality of Siberian fir) and by stage of development of a local outbreak foci of FFBB. Maximum mortality of trees was observed in 2013 after air temperature increase in the summer 2011 and especially in 2012, which led to physiological weakening of trees and an increase of quantity and harmfulness of invader.

As massive quantity of dead wood and fallen trees appears at fast rate in the stands damaged by FFBB, it will cause higher risks of forest fires and changes in the carbon depositional function.

Transformation of taiga ecosystems in the FFBB outbreak foci

The complex studies performed on the biota of forest ecosystems in the FFBB outbreak foci allowed us to convincingly demonstrate its impact on various components of indigenous communities and their subsequent transformations (Krivets *et al.*, 2015b; Fig. 4).

In the foci of FFBB, catastrophic and irreversible changes in the species and vitality structure of forest stands were observed owing to the weakening and destruction of trees (Fig. 5). Siberian fir drops out of the forest stands the more rapidly, the more homogeneous the original species composition.

As a direct result of FFBB infestation, stand density decreased by 34–37%, and stand volume by 30%. The mean height, individual age and diameter at the stand level consequently increased (Debkov *et al.*, 2019).

Thinning of the forest stands leads to changes in their microclimate, which transforms the living condition in the lower layers of vegetation, as well as their animal inhabitants.

FFBB has both direct and indirect influence on the fir undergrowth. In the first case, it happens when it attacks young plants and introduced phytopathogenic fungi under the bark, which weaken the plant. In the second case, the effect is achieved through changes in the microclimate conditions of

ecotopes. The vital status of undergrowth in the FFBB foci is directly determined by the level of degradation of the forest stand. In the completely degraded forest stands, there are no fir seedlings, and the loss of undergrowth reaches 40%, which creates preconditions for the future replacement of taiga stands by small-leaved forests. However, our overall assessment of the potential natural regeneration of damaged stands is that the Siberian fir forests are resilient to invasive species and that the fir ecosystems can potentially recover from this disturbance (Debkov *et al.*, 2019).

Significant changes are observed in the vegetation cover. In the fir stands with the slightly disturbed plant communities, phytocenoses dominated by small taiga herbs are still preserved. With the increasing influence of the invader on the tree stand and reduction of the crown closure of plant communities, the proportion of species of variherbetum and magniherbetum groups increases. At the highest degree of degradation of the fir stands, when they are absolutely dominated by deadwood, variherbetum and fern– variherbetum phytocenoses with dense shrubs are formed on the cleared areas and near some dead trees, which negatively affects the natural regeneration of fir.

In the FFBB foci on Tomsk Region, the number of dendrophages species typically inhabiting fir forests is reduced by one-third (Kerchev and Krivets, 2012). Most native species of stem pests have a very low occurrence and abundance. Such species as *Xylechinus pilosus* (Ratz.), which is one of the most common bark beetles developing on fir, is displaced from the forest stands. The ability to compete with the aggressive alien species is to some extent still retained by black fir long-horned beetle *Monochamus urussovi* (Fisch.), a typical dominant of disturbed Siberian fir forests. However, in pure fir forests, it becomes fully secondary to the invader in the colonization of trees.

Therefore, FFBB, influencing various components of the biogeocenosis, causes significant qualitative and quantitative transformations in it, thereby being an important factor of the recent zoogenic successions in the Siberian taiga ecosystems.

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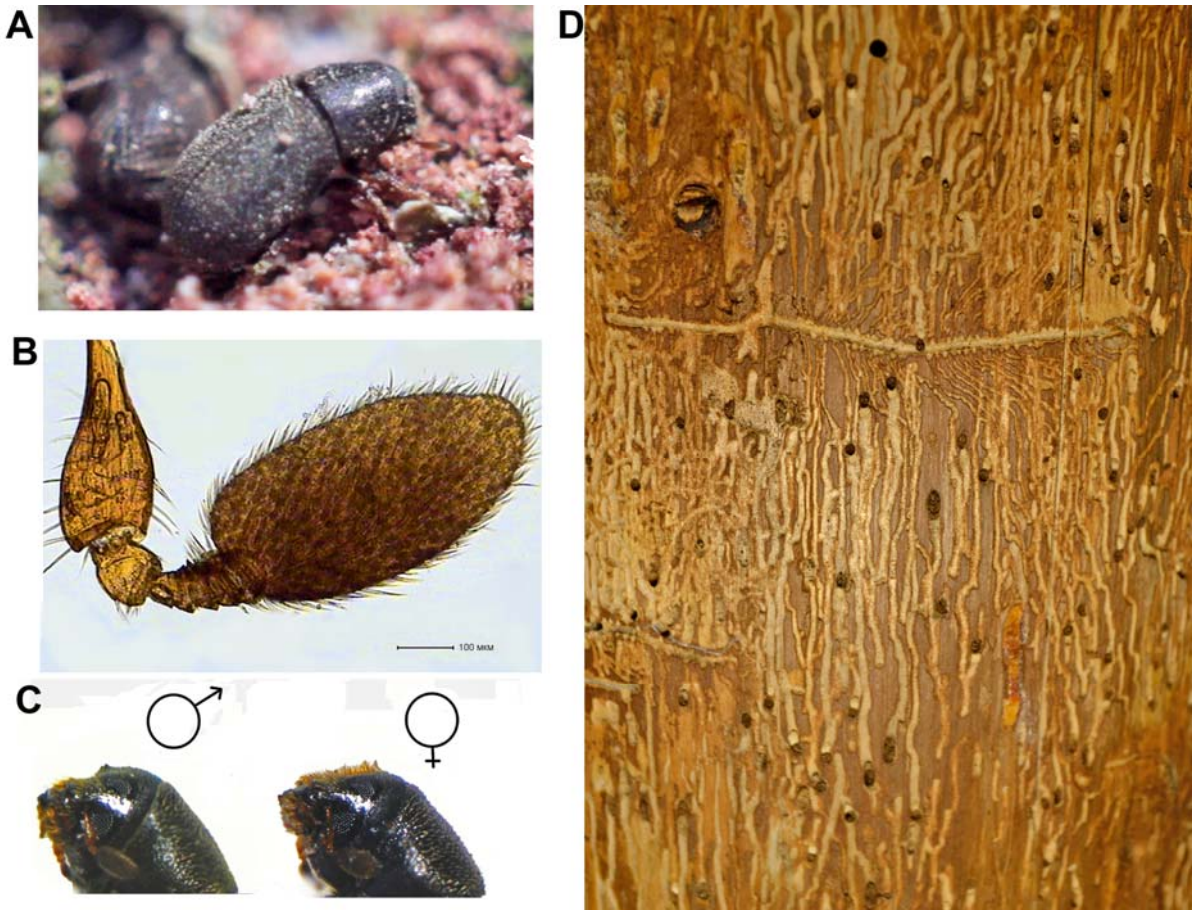


