The Frontline of Invasion: the Current Northern Limit of the Invasive Range of Emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), in European Russia

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Abstract

Agrilus planipennis is an aggressive beetle native to Asia, which has recently invaded North America and central Russia. In European Russia, the first specimens of *A. planipennis* were collected in Moscow in 2003 and the Moscow Province is therefore thought to be a likely entry point to Europe. The pest spread along roads and railways and, by 2013, it was recorded in 11 provinces of Russia. The goal of this study was to clarify the current northern range limit of *A. planipennis*. To do this, ash (*Fraxinus excelsior* and *F. pennsylvanica*) trees were surveyed along the federal highway M10 (*Russia*) between Moscow and Saint Petersburg in July 2016. The condition of ash trees and presence of *A. planipennis* was recorded at 15 locations. We found dead ash trees with galleries of *A. planipennis* at six locations (56° 27.799' N; 36° 35.383' E to 56° 47.665' N; 36° 03.584' E). At the more north-western sites ash trees became infrequent and signs of *A. planipennis* were not observed on any ash tree. Beyond the National Park Valdayskiy (58° 00.095' N; 33° 08.550' E) no ash trees were observed for about 100 km. Further north in Leningrad Province, there were fragments of ash forests and many ash trees planted in parks in Saint Petersburg and its suburbs, but no signs of *A. planipennis* were seen. Results of this survey suggested that, for summer 2016, the north-west limit of *A. planipennis* was close to Tver City (about 56° 47' N; 36° 03' E). Further range expansion of *A. planipennis* may have been limited by low host density north-west of Tver City, rather than by climatic factors. However, if *A. planipennis* can overcome low host abundance and reach Saint Petersburg or other settlements with planted ash in Russia or abroad, it will likely cause serious damage, similar to that already observed in Moscow Province or North America.

Key words: *Agrilus planipennis*, ash, Buprestidae, Coleoptera, Emerald ash borer, forest health, forest pest insects, *Fraxinus*, invasive pest

Introduction

Emerald ash borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) is a very aggressive invasive beetle native to Asia. It was accidentally introduced to North America and central Russia in recent years (Haak et al. 2002, Baranchikov et al. 2008, Izhevskiy, Mozolevskaya 2010, Orlova-Bienkowskaja 2013a, 2013b, 2014, 2015, Straw et al. 2013, Herms & McCullough 2014, Volkovitsh, Mozolevskaya 2014, Musolin et al. 2017). The beetle can act as a primary stem pest of species of ash (*Fraxinus*), infesting the lower and middle parts of stems with thick and intermediate bark. Flight of *A. planipennis* occurs mostly in June and a full generation of the buprestid takes one or two years, depending on environmental conditions (Haack et al. 2015, Orlova-Bienkowskaja and Bieńkowski 2016). Susceptibility of species of ash to attack by the beetle is greater in open landscapes (along roads, in parks, etc.) compared to forest (Liu et al. 2003).

In Moscow Province and Moscow City (central Russia), *A. planipennis* has mostly been observed infesting, and quickly killing, 30–60 year old ash trees, including those planted in cities, along boulevards, roads, and in parks and gardens. All dying ash trees had the same sequence of symptoms: wilting began at the top of the tree and spread gradually downwards, until the entire crown was affected.

In European Russia, the first specimens of *A. planipennis* were collected in Moscow City in 2003 (Volkovitsh and Mozolevskaya 2014) and, thus, Moscow Province is thought to be the likely starting point for the invasive European range of this species. The pest easily spread along roads and railway lines, because ash trees are commonly planted along roads and railway lines. Efforts to control *A. planipennis* had been limited and control measures were implemented only recently and only in Moscow parks and boulevards. By 2013, the species was recorded in 11 administrative divisions (provinces) of Russia (Volkovitsh and Mozolevskaya 2014, Orlova-Bienkowskaja and Bieńkowski 2016, Musolin et al. 2017).

