Horse-chestnut leafminer *Cameraria ohridella*: invasion history and prognosis

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**Abstract.** This work summarizes all known data on the distributive history of *Cameraria ohridella* in Europe and in Russia with special reference to current process of invasion to different regions of Russia and prognosis on its future spread through Russian territories. The invasion of the pest started in 1980s and to the present time *Cameraria ohridella* had occupied the most part of Europe. During last ten years from 2010 to 2020, *Cameraria ohridella* occupied 11 oblasts of the European Russia and was discovered in Kyrgyzstan and Kazakhstan. The main host trees of the pest are trees from the genus *Aesculus*. However, in the focus locations of invasion, the pest damages other trees growing near chestnuts. The data on biology of *Cameraria ohridella* showing that its larvae as a rule perish within the first two instars in case of development for example on *Acer pseudoplatanus* trees, give us confidence that the distributive range of the pest is restricted to the area of chestnut and locations of its decorative use.

1. **Introduction**

*Cameraria ohridella* [1], or horse-chestnut leaf miner or ohrid leaf mining moth (*Lepidoptera, Gracillariidae*) is a serious invasive insect pest which destroys leaves of chestnut *Aesculus hippocastanum* and other species of this plant genus. The trees defoliate to the middle of summer. The attack of this pest causes aesthetic damage to horse-chestnut, one of the favourite ornamental trees in many countries. As a result, some countries like Germany decided to abandon the use of chestnuts as a decorative culture for estimated losses might be several million euro. *Cameraria ohridella* has occupied a large portion of Europe to the present time (CABI, 2020) and is rapidly spreading to different regions of Russia [2–4]. This work summarizes all known data on the distribution of the pest in Europe and in Russia with special reference to current process of invasion to different regions of Russia and prognosis on its future spread on Russian territories.

2. **Materials and methods**

Data on the distribution of *Cameraria ohridella* in Europe were obtained by analyzing publications on the distribution of the insects and various aspects of its economic significance. The main sources of information were publications on damage and distribution of the pest. Although these data were present in CABI database, they cannot be considered complete because the data on the distribution of *Cameraria ohridella* in Russia were practically absent in this source. Data from published resources
(books and articles) were added from personal observations on the ecology of the pest in Moscow oblast in 2015–2019.

3. Stages of introduction and invasion history

*Cameraria ohridella* [1 or horse-chestnut leaf miner or ohrid leaf mining moth (*Lepidoptera, Gracillariidae*) was described based on material collected at the Ohrid Lake in Macedonia (hence its specific name). The horse-chestnut leafminer was collected and accidentally pressed in herbarium sheets by the botanist Theodor von Heldreich in Central Greece in 1879 [5] however it was first observed seriously damaging *Aesculus hippocastanum* in Macedonia in the 1970s, and described as a new species in 1986 only [1, 6]. A year later, in 1987, it was found in Serbia and in 1989 it was discovered in Austria, from where it spread to most of Europe.

Macedonia and Albania were reported to be the moth’s native range [7] although some authors supposed that the native area of this pest might be Eastern Asia or North America. Recent molecular studies and observations of ancient herbarium collections now suggest that the moth originates from some remote natural horse-chestnut stands in the Balkan mountains of Macedonia, Albania and Greece and that it has moved to urban areas in these countries in the second half of the 20th century [5, 8]). In Macedonia, Albania and Greece, the moth was considered to be native and not invasive in natural habitats in which the damage was less severe [9] but it became invasive in urban areas since 1996 (Greece) [7].

The further introduction history of this species in European countries was as follows: Bulgaria (1983); Montenegro (1987); Italy (1992); Bosnia and Herzegovina (1993); Hungary and Germany (1994); Slovenia and Croatia (1995); Slovakia and Greece (1996); Czech Republic (1997); Poland and Romania (1998); Switzerland and the Netherlands (1999); Belgium and France (2000); Denmark, United Kingdom, Latvia, Lithuania, Sweden, Spain, Ukraine (2002); Belarus, Luxembourg, Moldova (2003); European part of Turkey (2004); Finland (2006); Ireland and Norway (2013); Estonia (2016) (see map).

In Russia, the horsechestnut leafminer was first recorded in the Kaliningrad oblast in 2003; in Moscow, it was detected in 2005. In 2007, the moth appeared in the Moscow oblast and Saint Petersburg. It had spread to the Rostov, Belgorod, Voronezh, Volgograd and Ryazan oblasts by 2008; to the Kursk, Bryansk and Orel oblasts by 2009, to the Crimea, Adygea Republic, Krasnodar and Stavropol oblasts by 2010; Smolensk oblast (2010); Kaluga oblast (2012), Penza oblast (2012–2014); Pskov oblast (2012); Jaroslavl oblast (2013); Ivanovo, Tula, Vladimir, Lipetsk Oblasts (2014), Saratov oblast (2016); Tambov and Tver oblast (2018) [2–4, 10–13].

The range of the horsechestnut leafminer is expanding due to frequent usage of the horse chestnut for decorative purposes in urban and suburban areas in Europe and Asia. It was discovered in Kyrgyzstan in 2015 and Kazakhstan in 2016 [14, 15].

4. Biology, pathways and vectors of invasions

The horsechestnut leafminer lives on various species of chestnuts (mostly horse chestnut *Aesculus hippocastanum* and Japanese horse-chestnut *Aesculus turbinata* but some other *Aesculus* spp. are attacked too, among them are yellow buckeye *Aesculus flava*, Texas buckeye *Aesculus glabra* and Painted buckeye *Aesculus sylvatica* in natural conditions and artificial plantings. In addition, *C. ohridella* is occasionally found attacking and developing on maple trees *Acer pseudoplatanus* and *A. platanoides*, where damage levels may be as high as on horse chestnut [16]. These authors think that it cannot be ruled out that the damage to maple will increase with time because the pest is supposed to look for and find suitable new host trees when horse-chestnut trees are completely defoliated.