Figure 1. A – imagoes of *Polygraphus proximus* during coupling; B – antenna; C – external morphological features of male and female; D – maternal and larval galleries with pupa chambers in the sapwood



Figure 2. Imagoes and juvenile stages of *Medetera penicillata* Neg. (left). Devouring of pupa of FEFBB by larvae of *M. penicillata* (right)

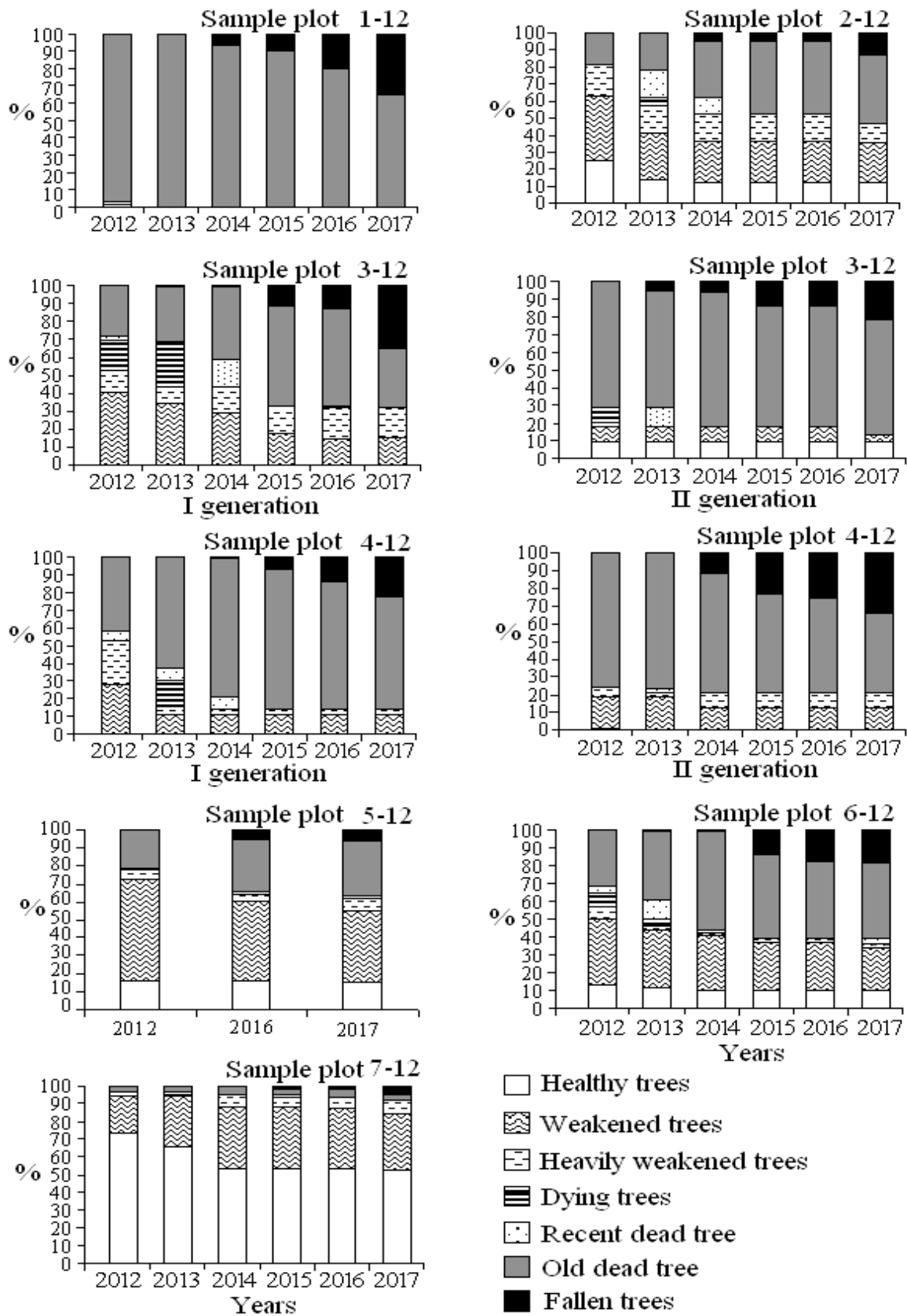


Figure 3. Vitality spectra of studied fir stands

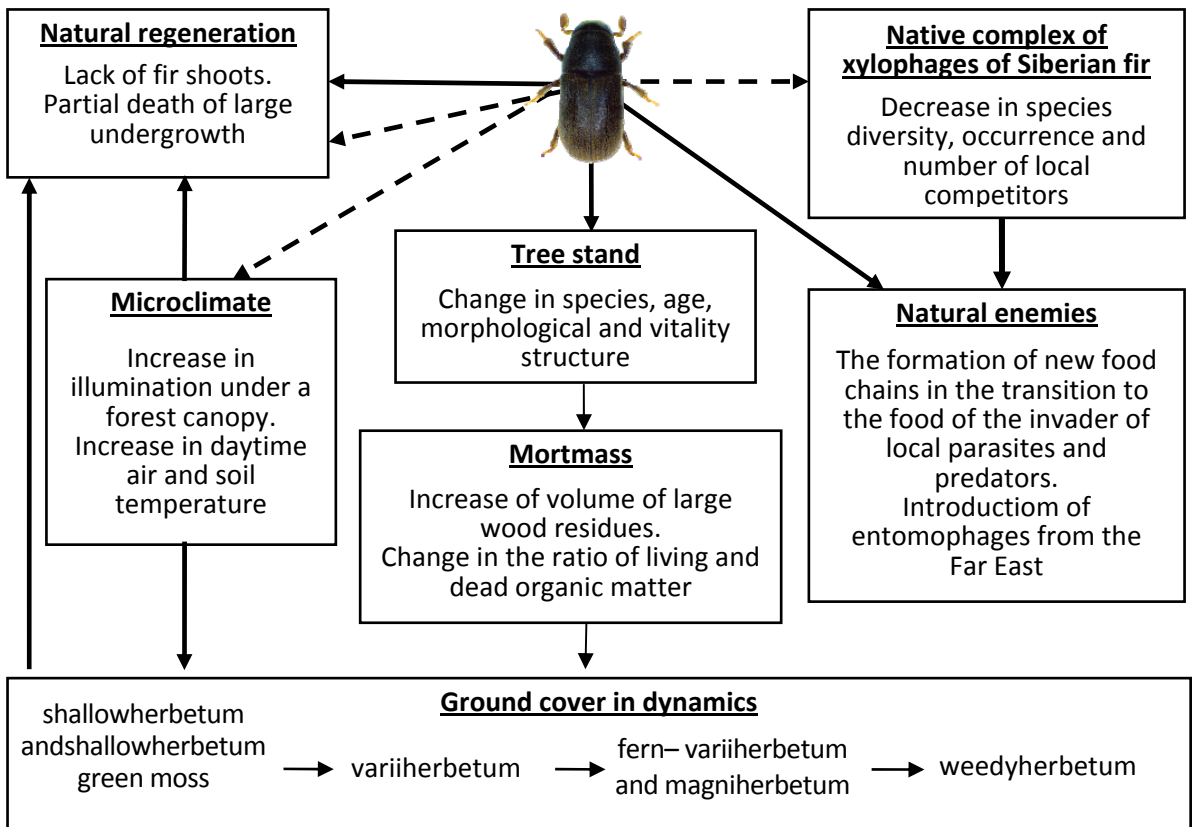


Figure 4. The effect of FFBB on various components of the dark coniferous ecosystems (solid arrows – direct effect, dashed arrows – indirect effect)



Figure 5. The death of fir trees in the outbreak focus of FFBB in Bakcharsky Forestry (Tomsk Region, 2017)

3.2.2. *Polygraphus proximus* in the Krasnoyarsk territory

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Уссурийский полиграф в Красноярском крае

Уссурийский полиграф *Polygraphus proximus* (Coleoptera: Curculionidae) после его появления в Сибири довольно быстро начал распространяться в пихтовых лесах. Он стал объектом многочисленных исследовательских работ, которые помогли довольно подробно изучить особенности биологии в новых для него местах обитания, его формирующийся комплекс энтомофагов. В работе приведены данные о развитии инвазии полиграфа в пихтовых лесах Красноярского края и о динамике формирования его очагов.

Ключевые слова: уссурийский полиграф, пихтовые леса, инвазия.

Abstract

After its appearance in Siberia, the ussuri polygraph, or four-eyed fir bark beetle quickly began to spread in the fir forests. It has been the subject of numerous researches works that have helped to study in some detail the features of biology in new habitats for it and its emerging complex of entomophages. To date, we have also studied the consequences of the damage caused by the ussuri polygraph and the transferred fir grosmanina to the fir forests.

Key words: *Polygraphus proximus*, complex of parasites and pathogens, fir forests.