In Russia, ash forests are composed of European ash *Fraxinus excelsior* (L.), Caucasian ash *F. angustifolia* (Vahl), Chinese, or Korean, ash *F. chinensis* (Roxburgh), and Manchurian ash *F. mandshurica* (Hance) and they cover less than 0.1% of the total forest area of the country (Musolin et al. 2017). Russian ash forests located in the Russian Far East and in central and southern parts of European Russia cover 402 000 ha and 264 300 ha, respectively (State Forest Registry 2014, Musolin et al. 2017). Ash stands and individual planted trees play important role in urban landscaping and along roads. Green ash *Fraxinus pennsylvanica* Marshall was introduced from North America and now is also widely used for landscaping in cities and in shelterbelts. Emerald ash borer can feed on all ash species, but the pest is much more dangerous to North American and European ash species than to Asian ones (Baranchikov et al. 2014).

In Europe, ash is not a major forest tree species but it does play an important role in urban landscaping. Arrival of Emerald ash borer to Central and Western Europe can cause severe damage and even complete disappearance of ash from forest and urban ecosystems, especially taking into consideration the current problem with ash dieback caused by the pathogenic fungus *Hymenoscyphus fraxineus* (Musolin et al. 2017, Vasaitis and Enderle 2017).

Within European Russia, information is available on the rapid invasive range expansion of *A. planipennis* in western and southern directions (Orlova-Bienkowskaja 2014, 2015, Volkovitsh and Mozolevskaya 2014, Baranchikov et al. 2016a, 2016b), but less is known about the northward spread of the pest, i.e. towards Saint Petersburg and further towards Estonia and Finland.

The main goal of this study was to clarify the current situation with the northern range limit of the Emerald ash borer between Moscow and Saint Petersburg.

Materials and Methods

The most likely route for the Emerald ash borer to spread from central regions of European Russia to Saint Petersburg is the federal highway M10 (*Russia*) that runs between Moscow and Saint Petersburg. This is because the highway has a side planting of *F. excelsior* and *F. pennsylvanica* and numerous ash trees of these two species are planted in urban areas along the highway, whereas the surrounding forests are predominantly coniferous. In order to map the current northern limit of the pest's distribution, planted ash trees were surveyed along the federal highway between Moscow and Saint Petersburg during a two-day trip conducted on July 1–2, 2016 (Fig. 1, Table 1). Fifteen sites were surveyed between Klin town (Moscow Province) and Saint Petersburg. Stands of ash trees (10 trees or more) as well as individual trees were surveyed. Taking into consideration that both *F. excelsior* and *F. pennsylvanica* are susceptible to *A. planipennis* (Baranchikov et al. 2014), we surveyed all ash trees and recorded data on both species together. Dead trees and those displaying such symptoms as dieback or wilting were targeted; however, healthy trees growing nearby without any obvious symptoms of wilting were also examined to record possible early stage infestation. During the survey, factors recorded included: the state of the tree, tree diameter at breast height (1.3 m), the presence of adults and/or larval galleries of jewel beetles (Buprestidae), longhorn beetles (Cerambycidae), bark beetles (Curculionidae: Scolytinae) and other insects under the bark and in wood, the presence of emergence (= exit) holes of beetles and the presence of dead insects under the bark and in wood. Galleries of *A. planipennis* were distinguished from galleries of other *Agrilus* species by D-shaped

