ISSN 2075-1117, Russian Journal of Biological Invasions, 2019, Vol. 10, No. 3, pp. 258–262. © Pleiades Publishing, Ltd., 2019.
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The Focus of the Emerald Ash Borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) in Tver, on the Northwestern Border of the Invasive Range

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Received January 13, 2019; revised April 7, 2019; accepted May 16, 2019

Abstract—The emerald ash borer is a serious pest of ash (*Fraxinus* spp.) in North America and European Russia. It was introduced to those territories from East Asia in the 1990s. Currently the pest has spread in 12 regions of European Russia. The northwestern border of its range is in the city of Tver. This poses a potential threat to ash trees of St. Petersburg and Western Europe. In 2016 and 2018, green ash trees were surveyed in the summer in several districts of Tver. There are only local foci of the emerald ash borer in the city; mass drying of ash trees is not observed. A species that accompanies the emerald ash borer (the jewel ash beetle *Agrilus convexicollis*) and a pest parasitoid (*Spathius polonicus*) were found. Both species are recorded for Tver region for the first time. In addition, parasitoid *Coeloides* sp. was found inside the bark beetle galleries.

Keywords: Agrilus planipennis, emerald ash borer, Tver, Tver Oblast, range, ash tree, *Fraxinus*

DOI: 10.1134/S2075111719030093

INTRODUCTION

The emerald ash borer *Agrilus planipennis* Fairmaire (hereafter, EAB) is a species that was unintentionally introduced into the European part of Russia and North America from East Asia in the 1990s (Musolin et al., 2017). The natural range of the species is the deciduous forests of East Asia (Orlova-Bienkowskaja and Volkovitsh, 2018). The emerald ash borer develops in its native range on weakened and depressed trees of the Manchurian ash (*Fraxinus mandshurica* Rupr.), rhynofolious ash (*F. rhynchophylla* Hance), and Siebold's ash (*F. lanuginosa* Koidz.), without causing them particular harm (Yurchenko et al., 2007; Baranchikov, 2009). In North America, all aboriginal ash species are damaged to varying degrees by the EAB, which is especially relevant for widespread species: the green ash (*F. pennsylvanica* Marsh.), white ash (*F. americana* L.), and black ash (*F. nigra* Marsh), and this leads to their mass drying (Herms and McCullough, 2014). In the European part of Russia, the emerald ash borer primarily damages the introduced ash species *F. pennsylvanica*; however, it also affects the aboriginal species—the common ash *F. excelsior* L. (Baranchikov et al., 2014).

In North America, dying trees produce root shoots, which, after reaching a diameter of 2.5 cm, are again settled by the pest (Herms and McCullough, 2014). In Moscow, the root shoots that reached 5–7 cm in diameter were not found to have flight holes of the emerald ash borer (Orlova-Bienkowskaja, 2018). Emerald ash borer larvae eat the bast and cambial layer of the trunk, as a result of which the tree can die in 2–7 years (Knight et al., 2013; Straw et al., 2013). In Asia and North America, the development of larvae lasts 1–2 years depending on the climate and state of the tree (Tluczek et al., 2011). In Moscow, its development cycle lasts two years (Orlova-Bienkowskaja and Bieńkowski, 2015).

At present, the EAB has been noted in Russia in 12 regions: Moscow oblast (2003), Smolensk oblast, Tula oblast, Kaluga oblast (2012), Ryazan oblast, Vladimir oblast, Yaroslavl oblast, Tver oblast, Tambov oblast, Voronezh oblast, Oryol oblast (2013–2014), and Lipetsk oblast (2017) (Orlova-Bienkowskaja, 2013; Baranchikov et al., 2017).

In Voronezh and Tula oblasts, the damage to ash trees by the emerald ash borer is catastrophic (Blummer and Shtapova, 2016; Baranchikov et al., 2018; Mamedov, 2018), and in Moscow oblast ash forests are beginning to recover after a pest outbreak in 2006–2013 (Orlova-Bienkowskaja, 2018).

In 2013, the foci of this beetle were first noted in Tver oblast (Konakovo, Zubtsov, Emmaus, and Novozavidovsky), but this pest was not yet found in Tver City (Orlova-Bienkowskaja, 2013; Straw et al., 2013). It was found somewhat later—in 2015 (Peregudova, 2016).