Introduction

Polygraphus proximus after its occurrence in Siberia commenced its fast expansion in fir forests. It became a target of numerous research activities that enabled a rather comprehensive study of its biology specifics in new habitats (Gninenko, Klukin, 2011; Baranchikov *et al.*, 2011; Krivets *et al.*, 2015 and others), and shaping package of its entomophages (Kerchev, 2012, Krivets, Kerchev, 2016 and others). So far *Polygraphus proximus* and transmitted by it fir *Grosmanina aoshimae* damage impacts on fir forests have been studied (Baranchikov *et al.*, 2014; Debko *et al.*, 2018; Krivets *et al.*, 2015; Chernova, 2014; *et al.*, 2015).

Material and methods

We have studied *Polygraphus proximus* mass outbreak shaping dynamics in the Krasnoyarsky territory fir woods. For this purpose, Landsat 5, 7, 8 and Sentinel 2 imagery computerized interpretation with elements of visual control of results was applied.

Usually official reports show area of active mass outbreaks that conceals a real scope of *P. proximus* and fir *Grosmannia aoshimae* activity. New outbreaks arise annually while old earlier active ones where all fir trees are already dead are not subject to record any more.

We analyzed satellite images with regard to all areas killed by *Polygraphus proximus* and the *G. aoshimae*. It enables demonstration of the invasion true scope.

Results and discussion

First *Polygraphus proximus* outbreaks in the Krasnoyarsky territory were found in Kozulky township area in 2009. Year ring analysis showed that for the 1st time the pest this area appeared in 1976-1988 (Baranchikov *et al.*, 2014). It was suggested that *P. proximus* was delivered there with cargoes by the Trans-Siberian railway (Baranchikov *et al.*, 2011). After establishment *P. proximus* commenced own expansion of its areal infesting regional fir forests. First outbreaks were identified officially in 2009 in comparatively small area (Table 1).

Table 1. Active *Polygraphus proximus* and fir *G. aoshimae* outbreak area in the Krasnoyarsky territory according to official end year reports

Year	Outbreak area, thousand ha
2009	
2010	1.9
2011	
2012	
2013	
2014	
2015	8.2
2016	10.3
2017	10.3
2018	22.7
as of 01.09.2019	22.9

This data gives a rather incomplete invasion development picture. It is important to take into consideration not only active outbreaks in a specific year but demonstrate an overall invasion scope through summing up areas killed due to *Polygraphus proximus* and *G. aoshimae* damages. Visually such demonstration can be viewed in figures showing fir mortality expansion dynamics in invasive outbreak areas (Fig. 1, 2).

The figures (Table 2) prove this obvious picture.

Table 2. Fir forest area killed by *Polygraphus proximus* and fir *G. aoshimae* activities

Year	Dead fir forest area, thousand ha	Growth, times
2009	2.4	-
2010	4.9	2.04
2011	9.1	1.86
2012	11.5	1.26
2013	30.7	2.67
2014	42.4	1.38
2015	68.6	1.62
2016	330.7	4.82
2017	479.2	1.45
2018	541.4	1.13
Total area growth over observation years		225.58

It is noteworthy to point out that dead fir forest area estimations are based on satellite images (with follow-up compulsory ground control surveys) and cover only forests where fir prevails. If fir share in tree species composition in this or that specific forest lot is 10-20% it is unfeasible to identify dead trees in this lot using satellite images. Therefore, in fact forest area where *Polygraphus proximus* and *Grosmannia aoshimae* activities resulted in mortality of fir as a valuable forest community component is bigger compared to what we presented.

However, record of the only forests where fir is a prevailing species shows that these 2 invaders activity scale is very great.

It is noteworthy that in 2016 there was a slight growth of dead fir wood area. Obviously, this fir decline was due to *Dendrolimus sibiricus* Tscshw., 1908 (Lepidoptera, Lasiocampidae) mass outbreak that started then which promoted the highest growth of dead forest area.

Thus, scope of *Polygraphus proximus* and *Grosmannia aoshimae* impacts on Siberian fir forests is very great. Both invaders result in fir wood mortality in big areas where other tree species and fir undergrowth are left after its invasion. Still it is impossible to predict long-term chances of these invader modified taiga forests. Both organisms' invasion does not challenge (at least at the moment) existence of Siberia fir as a species but it highly likely to state that fir woods as a specific forest community pattern will be mainly lost.