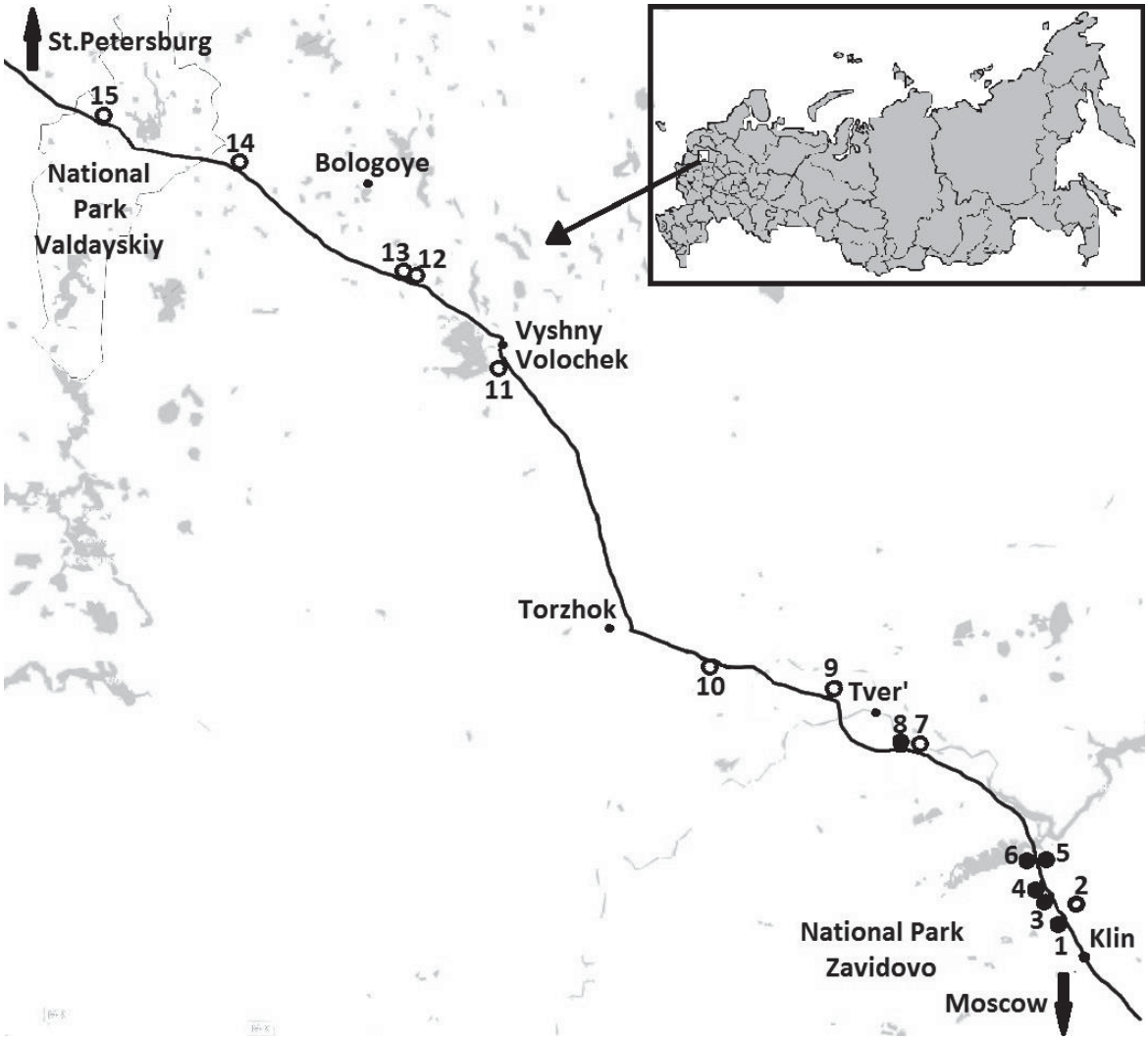

Figure 1. Locations of the inspection sites during the survey of ash trees along federal highway M10 (*Russia*) between Moscow and Saint Petersburg on July 1–2, 2016. Insert is a map of Russia with the region of the survey indicated as a white square. Closed circles indicate sites, at which *Agrilus planipennis* was recorded; open circles indicate sites at which this species was not recorded (see Table 1 for further details)