The purpose of this study is to assess the state of the EAB focus in Tver oblast as well as to note what other

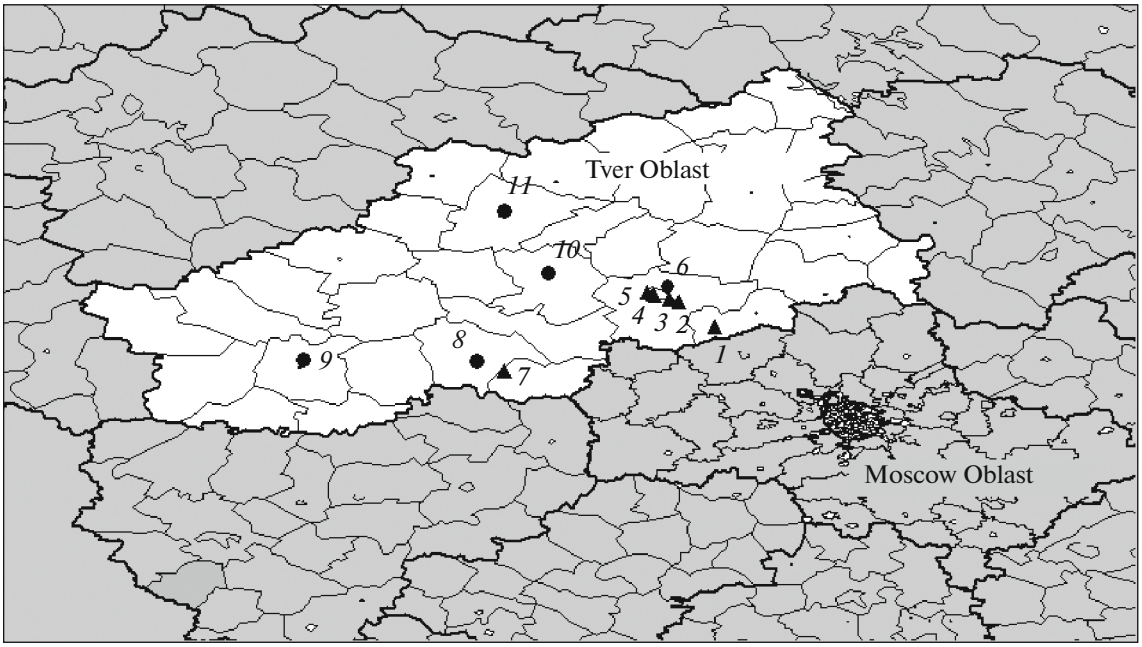

Fig. 1. Map of the distribution of *Agrilus planipennis* in Tver Oblast. The triangles show the detection points. The circles mean that the survey gave a negative result. The year of survey is indicated in brackets. (*1*) Novozavidovsky district (2013); (*2*) Emmaus (2013); (*3*) Tver, Moskovsky district (2015, 2016); (*4*) Tver, Proletarsky district (2016); (*5*) Tver, Zavolzhsky district (2018); (*6*) Tver, Central district (2017); (*7*) Zubtsov (2013); (*8*) Rzhev (2013); (*9*) Nelidovo (2013); (*10*) Torzhok (2013); (*11*) Vyshny Volochyok (2013) (according to Orlova-Bienkowskaja, 2013; Straw et al., 2013; Volkovitsh and Mozolevskaya, 2014; original data).

xylophages and their parasitoids are present on the examined trees.

MATERIALS AND METHODS

The survey was conducted in Tver in 2016 in the period from June 16 to July 21 and in 2018 at the end of June and in mid-August. It consisted in inspecting green ash plantations (*Fraxinus pennsylvanica* Marsh.) in some areas of the city (Fig. 1). The lower part of the trunk from the ground up to 2 m in height was examined, and the presence of characteristic D-shaped flight holes of the emerald ash borer was noted. Flight holes of the bark beetle *Hylesinus varius* Fabricius, 1775 (Coleoptera: Scolytidae) were also noted. In 2018, the upper parts of trunks and branches that were cut down during sanitary felling were examined once with bark removal. The bast and inner bark, which was removed with a knife and axe, were examined.

In the Moskovsky district on the southeastern border of the city, the roadside green ash plantations (*Fraxinus pennsylvanica* Marsh.) were examined at the section of the Moskovsky highway (from the village of Vlasyevo to the Gagarin Railway Station). The trees are located there in one or two rows along the highway and are warmed well by the sun on all sides. Almost all the trees in this area had sawed-off tops and drying of half of the crown. A total of 250 trees were examined. In the same area (near the village of Khiminstitut), felling remains of ash, namely, six trunks and branches of various lengths (up to 1.5 m) and diameter (5–18 cm) were examined. The survey was conducted in 2016.

