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Analysis of the phytosanitary risk of the pest *Agrilus planipennis* Fairmaire, 1888 for tree species in Bulgaria

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Summary

Bulgaria is characterized by the fact that it is one of the richest countries in plant diversity in Europe - more than 4,200 higher plant species and about 3,700 species of algae and mosses have been described. On the country territory you can see the last deposits in Europe of a number of rare plant species, as well as another 170 Bulgarian and 200 Balkan endemics.

For this reason, the introduction, establishment and spread of new species of plant enemies is a critical moment for the conservation of our nature.

Precisely such a species is *Agrilus planipennis*, which is an East Asian species for which there is currently no evidence of being present in the European Union (EU) territory and in the analyzed threatened area.

A. planipennis spreads naturally and through human-assisted routes, such as infested ash logs, firewood and nursery plants. Other potential routes of entry have been identified, such as: wood, sawdust, mulch (composted and uncomposted), and the probability of entry of this enemy is considered moderate.

A. planipennis has been added to the A2 list of pests recommended for regulation as quarantine for the EPPO region, meaning that the pest is locally present in the EPPO region. It is also a Union quarantine pest listed in Part A of Annex II to Commission Implementing Regulation (EU) 2019/2072 and a priority pest under Commission Delegated Regulation (EU) 2019/1702, which obliges Member States to carry out annual surveys.

Bulgaria falls into an area with suitable eco-climatic conditions for establishment, i.e. in case of possible penetration into the country, the risk of establishing *A. planipennis* is high.

Its current distribution in N. America and European Russia, as well as its native range in Asia, suggests that this species can survive winter at temperatures well below freezing. For this reason, low temperatures in winter are not expected to have a negative impact on the establishment and spread of *A. planipennis* in Bulgaria, since this species has established itself in areas with much lower temperatures than those in the country (for example, the Moscow region). Given the climatic changes in Bulgaria and the trend towards warming in most regions of the country, and the forecast for milder winters in the coming decades, it is assumed that the conditions will be increasingly suitable.

If established and spread, the pest is likely to cause major ecological losses and impacts, as well as some social effects. Long-distance spread will be via human-assisted pathways, and its natural spread will occur, but at a slower rate.

In the event of the introduction, establishment and spread of *A. planipennis* in the country, it could have a negative impact, especially in the areas where the different species of ash are found, and its destruction or containment will be difficult and expensive, and it is unlikely that it would be successful.

Keywords: *Agrilus planipennis, Emerald ash borer, Buprestidae, Bulgaria, pest*

1. Pest

Agrilus planipennis (Fairmaire, 1888) is a phytophagous beetle of the order *Coleoptera*, family *Buprestidae,* genus *Agrilus*, native to eastern Asia, which was accidentally introduced into North America and European Russia (Haack et al. 2002, Liu et al., 2003 ; Baranchikov et al., 2008, Evans et al., 2020). Its native range includes China (Beijing, Hebei, Heilongjiang, Jilin, Liaoning, Shandong, Tianjin and Xinjiang provinces), Russian Far East (Khabarovsk and Primorsky krai), and the Korean peninsula (Orlova-Bienkowskaja and Volkovitsh, 2018). Since its discovery in the US in 2002, *A. planipennis* has spread quickly throughout eastern and mid-western North America, with data showing that the pest is currently found in 35 eastern and mid-western US states and five Canadian provinces (USDA APHIS PPQ, 2020).

At the moment, the distribution of *A. planipennis* in Europe is currently restricted to 16 regions of the Russian Federation and to the Luhansk Oblast province in Ukraine, where outbreaks are under attempt of eradicationas. (CABI, 2019a; EPPO, 2020; Orlova-Bienkowskaja et al ., 2020).

A. planipennis is currently not known to occur in the European Union (EU).

Adults – *A. planipennis* (Figure 1.) are metallic violet-blue or green in color, with purple-red metallic abdominal segments below the elytra. The pronotum and head are often honey-red. The minimum body size is 7.5 mm, but it is usually about 12 to 15 mm and is typical of the genus *Agrilus* (elongated, bullet-like). **Eggs** – *A. planipennis* eggs are bright to brownish yellow, oval in shape and 0.6 to 1 mm in size. **Larvae** – The mature larva is creamy white, 26 to 32 mm in size. **Pupae** – Pupae are creamy white color, 10 to 14 mm in size.

Biology and life cycle

A. planipennis usually completes one generation per year, but in colder climates, lower insect densities on healthy and less susceptible host trees, or when oviposition is late in the season, individuals with a two-year life cycle may be observed (Cappaert et al., 2005; Wei et al., 2007; EPPO, 2013a; Herms and McCullough, 2014), including in Europe (Orlova-Bienkowskaja and Bieńkowski, 2016).