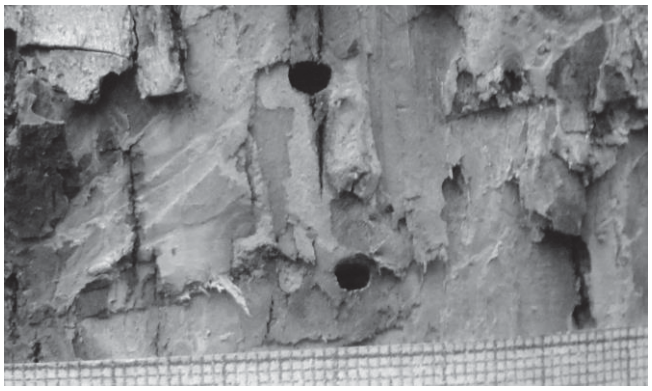

Figure 2. Typical D-shaped emergence holes of *A. planipennis* on an ash tree. Grid – 1 mm. July 1, 2016 (photo by B. G. Popovichev)

emergence holes and dimensions of the exit holes with the transverse diameter exceeding 3 mm (Fig. 2). This diameter is significantly greater than that of other *Agrilus* species breeding on ash in the region. The GPS coordinates of each site were recorded using a Garmin GPSmap 60Cx navigator (Table 1).

Results and Discussion

The survey began at Klin town (Moscow Province), where *A. planipennis* had already been recorded (Baranchikov 2013, Orlova-Bienkowskaja 2013a, 2013b, 2014, 2015, Volkovitsh and Mozolevskaya 2014). Numerous dead ash trees with galleries of *A. planipennis*

Table 1. Results of the survey of ash trees* along federal highway M10 (*Russia*) between Moscow and Saint Petersburg on July 1–2, 2016

Location №	Location coordinates (and name of a settlement, if appropriate)	Description of ash trees examined	Confirmed presence of *A. planipennis*	Insects recorded
1	56° 27.799′ N; 36° 35.383′ E	2 old dead trees; diameter 24 and 28 cm	Yes	Galleries of buprestids including *A. planipennis* but no adults or larvae of *A. planipennis* collected
2	56° 27.799′ N; 36° 35.383′ E	4 dying trees with dry crowns; diameter 16–28 cm	No	No buprestid galleries
3	56° 27.900′ N; 36° 35.275′ E (Spas-Zaulok)	3 dying trees with dry crowns; diameter 12–26 cm	Yes	Galleries of buprestids including *A. planipennis*, but no adults or larvae collected
4	56° 27.999′ N; 36° 35.160′ E (Spas-Zaulok)	2 dying trees; diameter 32 and 36 cm	Yes	Galleries of buprestids including *A. planipennis*
5	56° 34.765′ N; 36° 29.721′ E	1 dying tree; diameter 26 cm	Yes	1 D-shaped emergence hole of *A. planipennis*
6	56° 35.042′ N; 36° 29.550′ E (Bezborodovo)	13 old dead trees; diameter 36–44 cm	Yes	D-shaped emergence holes; dead adults of *A. planipennis*
7	56° 47.278′ N; 36° 04.909′ E (Pasinkovo)	100+ mostly healthy or weakened trees with only a few dying trees; diameter 16–44 cm	No	No galleries or other signs of infestation
8	56° 47.665′ N; 36° 03.584′ E	2 old dead trees; diameter 28 and 28 cm	Yes	Galleries of buprestids and typical D-shaped emergence holes of *A. planipennis* (Fig. 3)
9	56° 53.203′ N; 35° 46.357′ E (Tver)	hundreds of healthy trees; diameter 16–24 cm	No	No galleries or other signs of infestation
10	56° 58.649′ N; 35° 18.245′ E (Kolesnie Gorki)	100+ mostly weakened trees; diameter 16–24 cm	No	No galleries or other signs of infestation
11	57° 33.205′ N; 34° 34.911′ E (Vyshny Volochek)	100+ mostly healthy and weakened trees; diameter 16–24 cm	No	No galleries or other signs of infestation
12	57° 40.425′N; 34° 19.851′ E	100+ mostly healthy and weakened trees; diameter 16–24 cm	No	No galleries or other signs of infestation
13	57° 40.462′ N; 34° 19.723′ E (Bahmara)	40 alive trees and 4 old dead ash trees; diameter 32–48 cm	No	Entrance holes of *Hylesinus varius* with no galleries under the bark; holes of cerambycids and siricids; 3 dead *H. varius* beetles
14	57° 54.291′ N; 33° 38.188′ E (Endrovo)	100+ trees, mostly healthy and weakened; diameter 16–32 cm	No	No galleries or other signs of infestation
15	58° 00.095′ N; 33° 08.550′ E (Mironegi)	50 weakened and dying trees; diameter 12–28 cm	No	Siricid larvae in wood of two trees