In the southwestern part of the city (**the Proletarsky district**), green ash plantations (79 trees) were examined along roads and in yards in the environs of the railway and bus stations (Komintern st., Zheleznodorozhnikov st., and Mashinistov st.).

In the Zavolzhsky district (northwestern part of the city), green ash plantations were examined opposite the Doroshikha railway station. In this place, ash trees were few in number (approximately 20 trees) and were arranged in two or three rows along the railway. Out of these, 11 trees were surveyed. There, in addition to visual examination, we measured the diameter of trunks at a height of 1.3 m, noted the presence of water shoots with measurement of the diameter of the thickest shoots at the base.

To identify the collected imagoes of both ash borers and bark beetle, we used the Guide to Insects of the European Part of the Soviet Union: Coleoptera and Strepsiptera (*Opredelitel'...*, 1965) and the book Fauna of the Soviet Union: Coleoptera (Stark, 1952), as well as an illustrated guide for the EAB and related species (Chamorro et al., 2015). The bark beetle galleries were identified using the Illustrated Reference Book of Xylophage Beetles—Pests of Forest and Timber of the Russian Federation (Izhevskii et al., 2005). The found specimens of the emerald ash borer and bark beetle were checked and identified to the species level by M.J. Orlova-Bienkowskaja. Assistance in identifying

Table 1. Results of surveys of green ash stands in Tver, 2016 and 2018

Region, year of survey	Trees, pcs.					Beetle imagoes, pcs.	
	without damage**	flight holes of *Hylesinus varius*	EAB flight holes	other insects*	total number of surveyed trees	EAB	*Agrilus convexicollis*
Moskovsky district (settlement of Vlasyevo—Gagarin station), 2016	17	229	22	4	250	5 (4 live beetles, 1 dry beetle)	15
Proletarsky district (Zheleznodorozhnikov st., Mashinistov st., and Komintern st.) 2016	69	8	0	2	79	0	0
Zavolzhsky district (Doroshikha railway station), 2018	0	11	6	1	11	1 (dry)	0

* Flight holes not belonging to emerald ash borers or bark beetles were detected. Also, if ant hill was found in tree. **Upon examination of lower part of trunk, no flight holes of emerald ash borers or bark beetles were detected.

Table 2. Results of surveying felling remains of green ash trees, 2018

Data of surveys	Number, pcs.
EAB galleries	33
Remains of EAB larvae damaged by parasitoids	3
EAB larvae covered with molt	1
Cocoons of the parasitoid *Spathius* sp. (empty)	3
Larvae of the parasitoid *Spathius* sp.	39
Adult parasitoids *S. polonicus*	2
Successful EAB galleries*	18
Unsuccessful EAB galleries**	15

* Galleries that end with a flight hole. ** Galleries that do not have a flight hole, i.e., unfinished galleries.

the found parasitoides was provided by S.A. Belokobylskij.

RESULTS

Moskovsky District

Out of the 250 trees surveyed, 9% had the EAB flight holes. Imagoes of the jewel ash beetle *Agrilus convexicollis* Redtenbacher, 1849 (Coleoptera: Buprestidae) were found on leaves of young, slightly damaged trees, as well as on leaves of older trees that had completely dried, except for the lower skeletal branches. The dried trees had the EAB flight holes and flaking bark with pest galleries under it. The flight holes of the bark beetle were abundant—92% of the 250 trees surveyed. The results of the survey are shown in Table 1.

When felling residues were examined in 2018, the EAR galleries were observed to be located around the entire circumference of the surveyed trunks and branches. The galleries were scattered chaotically with respect to each other and more often passed along the trunk. A total of 33 ash borer galleries were examined. A gallery was considered to be examined if it was completely cleared from the bark. Out of the 33 ash borer galleries, 15 galleries were incomplete, including because of the parasitization of parasitoids, which is 45% of the total number of galleries. The data are shown in Table 2.

In addition to the emerald ash borer galleries, the bark beetle galleries (*Hylesinus varius* (F.)) were discovered in the bast. Like the emerald ash borer galleries, they were scattered around the entire circumference of trunks and branches. In addition, such galleries were also noted on the inner side of removed bark. White cocoons were found at the end of some galleries—they were empty and contained adult parasitoids of the genus *Coeloides* sp. that were stuck in the flight holes.