Figure 1. Adult specimen of *A. planipennis, EPPO Global Database, Agrilus planipennis(AGRLPL)* – https://gd.eppo.int/taxon/AGRLPL/photos

To complete one generation per year, *A. planipennis* requires at least 150 frost-free days (with minimum temperatures above 0°C) (Wei et al., 2007) and an accumulation of 450 degree days (base temperature 10°C) before emergence adult beetles (USDA APHIS PPQ, 2018; Herms et al., 2019).

In situations where development lasts a year, adults begin to emerge in late spring or early summer, larvae develop in summer and fall, the pest overwinters as a fourth-instar larva or pre-pupa, and pupation occurs in the spring of the following year. In situations where it takes two years to complete one generation, the young larvae (first to third instars) overwinter in the cambial zone and resume feeding in the spring of the following year. These individuals overwinter a second time as fourth instars, or pre-pupae, then pupate and emerge host trees as adult beetles the following year. The proportion of individuals completing development in more than one year depends on when the eggs are laid in the summer months, the local climate and the condition of the host. Prolonged larval development is more common in healthy trees and low density of *A. planipennis* on the infested tree (Siegert et al., 2010).

In the one-year development cycle, adults emerge from host trees in spring or early summer, feed on ash leaves (an obligate feeding necessary for the species to reach sexual maturity), and mate. Mated females lay individually or in small groups on the bark surface, but most often in bark cracks, one female laying from 68 to 90 eggs (Haack et al., 2002). Eggs are usually laid on living trees, but have occasionally been observed laying on freshly felled ash logs, although these larvae rarely complete their development (Petrice & Haack, 2006; Anulewicz et al. 2008).

A. planipennis eggs hatch within 2 weeks of oviposition, after which first-instar larvae penetrate the bark and feed on phloem and cambial tissue during summer and autumn, moulting three times until they reach the fourth instar. The larvae dig galleries (up to 26 – 32 cm long) that are S-shaped and filled with excrement.

A. planipennis larvae overwinter as pre-pupae in the outer wood or thicker parts of the bark of larger trees.

In the following spring they pupate, the pupae being located on the outer part of the sapwood or bark, at the end of the larval gallery. When the bark is thin, the pupae are mostly found in the sapwood.

After pupation, adults remain under the bark for 1 – 2 weeks, then emerge through D-shaped holes (3 – 4 mm wide). After emerging, they feed on the leaves of their host. Adults are active during the day, and at night they are located on the leaves. When conditions are not favorable for flight, adults are found in bark cracks and on leaves. In the laboratory, it was found that under favorable conditions the life cycle of adult females averaged 63 days (with a range of 28 to 120 days), during which they laid an average of 74 eggs, while adult males lived an average of 43 days (with a range of from 12 to 83 days).

Damage

A. planipennis causes serious direct damage by killing ash trees, resulting in loss of forest products, and economic losses from the damaged timber (McKenney et al., 2012).Adults feed on the leaves of their host throughout their lives, beginning to feed and fly soon after hatching. The larvae carve larval galleries, which leads to a decrease in the quality of the wood.

In its native range, *A. planipennis* prefers to attack stressed trees, although it also attacks healthy trees, especially in the introduced area. In addition to direct damage, this species also has an impact on the environment (ecosystem services, landscape) and social impacts (need to remove trees, impact on culture and traditions, reduced value of sites, loss of aesthetic value due to the removal of damaged ornamental trees in the landscape etc.) (Kovacs et al. 2010; Lyons & Scarr, 2010).

Symptoms

Signs of *A. planipennis* infestation include: D-shaped exit holes, larval galleries characteristic of the genus *Agrilus*, yellowing and subsequent premature browning of leaves, crown thinning, dying of branches, longitudinal splitting of the bark with larval galleries underneath, injury from woodpeckers on infested trees (usually in North America and European Russia). All life stages (except adults) are hidden (eggs in bark cracks; larvae, pre-pupae and pupae in bark or sapwood, making them difficult to detect. Infested trees do not present obvious symptoms until they are heavily attacked.

Symptoms may remain latent for 2 – 3 or more years after the initial attack, especially if the infestation starts in the upper part of the tree (Ryall et al., 2011).

Currently, there is no reliable and single method for detecting low levels of *A. planipennis* populations. Monitoring usually relies on several methods, most often a combination of trapping, visual inspection of trees, and branch or tree sampling.

Host range

Agrilus planipennis primary hosts are ash trees, *Fraxinus* species (*Oleaceae*) (Jendek and Poláková, 2014). All native European ash species *F. excelsior*, *F. angustifolia* (syn. *F. oxycarpa, F. oxyphylla*) and *F. ornus* are confirmed as susceptible hosts (EFSA PLH Panel, 2011; EPPO, 2013a; Baranchikov et al., 2014; Herms, 2015).