*, both ash species (*F. excelsior* and *F. pennsylvanica*) were surveyed together (see Materials and Methods for details)

were observed around Klin town. Either typical D-shaped emergence holes of *A. planipennis*, its larval galleries or adults were observed at site 1 and sites 3 to 6 (Figs 1 and 2, Table 1). At site 2, four ash trees with heavy wilting symptoms were surveyed, but no galleries or emergence holes of buprestids were observed (Table 1). Dead ash trees with dead or alive basal shoots and with D-shaped emergence holes, characteristic of *A. planipennis*, were recorded up to the southern border of Tver City (close to site 8 at the settlement Pasinkovo, Fig. 3). At the same time, at sites 9–15 hundreds of healthy or weakened ash trees were examined, but no galleries or larvae/adults of *A. planipennis* were ob-

served (Fig. 1, Table 1). Hundreds of ash trees were also surveyed in Tver City (Fig. 1). The great majority of these trees were healthy. Small entrance holes were observed on a few dead ash trees in Tver, which were considered to be the result of unsuccessful infestation attempts by *Hylesinus varius* (F.) (Curculionidae, Scolytinae). Neither emergence holes nor galleries of buprestids were observed in Tver City, despite the recent record of *A. planipennis* in a south-eastern district of the city (Peregudova 2016).

Figure 3. Dead ash trees along the federal highway M10 (*Russia*) between Moscow and Saint Petersburg, near settlement Zavidovo. July 1, 2016 (photo by B. G. Popovichev)

North-west from Tver City, stands of ash trees became infrequent, with distances of about 20–30 km between neighboring groups of trees. There were only individual old ash trees. No ash trees in this area had any symptoms of presence of *A. planipennis*.

A stand of ash trees in the Bakhmara settlement (site 13) consisted of 40 alive and 4 old dead ash trees (Table 1). Entrance holes of *H. varius* were observed on the bark of the dead trees, but no galleries of any beetles were observed under the bark. Three dead individuals of *H. varius* were observed on the bark of these trees. In addition, entrance holes of cerambycids and siricids were also recorded (Table 1).

North of site 12, many planted ash trees were observed, but most of them were healthy without any symptoms of dieback or infestation.

North of sites 14 and 15 (near National Park Valdayskiy), no ash trees were recorded for about 100 km. However, ash might grow inside numerous small settlements along the federal highway. In any case, this gap in the planted ash along the highway might represent a relatively natural barrier slowing the spread of *A. planipennis* further towards the north-west.

The next region along the highway was Leningrad Province where there were fragments of natural ash forests (between Baltic Sea and Ladoga Lake, e.g., in villages Koporje and Orzhitsy) and also many ash trees planted in the historical parks of Saint Petersburg's suburbs (including Alexandrovskiy Park in Pushkin and the park in New Peterhof). In addition, there are many planted ash trees in Saint Petersburg: at Mozhayskaya railway station at Duderhof Heights, Primorskiy Park of Victory, Vyazemsky Boulevard, along large roads at the beginning of Gostilitsy highway, Bolshoy Prospect of Vasilievsky Island and so on. At most of these locations, different symptoms of ash decline have been seen, however, the presence of *A. planipennis* has not been recorded up to date. The major cause of ash death in Leningrad Province is attacks by *Hylesinus crenatus* (F.) and *H. varius*. It is also possible that the initial decline might be caused by the pathogenic fungus *Hymenoscyphus fraxineus*, which was recorded in Saint Petersburg in 2011 (Shabunin et al. 2012, Selikhovkin et al. 2012, Selikhovkin and Musolin, 2013, Musolin et al. 2017).