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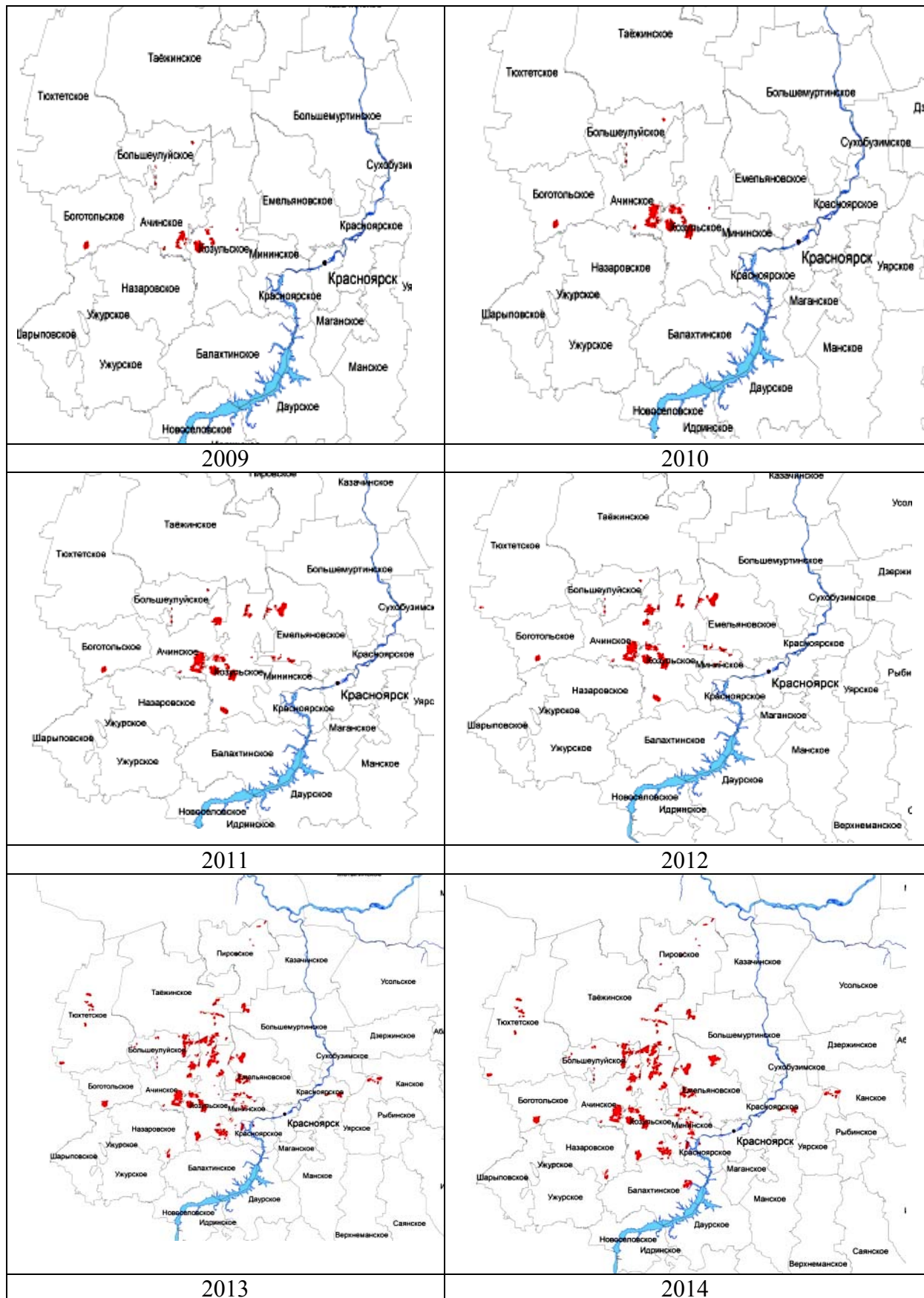


Figure 1. Fir forest decline dynamics due to *Polygraphus proximus* and fir *Grosmannia aoshimae* (2009-2014)