Proletarsky District

The survey of ash trees in 2016 in this region did not result in finding any traces of *A. planipennis*. On Komintern street, the tops of ash trees were cut, but

this most likely had the purpose of improving the landscape and was not caused by damage by the emerald ash borer, since there were no flight holes in the lower part of the trunk, and the trees located nearby in the courtyards had a normal crown. In this area, completely dried trees were met sporadically; some of them had a sparse crown. Out of the 79 surveyed trees, 10% had flight holes of the bark beetle (Table 1).

Zavolzhsky District

In the area near the Doroshikha railway station, the EAB focus was discovered in 2018. Some trees had root shoots 1–1.5 cm in diameter. Flight holes were found on the trunks of all diameters (11–26 cm). All of the surveyed trees were noted to have bark beetle galleries; live imagoes were found on some of them (Table 1).

DISCUSSION

In 2013, the northwestern point of the spread of the emerald ash borer was considered to be located in the village of Emmaus (Tver oblast, 8 km from Tver); the survey of the city did not result in detecting the pest (Orlova-Bienkowskaja, 2013; Straw et al., 2013). We discovered a pest focus in the city of Tver in the Moskovsky district in 2015 (village of Khiminstitut) (Peregudova, 2016). Apparently, this focus had existed for at least three years, since at the time of the survey (2016) the trees had crowns that had dried by one half or more and had a flaked-off bark and visible EAB galleries under it, as well as water shoots. Along the Moskovsky highway, the ash trees were noted to have the flight holes of the pest at a height of no more than 1.5 m, traces of woodpecker strokes, and water shoots, which indicates the complete population of the tree. However, this situation was not observed throughout the area. For example, on Vagzhanov street (immediately after the Moscow highway), the green ash trees were not found to have any traces of the emerald ash borer. Apparently, the emerald ash borer chooses more illuminated places and less closed crowns, which is typical of its primary range in the Far East (Yurchenko et al., 2007).

In the Zavolzhsky district (opposite the railway station), the EAB focus was discovered in 2018. Apparently, it had existed there for several years, since the tree crowns had dried by one half or more and some of the trees had flaking bark as well as water shoots. Obviously, this outbreak continues to function at the present time.

It is interesting that the emerald ash borer settled not all over the city, but locally. For example, in the Proletarsky district (not far from the railway station), no traces of the emerald ash borer were found and the trees looked relatively healthy.

The jewel ash beetle *A. convexicollis* is a species that accompanies the EAB, settling on trees weakened by it. In Central Russia, it has been noted only since 2007 (Orlova-Bienkowskaja and Volkovitsh, 2014). This is the first find of this species in Tver oblast.

The parasitoid *Spathius polonicus* is not a mass, but widespread western palaearctic species (Orlova-Bienkowskaja and Belokobylskij, 2014). This species was noted for the first time for Tver oblast.

All the detected foci are relatively old, since the focus in the Moskovsky district had existed until its discovery in 2015 for at least three years. In the Zavolzhsky district, at least 2–3 years had passed before its discovery in 2018. Thus, the data suggest that the settlement of the EAB in the northwest is not as fast as in the southern part of the range. The reasons for this are not yet clear. It is possible that the slow spread of the pest (in Moscow, the pest outbreak began as early as three years after the discovery of the first specimen of *Agrilus planipennis* (Orlova-Bienkowskaja, 2018); this is not observed in Tver) was influenced by the *S. polonicus* parasitoid. On one hand, gradual fading of the foci and recovery of ash trees are possible, as has happened in Moscow, and, on the other hand, new pest outbreaks are not improbable, since there are still many intact trees in the city.

ACKNOWLEDGMENTS

I sincerely thank Marina Yakovlevna Orlova-Bienkowskaja (Doctor of Biological Sciences, senior scientific researcher at the Severtsov Institute of Problems of Ecology and Evolution of the Russian Academy of Sciences) for help and valuable recommendations and Sergei Aleksandrovich Belokobylskij (Doctor of Biological Sciences, leading scientific researcher at the Zoological Institute of the Russian Academy of Sciences) for help in identifying the material.

FUNDING

The collection and analysis of data on the distribution of the species and also the preparation of the manuscript were carried out in preparation for writing the master's thesis. This study had no funding.

CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest.

COMPLIANCE WITH ETHICAL STANDARDS

This article does not contain any studies involving animals performed by the author.

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Translated by L. Solovyova