It should be noted that all ash trees with entrance holes or galleries of *A. planipennis* along the federal highway (Table 1) were most likely infested and critically damaged by this pest in 2015 or earlier. We failed to find fresh infestations of 2016. Rich food potential in the form of numerous ash trees towards the north of Tver City is not used by the buprestid. Our data are in accordance with the observations of Peregudova (2016), who record *A. planipennis* only in the southern parts of Tver City in 2016. Thus, we believe, that the latest advance of the range limit of *A. planipennis* towards north-west took place not later than in 2015, when the species reached south-west districts of Tver City.

Somewhat similar slowing down of the outbreak dynamics was noted in Moscow City and Moscow Province, where after devastating outbreak and expansion of *A. planipennis* in 2003–2014, abundance of the buprestid declined in 2015 due to so far unknown reasons. At the same time, the invasive range expansion actively continues in the southward direction (Baranchikov et al. 2016b).

It might be speculated that the northward range expansion has slowed down because the range had reached its thermal limits. However, it was recently suggested that temperature is not a limiting factor for the Emerald ash borer's range expansion: the highly flexible seasonal cycle of *A. planipennis* might allow this species to move behind the northern limit of ash's continuous range (Afonin et al. 2016). Some slowdown of range expansion might be caused by activity of parasitoids or other so far unidentified factor(s) (Musolin et al. 2017).

Conclusions

Results of the present survey suggest that, for summer 2016, the north-west limit of *A. planipennis* was close to Tver City (about 56° 47' N; 36° 03' E; Fig. 1, Table 1) and this limit has not advanced northward since 2015. Further range expansion of *A. planipennis* may have been limited by low host density north-west of Tver City, rather than by climatic factors. However, if *A. planipennis* can overcome low host density and reach Saint Petersburg or other large cities or small settlements with planted ash in Russia or abroad, it will likely cause serious damage similar to that recorded in Moscow Province or North America in the early 2000s.

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References

Afonin, A. N., Musolin, D. L., Egorov, A. A., Selikhovkin, A. V. 2016. Possibilities of further range expansion of the emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae) in the North-West of European Russia: What factors will limit the invasive range? UArctic Congress 2016. Abstract Book. (Edited by O. Moilanen): Saint Petersburg (Russia), p. 100.

Baranchikov, Yu. N. 2013. Баранчиков, Ю. Н. ЕАВ – ведущая аббревиатура в Европейской лесозащите в первой половине текущего столетия [EAB – a leading acronym in European forest protection in the first half of the current century]. The Kataev Memorial Readings – VII. Pests and Diseases of Woody Plants in Russia. Proceedings of international conference (Edited by D. L. Musolin and A. V. Selikhovkin). Saint Petersburg (Russia): Saint Petersburg State Forest Technical University, p. 8-9. (in Russian).

Baranchikov, Yu. N., Demidko, D. A. and Seraya, L. G. 2016a. Баранчиков, Ю. Н., Демидко, Д. А. и Серая, Л. Г. Спросить у ясеня: определение скорости расширения вторичного ареала ясеневой узкотелой златки при помощи перекрестного дендрохронологического датирования [To ask an ash tree: Determination of the rate of secondary range expansion in emerald ash borer using a dendrochronological cross-dating method]. Monitoring and biological control methods of woody plant pests and pathogens: From theory to practice. Proceedings of international conference (Edited by Yu. N. Baranchikov). Krasnoyarsk (Russia): Institute of Forest (RAS), p. 23-24 (in Russian).

Baranchikov, Y. N., Demidko, D. A., Zvyagintsev, V. B., Seraya, L. G. and Yaruk, A. V. 2016b. Баранчиков, Ю. Н., Демидко, Д. А., Звягинцев, В. Б., Серая, Л. Г. и Ярук, А. В. На запад поехал один из них, а на восток – другой? [Did one of them move westwards, while another – eastwards?]. Invasive Far eastern ash consumers in European part of Russia. Intensification of the Russian forest management: Problems and innovative solutions. Proceedings of the All-Russian conference (Edited by Yu. N. Baranchikov et al.). Krasnoyarsk (Russia): Institute of Forest (RAS), p. 27–28.