The greatest damage to trees is caused by caterpillars of the horsechestnut leafminer, which graze only on the internal tissues of the leaf staying hidden under the epidermis. Caterpillar survival is extremely high since they are not washed off by rain and are protected from insecticides. The horsechestnut leafminer goes through two-three generations gradually destroying the foliage of the tree. The imago's search abilities for a host tree are extremely high. Inspection of the chestnuts in the
Shakhovsky district of the Moscow oblast in 2016–2018 showed 100% infestation so that even solitary chestnut seedlings with several leaves, hidden in dense stands, were damaged.

Larvae of *C. ohridella* develop in the parenchyma tissue of leaves of *Aesculus hippocastanum*, the observer can see many transparent or brownish mines on the leaf. The first generation damage the leaflets to varying degrees, however in May-June the half and more of their surface in the lower third of the crown can be damaged. The next generation enhances impact and the mines cover the entire surface of the lowest leaflets and significant surface of them in the mid and high two-thirds of the crown. This effect is typical for July. We did not observe the third generation in Moscow oblast. The trees were defoliated at the end of July.

The fast dispersal of the moth, which spread from Macedonia to most of Europe in less than 20 years, is attributed mainly to human transport, which carry adults and overwintering pupae in dead leaves [17]. Some long-distance unintentional introductions have been attributed to the transportation of infested seedlings [18]. The natural dispersal capacity of adults is poorly known. The moth is able to spread by natural flight only over short distances, yet the adults can disperse over longer distances by ascending airflows. Within cities, the moth probably disperses by flight and in dead leaves that are blown away [19] and probably also by tree waste disposal.

**Figure 1.** Map of distribution of *Cameraria ohridella* Deschka & Dimic, 1986 in 1980s–2020

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5. Impact on other plant species, humans and control measures

Salleo et al. [20] conducted research in Italy and made conclusions that the impact of *Cameraria ohridella* caterpillars on tree survival and tree growth in urban areas is minimal or absent. Furthermore, in the Balkans trees still survive after more than 20 years of heavy outbreak. This would suggest that there is no immediate danger for the tree. However, in Germany, *C. ohridella* is suspected to cause the decline of horse-chestnut because defoliation induces a second flowering, decreasing frost hardness [21]. Reinhardt et al. [22] estimated that the additional leaf removal In Germany, caused by *C. ohridella*, costs about 8 million Euro per year. Despite a low risk for the survival of the trees in urban areas, the aesthetic damage is so severe that many municipalities are replacing this highly valuable tree by other species. The replacement costs for the all horse-chestnut trees in Germany would be as high as 10.7 billion.

The additional negative effect is that the horsechestnut leafminer can infest not only the species of the genus *Aesculus* but also maple trees (*Acer*) and occasionally Virginia creeper (*Parthenocissus quinquefolia*). Hence, the insect lowers the aesthetic effect of other green spaces.

Some representatives of Gracillariidae family, e.g. poplar moth *Phyllonorycter populifoliella*, can cause human allergic reactions, but there have been no special evidences for allergies caused by the horsechestnut leafminer *C. ohridella* [23].

In Europe, entomologists study natural enemies of the moth to use them for biological control. Predators, parasitoids and entomopathogenic fungi have been recently established and their usage (mainly fungi) for controlling the moth are under elaboration. Despite the high extent of infestation of the horsechestnut leafminer with parasites (to 66.7 %), this was not enough to keep the numbers of the moth at an economically insignificant level [24]. One of the preventive methods against horsechestnut leafminer is to make insecticidal injections or spray tree crowns by long-acting insecticides. Application of this method is desirable in May-June. It is also important to collect and eliminate fallen leaves. If the moth has already attacked the trees, besides above methods, the trees must be treated with fungicides because horsechestnut leafminer commonly infests a tree with dangerous fungal diseases. Fungicides are used to treat the crown from the outside or are injected directly into the trunk. Some countries of Europe completely cut down chestnuts in urban plantings and replace them with other tree species.

In Moscow, in those places where the foliage was removed, the chestnuts remained green until September. Defoliation caused annually by *Cameraria ohridella* has a considerable impact on the general condition of horse chestnut trees. In all invaded regions, outbreaks are regular and the pest causes aesthetic damage to horse-chestnut, one of the favorite ornamental trees in many countries.

6. Prognosis of the further spread of *Cameraria ohridella* in Russia

The range of the horsechestnut leafminer was lately constrained in the east by the territories of the European countries and the European part of Russia, however, the recent records of the pest in Kazakhstan and Kyrgyzstan have demonstrated its ability to further expand the range. To date, chestnut moth has almost completely occupied Europe.

As for the territory of Russia, we see that the invasion of chestnut moth is actively continuing to the east. Given the resistance of horse chestnut to frost and its widespread usage in urban plantings, including private gardens, we can expect further spread of the horsechestnut leafminer due to the transfer of the pest with the chestnut seedlings.

We expect the distribution of *Cameraria ohridella* by natural dispersal (by flight and blown away leaves) for short distances as well as by unintentional introduction by human with tree waste and infested seedlings for long distances. We suppose that the pest will soon appear in Novgorod, Nizhny Novgorod and other adjoining oblasts in case of distribution horse-nut trees there as decorative tree. The data on biology of *Cameraria ohridella* showing that its larvae as a rule perish within the first two instars in case of development on *Acer pseudoplatanus* trees [16] give us confidence that the distributive range of the pest is tied to chestnut only.
Acknowledgements
This study was supported by the Russian Science Foundation (project no. 16-14-10323).

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