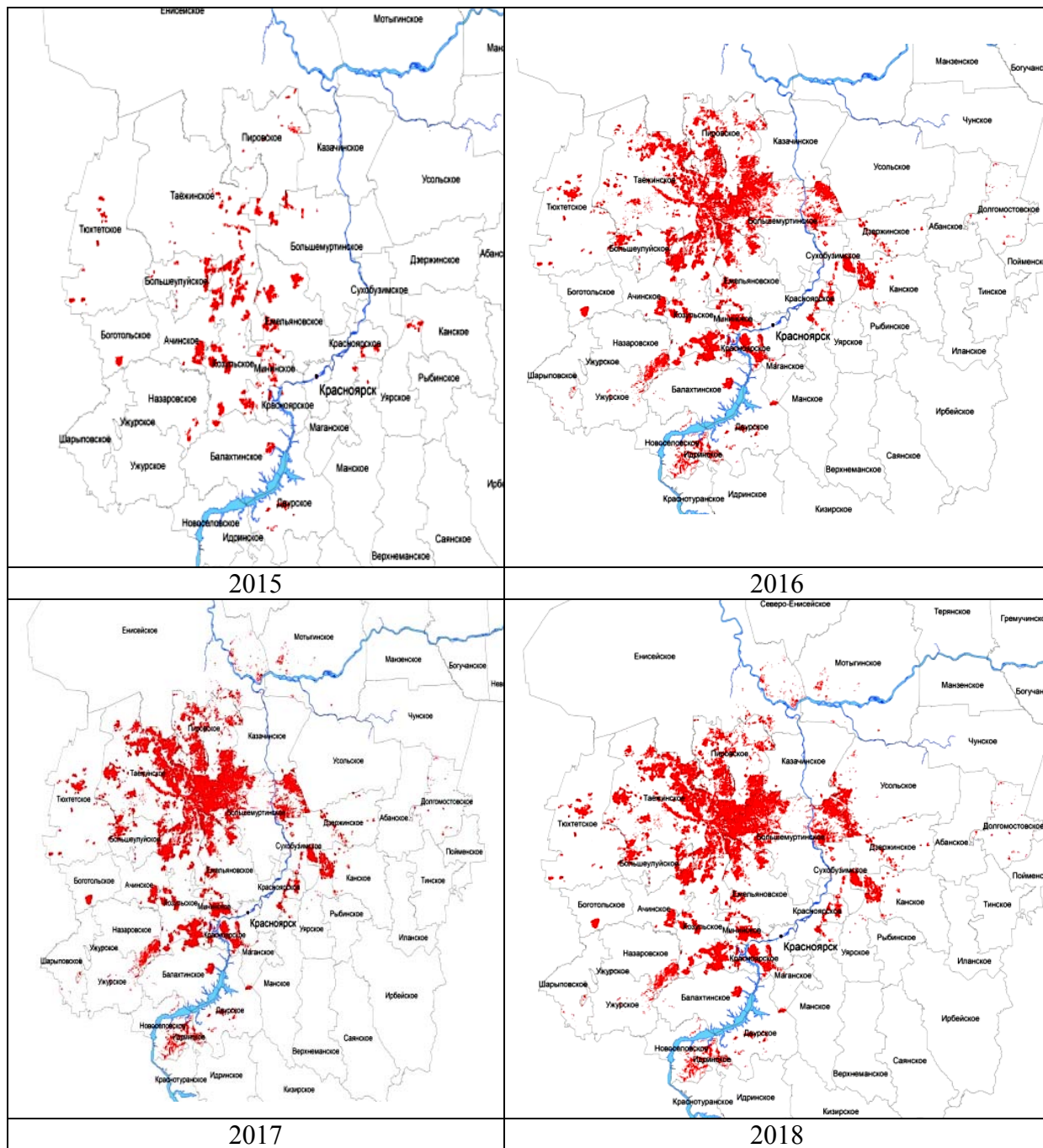


Figure 2. Fir forest decline dynamics due to *Polygraphus proximus* and fir *Grossmannia aoshimae* (2015-2018)

3.3. *Ips amitinus* (Eichhoff, 1872) (Coleoptera, Curculionidae: Scolytinae) – a new pest of *Pinus sibirica* in Western Siberia

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Союзный короед *Ips amitinus* (Eichhoff, 1872) (Coleoptera, Curculionidae: Scolytinae) – новый вредитель кедра сибирского в Западной Сибири

Союзный короед *Ips amitinus* – широко распространенный вид во многих европейских странах. В 2019 году он был обнаружен в Западной Сибири в припоселковых кедровниках Томской и Кемеровской областей. В регионе инвазии чужеродный короед питается на новом растении-хозяине – кедре сибирском *Pinus sibirica* Du Tour, а также спорадически встречается на ели сибирской *Picea obovata* Ledeb., колонизируя верхнюю часть ствола и ветви стоячих и ветровальных деревьев. Характерные признаки гибели деревьев впервые были отмечены в припоселковых кедровниках Яшкинского района Кемеровской области в 2014 году. В настоящее время *I. amitinus* распространен во всех кедровых насаждениях этого района. Росту численности *I. amitinus*, по-видимому, способствовали сухая и жаркая летняя погода на юго-востоке Западной Сибири в течение последнего десятилетия и обильные снегопады в предшествующую зиму, приведшие к повреждению крон многих деревьев. В Томской области наиболее интенсивный очаг *I. amitinus* установлен в 2018 году в Лучановском припоселковом кедровнике, ослабленном массовым размножением сибирского шелкопряда *Dendrolimus sibiricus* Tschetv. Инвазия *Ips amitinus* в Западной Сибири и дальнейшее распространение его в соседние регионы могут привести к увеличению темпов деградации кедровых насаждений и высоким рискам снижения их продуктивности в течение последующих десятилетий.

Ключевые слова: союзный короед, кедр сибирский, западная Сибирь.

Abstract

The small spruce bark beetle *Ips amitinus* is a widespread species in many European countries. In 2019 it was detected in Siberian pine forests in Western Siberia in the Tomsk and Kemerovo Regions. In the region of invasion alien bark beetle is abundant on new host – *Pinus sibirica* Du Tour, and is also sporadically found on the Siberian spruce *Picea obovata* Ledeb. It colonizes the upper trunk and branches of standing and windfall trees. This pattern of tree dying was noted for the first time in Siberian pine stands near settlements in

Yashkinsky District of Kemerovo Region in 2014. Nowadays outbreak foci of *I. amitinus* exist in all the Siberian pine forests in this district. The population growth of *I. amitinus* was presumably facilitated by dry and hot summer weather in the southeast of Western Siberia during the last decade and heavy snowfalls in previous winter resulting in damage of crowns in many trees. In Tomsk Region the most active outbreak focus of *I. amitinus* appeared in 2018 in the Siberian pine forest near Luchanovo, following an outbreak of the Siberian moth *Dendrolimus sibiricus*. The invasion of *Ips amitinus* in Western Siberia and further spread to the neighboring regions may lead to increasing degradation rates of Siberian pine forests and high risks of dumping their productivity over decades.

Key words: *Ips amitinus*, *Pinus sibirica*, Western Siberia.