Baranchikov, Yu., Mozolevskaya, E., Yurchenko, G. and Kenis, M. 2008. Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. *EPPO Bulletin* 38: 233-238.

Baranchikov, Yu. N., Seraya, L. G. and Grinash, M. N. 2014. Баранчиков, Ю. Н., Серая, Л. Г. и Гринаш, М. Н. Все виды европейских ясеней неустойчивы к узкотелой златке *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) − дальневосточному инвайдеру [All European ash species are susceptible to emerald ash borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) – a Far Eastern invader]. *Siberian Forest Journal* 6: 80-85. (in Russian with English summary).

Haack, R. A., Baranchikov, Yu., Bauer, L. S. and Poland, T. M. 2015. Emerald ash borer biology and invasion history. In: R. Van Driesche, J. Duan, K. Abell, L. Bauer and J. Gould, Biology and control of emerald ash borer. FHTET-2014-09, USDA Forest Service, Forest Health Technology Enterprise Team: Morgantown, p. 1-13.

Haack, R. A., Jendek, J. E., Liu, H., Marchant, K. R., Petrice, T. R., Poland, R. M. and Ye, H. 2002. The emerald ash borer: a new exotic pest in North America. *Newsletters of the Michigan Entomological Society* 47: 1-5.

Herms, D. A. and McCullough, D. G. 2014. Emerald ash borer invasion of North America: History, biology, ecology, impacts, and management. *Annual Review of Entomology* 59: 13-30.

Izhevskii, S. S. and Mozolevskaya, E. G. 2010. *Agrilus planipennis* Fairmaire in Moscow ash trees. *Russian Journal of Biological Invasions.* 1(3): 153-155.

Liu, H. P., Bauer, L. S., Gao, R. T., Zhao, T. H., Petrice, T. R. and Haack, R. A. 2003. Exploratory survey for the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), and its natural enemies in China. *The Great Lakes Entomologist*, 36: 191-204.

Musolin, D. L., Selikhovkin, A. V., Shabunin, D. A., Zviagintsev, V. B. and Baranchikov, Yu. N. 2017. Between ash dieback and emerald ash borer: two Asian invaders in Russia and the future of ash in Europe. *Baltic Forestry* 23(1): 316-333.

Orlova-Bienkowskaja, M. J. 2013a. Dramatic expansion of the range of the invasive ash pest, buprestid beetle *Agrilus planipennis* Fairmaire, 1888 (Coleoptera, Buprestidae) in European Russia. *Entomological Review* 93: 1121-1128.

Orlova-Bienkowskaja, M. J. 2013b. Орлова-Беньковская М. Я. Ясеневая изумрудная узкотелая златка (*Agrilus planipennis*) расселилась по девяти областям европейской России: от Ярославля до Воронежа [Emerald ash borer (*Agrilus planipennis*) has spread over nine administrative regions (provinces) of European Russia: from Yaroslavl' to Voronezh]. The Kataev Memorial Readings – VII. Pests and Diseases of Woody Plants in Russia. Proceedings of international conference (Edited by D. L. Musolin and A. V. Selikhovkin). Saint Petersburg (Russia): Saint Petersburg State forest Technical University, p. 65-66. (in Russian).

Orlova-Bienkowskaja, M. J. 2014. Ashes in Europe are in danger: the invasive range of *Agrilus planipennis* in European Russia is expanding. *Biological Invasions* 16, 1345-1349.

Orlova-Bienkowskaja, M. J. 2015. Cascading ecological effects caused by establishment of the emerald ash borer *Agrilus planipennis* in European Russia. *European Journal of Entomology* 112: 778-789.

Orlova-Bienkowskaja, M. J. and Bieńkowski, A. O. 2016. The life cycle of the emerald ash borer *Agrilus planipennis* in European Russia and comparisons with its life cycles in Asia and North America. *Agricultural and Forest Entomology* 18(2): 182-188.