Introduction

Invasions of alien organisms with different cargos is one of the main adverse effects of active international trade (Pimentel et al., 2005; Roques et al., 2016). The spread of bark beetles in new regions is facilitated by the transportation of fresh unbarked wood (Piel et al., 2008), different types of wood packaging materials with goods (McCullough et al., 2006; Rassati et al., 2015), and sawdust or wood chips (Flø et al., 2014). In particular, invasive bark beetles (Curculionidae: Scolytinae) have high economic significance (Brockerhoff et al., 2006; Piel et al., 2008; Hu et al., 2009) and pose an ecological threat to forests in new regions. Due to their hidden lifestyle, bark beetles are able to bypass easily phytosanitary control and quarantine services (Brockerhoff et al., 2006; Haack, 2006) and remain undetected for a long time in the new habitats during so called lag-phase of invasion (Kirkendall and Facolli, 2010). The primary range of the small spruce bark beetle *Ips amitinus* (Eichh.) covers nearly the entire Europe. According to EPPO it is widespread in Bulgaria, Czech Republic, Finland, Germany, Poland and Romania restricted distribution was noted for Bosnia and Herzegovina, Macedonia, Montenegro, Serbia, Austria, Belgium, Switzerland, Croatia, Estonia, France, Hungary, Italy, Slovak Republic, Slovenia and Sweden (Izhevsky et al., 2005; Cognato, 2015, EPPO GD 2019).

The list of *I. amitinus* hosts include coniferous plants from four genera: *Picea* A. Dietr., *Pinus* L., *Larix* Mill., and *Abies* Mill. Of special concern is active expansion of *I. amitinus* to the North European countries (Finland, Sweden, and Norway), observed in the recent decades and believed to be largely related to climate changes (Økland et al., 2019). In the territory of Russia, *I. amitinus* was for the first time recorded by Stark (1926) for Bryansk Region, but this record was not mentioned in the later Fauna of the USSR edition (Stark, 1952). In 1999 the species was discovered in Leningrad Region (Mandelstam, 1999), and during the following five years it spread into a number of northwestern regions of Russia: Pskov and Novgorod Regions, the Republic of

Karelia, and the south of Murmansk Region (Voolma et al., 2004). Now, as the result of ongoing expansion, *I. amitinus* has reached the north of the Kola Peninsula and Arkhangelsk Region (Mandelstam and Musolin, 2016). The small spruce bark beetle was not previously recorded in Siberia despite the dedicated studies of bark beetles that have been carried out in this territory for 90 years (Kiseleva, 1928, 1946, 1951, 1952; Kolomiets, 1960; Krivolutskaya, 1965, 1983; Bogdanova, 1971, 1976; Yanovskij, 1995; Krivets and Chemodanov, 2005; Kerchev, 2011; Krivets and Vysotina, 2011, etc.). In 2019 *I. amitinus* was for the first time discovered in Siberia, near human settlements within Tomsk and Kemerovo Regions where it formed outbreak foci and caused drying of Siberian pines starting with the crown tops.

Materials and methods

Beetles were collected in forest stands with absolute prevalence of the Siberian pine in Tomsk Region and in Kemerovo Region.

Material: Russia; Tomsk Region: Tomsk District, Siberian pine forests near settlements: Aksenovo, Belousovo, Ipatovo, Luchanovo, Nekrasovo, Petukhovo, Nizhne-Sechenovo, Gubino, and Yarskoe; Shegarskiy district near Melnikovo settlement and Tuendat in the Pervomayskiy district. Beetles collected under bark of branches and upper trunks of drying and dead (standing and windfall) Siberian pines. In the Kemerovo Region *I. amitinus* was found in Yashkiy District, Siberian pine forest near Itkara and Siberian pine forest near Bot'evo.

The collected bark beetles were identified based on external morphological characters (Douglas et al., 2019) and verified with *I. amitinus* specimens from its native area depositing in Zoological institute of RAS, Natural History Museum (Vienna, Austria), and the private collection of M.Yu. Mandelstam (St. Petersburg).

Results and discussion

The examined specimens very closely resemble *Ips amitinus* from its primary range. Average body length is 4.1 ± 0.15 mm. Sutures on antennal club is straight, not curved at middle toward segment apex. This character makes *I. amitinus* well distinguishable from all *Ips* species of Holarctic (Cognato, 2015). In 1913, Fuchs described a new race of *I. amitinus* infesting Swiss pine *Pinus cembra* L. and mountain pine *P. montana* Lamarck, *I. amitinus* var. *montana*. This race was first reported in the mountainous parts of Switzerland. The morphological and structural differences between *I. amitinus* and *I. amitinus* var. *montana* were based on host tree and body length. However, using morphometric, behavioural and chemical criteria as well as molecular genetics, it was found no differences between *I. amitinus* and *I. amitinus* var. *montana* (Stauffer and Zuber, 1998).

When developing on the Norway spruce *Picea abies* (L.) Karst. *I. amitinus* clearly prefers the thin bark of undersized trees, whereas on large trees this species always occurs higher up the trunk than *I. typographus*. In the Korelia peninsula and Arkhangelsk Region for *I. amitinus* was also recorded colonization of the Scots pine *P. sylvestris* L (Mandelshtam, 1999; Mandelshtam and Musolin, 2016). The mating systems of *I. amitinus* are characterized as harem-polyginous with 3-5, less often 7 females per male (not 2 or, rarer, 3 as in *I. typographus*) diverging in a star-like pattern from the mating chamber.

The discovery of this new pest on the Siberian pine reminds the infamous history of invasion and outbreaks of *Polygraphus proximus* Blandf. in the fir forests of Siberia. The same shortcomings in the forest protection system, namely lack of professional skill in identification of the root cause in dramatical rates of forest degradation (Baranchikov and Krivets, 2010) collapse of the existing regulatory framework for forest management under the absence of an alien species in the list of quarantine objects and the need for urgent measures to localize its foci, have manifested one more time. In the southeast of Western Siberia, the unusual pattern of tree mortality was first noticed by the local people in a Siberian pine forest near Itkara (Yashkinsky District of Kemerovo Region), in 2014 (Skorokhodov, 2017). During the first year, the upper crown died off while the lower branches remained green; on the second year the whole tree died. A layer of fallen branches, with green needles preserved on some of them, appeared under the damaged trees. Examination of these branches in 2016 revealed bark beetles which were preliminarily and with much reservation identified as *I. duplicatus* (Sahlb.) by S.A. Krivets. The sanitary felling of infested Siberian pines in 2017 was of little effect, since most of the logging slash remained in the forest and the pest development continued in it. In the subsequent years, the areas of Siberian pine drying in Yashkinsky District expanded and new such areas appeared in forests near the settlements: Krasnoselska, Bot`evo, Pashkovo, Mugalovo, Balakhnino, Istomino, Vlaskovo, and Kosogorovo. The last one is only 5 km apart from Yarskoe settlement in Tomsk Region. In view of large-scale apical drying of Siberian pines, in 2019 specialists of Tomsk Forest Protection Center used traps baited with aggregation pheromone for trapping *I. acuminatus* in the Siberian pine stands of Yashkinsky forestry. The collected beetles were erroneously identified as *I. duplicatus* and *I. typographus*. In the same year, Tomsk forestry applied to the Institute of Monitoring of Climatic and Ecological Systems, Siberian Branch of the Russian Academy of Sciences, for help with forest pathology evaluation of the Siberian pine forest between Luchanovo and Ipatovo settlements (Tomsk District of Tomsk Region), where apical drying of trees was recorded for the first time following the outbreak of the Siberian moth *Dendrolimus sibiricus* Tschetw. in 2016 and 2017 (Fig. 1).

There, abundant of the boring dust was found on the leaves of herbs and shrubs under the damaged Siberian pines, and bark beetles occurred in great

numbers on the fallen branches and on the tops of windfall trees. Based on the results of morphological features of collected insects analysis and molecular-genetic analysis, they were identified as *I. amitinus*. Further surveys revealed the presence of this species, in other Siberian pine forests located near the settlements of Tomsk District. The beetles previously collected in the Siberian pine forests of Kemerovo region proved to be representatives of the same species. The small spruce bark beetle must have only recently appeared in West Siberia or at least in Tomsk Region approximately during last decade. Under trapping of bark beetles carried out by us and colleagues from Tomsk Forest Protection Center in Tomsk region in 2008-2012, we captured various species of bark beetles including the invasive *Polygraphus proximus* in traps baited with synthetic pheromones of *Ips sexdentatus* (Boern.) and *I. acuminatus*. No one specimens of *I. amitinus* was collected at that time. Nevertheless, invasion into the Yashkinsky district of the Kemerovo region may have appeared much earlier via the Trans-Siberian Railroad. The bark beetle may have remained undetected until it revealed itself as an aggressive pest. The formation of outbreak foci of *I. amitinus* was probably facilitated by favorable for population growth summer weather in the southeast of Western Siberia during the last decade, especially drought in 2012, and also by heavy winter snowfalls broken the Siberian pine branches, vulnerable for colonized by the bark beetles in spring. Further expansion of this alien species into the adjacent Tomsk region was additionally promoted by weakening of Siberian pine forests due to defoliation in the Siberian moth outbreak foci.

Conclusions

Assessing the harmfulness of *I. amitinus*, it should be noted that, according to published data, this species is a rather aggressive bark beetle, characterized by a high breeding potential, and is capable of long-distance migrations and development of different conifers. In connection with the invasion of the small spruce bark beetle into Siberia and the mass death of trees in the Siberian pine forests, there is a risk of degradation of valuable forest stands, a decrease in their walnut productivity and the further spread of the alien bark beetle in the forests of the Siberian region.

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Figure 1. Outbreak foci of *Ips amitinus* in Siberian pine forest near the settlement Luchanovo (Tomsk Region, 2019 year)

Editor's opinion

The All-Russian Scientific Research Institute for Forestry and Mechanization of Forestry, together with the East Palaearctic Section of the International Organization for Biological Control of Pests and Animals, prepared this collective monograph to show the scale of penetration of new invaders into the forests of Eurasia and the problems that arise when each new invader appears. For quite a long time, new invaders appeared only in the forests of European countries, while the vast forests of Siberia were, as it were, outside their influence. However, the 21st century brought not only an increase in the flow of invasive deedrophilic insects into the forests of Europe, but also the spread of this process into Siberian forests. It is now becoming clear that the process of the emergence of new invaders in the forests of Europe and Siberia will not only slow down, but most likely, it may intensify. In order to effectively confront these new "invaders", the combined efforts of scientists and practitioners from all concerned countries are needed.

This collective monografia is an attempt to summarize some intermediate results of the study of forest invaders in the space from Western Europe to Siberia and Central Asia. It does not pretend to provide an exhaustive coverage of the issue: as the process of penetration of new invaders continues, so does the process of studying and developing measures to protect against them.

Yu.I. Gninenko

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