Peregudova, E. Yu. 2016. Перегудова, Е. Ю. Первые находки златок *Agrilus planipennis* в Твери и *Agrilus convexicillis* в Тверской области [First records of buprestids *Agrilus planipennis* in Tver and *Agrilus convexicollis* in Tver Region]. The Kataev Memorial Readings – IX. Dendrobiotic Invertebrates and Fungi and their Role in Forest Ecosystems. Proceedings of the international conference (Edited by D. L. Musolin and A. V. Selikhovkin). Saint Petersburg (Russia): Saint Petersburg State forest Technical University, p. 82-83. (in Russian).

Shabunin, D. A., Semakova, T. A., Davydenko, E. V. and Vasaitis, R. A. 2012. Шабунин, Д. А., Семакова, Т. А., Давиденко, Е. В. и Васаитис, Р. А. Усыхание ясеня на территории памятника природы «Дудергофские высоты», вызванное грибом *Hymenoscyphus pseudoalbidus*, и морфологические особенности его аскоспор [Ash decline in the nature monument Dudergof Heights, caused by the fungus *Hymenoscyphus pseudoalbidus*, and morphological features of its ascospores]. *Proceedings of the Saint Petersburg Forest Research Institute* 1-2: 70-79. (in Russian with an English summary).

Selikhovkin, A. V. and Musolin, D. L. 2013. Селиховкин, А. В., Мусолин, Д. Л. *Hymenoscyphus pseudoalbidus* (Ascomycetes) – новый опасный патоген ясеня в России [*Hymenoscyphus pseudoalbidus* (Ascomycetes), a new dangerous pathogen of ash in Russia]. The Kataev Memorial Readings – VII. Pests and Diseases of Woody Plants in Russia. Proceedings of international conference (Edited by D. L. Musolin and A. V. Selikhovkin). Saint Petersburg (Russia): Saint Petersburg State forest Technical University, p. 83-84. (in Russian).

Selikhovkin, A. V., Musolin, D. L. and Lukmazova, E. A. 2012. Situation with ash in Russian Federation: stand characteristics, health condition, ongoing work and research needs. COST ACTION FP1103 FRAXBACK (*Fraxinus* dieback in Europe: elaborating guidelines and strategies for sustainable management) 1st MC/WG Meeting. Program and Abstracts. Vilnius (Lithuania), p. 32-33.

State Forest Registry of the Russian Federation 2013 [Государственный лесной реестр 2013]. 2014. Ministry of Natural Resources and Ecology, Moscow, 690 pp. (in Russian). Available: http://www.forestforum.ru/in fo/glr_2014.pdf (accessed: 19 January, 2016)

Straw, N. A., Williams, D. T., Kulinich, O. and Gninenko, Y. I. 2013. Distribution, impact and rate of spread of emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae) in the Moscow region of Russia. *Forestry* 86: 515-522.

Vasaitis, R. and Enderle, R. (editors). 2017. Dieback of European Ash (*Fraxinus* spp.) – Consequences and Guidelines for Sustainable Management. The Report on European Cooperation in Science & Technology (COST) Action FP1103 FRAXBACK. SLU Service/Repro, Uppsala, 2017. 320 pp.

Volkovitsh, M. G. and Mozolevskaya, E. G. 2014. Волкович, М. Г. и Мозолевская, Е. Г. Десятилетний «юбилей» инвазии ясеневой изумрудной узкотелой златки *Agrilus planipennis* Fairm. (Coleoptera: Buprestidae) в России: итоги и перспективы [The tenth «anniversary» of the invasion of emerald ash borer *Agrilus planipennis* Fairm. (Coleoptera: Buprestidae) in Russia: results and prospects]. *Izvestia Sankt-Peterburgskoj Lesotehniceskoj Akademii (Transactions of the Saint Petersburg Forest Technical Academy)* 207: 8-19 (in Russian), 268-269 (English synopsis).