In its place of origin (East Asia), host plants include Asian Manchurian ash (*F. mandshurica*) and *F. chinensis*. All ash species native to North America, including American ash (*F. americana*), *F. nigra*, Pennsylvania ash (*F. pennsylvanica*) and Arizona ash (*F. velutina*), are also suitable hosts (Herms, 2015; Orlova-Bienkowskaja and Volkovitsh, 2018).

In the literature, species of elm (*Ulmus*, *Ulmaceae*), walnut (*Juglans*, *Juglandaceae*) and pterocarya (*Pterocarya*, *Juglandaceae*) have been described as potential hosts in Asia, but this has not been confirmed (Cipollini and Peterson, 2018; Orlova-Bienkowskaja and Volkovitsh, 2018).

In North America, China and European part of Russia, *A. planipennis* has been reported to complete its life cycle only on *Fraxinus* spp. (Yu, 1992; Liu et al., 2003), while in Korea, it was observed only in *Ulmus davidiana* var. *Japonica*.

2. Distribution

According to the information from the global database of the European and Mediterranean Plant Protection Organization (EPPO) as of 26.01.2024, *A. planipennis* is present in Asia (China, Japan and South Korea), Europe (the European part of Russia and the Russian Far East - Khabarovsk and Primorsky Krai and Ukraine) and America (USA and Canada).

At this moment, there is no evidence that *A. planipennis* is present on the territory of the EU and Bulgaria.

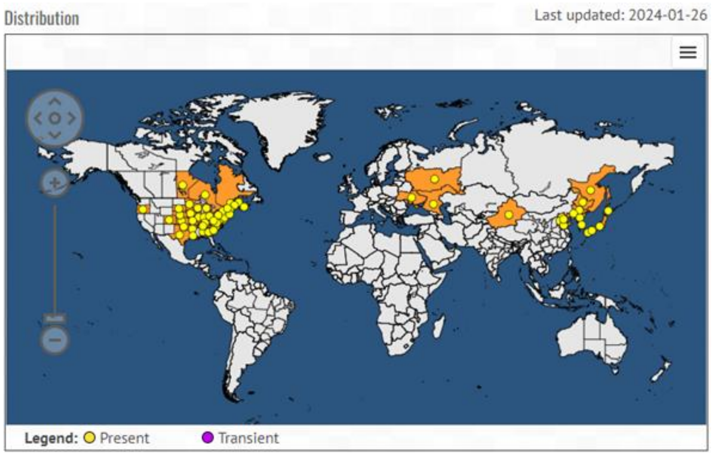

Figure 2. Global distribution of *Agrilus planipennis* (*latest update: EPPO 2024-01-26, https://gd.eppo.int/taxon/AGRLPL/distribution*)

Figure 3. Distribution of *Agrilus planipennis* in Europe (Source: *EU background map EC-GISCO;* A. planipennis *detection map modified from Orlova-Bienkowskaja et al., 2020-09-28, https://www.efsa.europa.eu/en/supporting/pub/en-1945*)

3. Risk analysis and assessment

Probability of the pest entering Bulgaria

A. planipennis is thought to have been originally introduced to North America via infested crating, strengthening elements for cargo during transport or pallets. Since then, *A. planipennis* has spread naturally and through human-assisted pathways, such as infested ash logs, firewood and nursery plants. Other potential pathways of entry have been identified, such as: lumber, chips, mulch (composted and non-composted).

Pathways not considered suitable for the entry of this pest are: treated timber of *Fraxinus* spp., *Juglans mandshurica*, *Juglans ailanthifolia*, *Pterocarya rhoifolia*, *Ulmus davidiana* and goods made from them. Such timber will be treated to a degree that does not allow the survival of eggs on the bark or larvae and pupae in the wood. Seeds of *Fraxinus* spp., *Juglans mandshurica*, *Juglans ailanthifolia*, *Pterocarya rhoifolia*, *Ulmus davidiana*, are also not considered suitable as the life cycle stages of *A. planipennis* are not associated with them.

The distribution of *A. planipennis* is characterized by both short- and long-distance movements (Siergert et al., 2015). Dispersal can occur naturally by flight of the adults or by accidental human-assisted transport (movement of infested material from host plant).

There is a significant risk of *A. planipennis* spreading from Moscow to most of Europe, where ash species are commonly found in forests and urban environments (recreational and recreational areas). Recorded dispersal rates of this species in North America are between 2.5 and 80 km per year and between 13 and 41 km per year in European Russia.

These data suggest that *A. planipennis* will reach Central Europe within 15 – 20 years (Valenta et al., 2017).

On the territory of Bulgaria, *A. planipennis* is likely to enter through an accidental gap during phytosanitary inspections.

Probability of establishing and spreading the pest in Bulgaria

Considering current distribution in North America and European Russia, as well as its native area in Asia, it is suggested that *A. planipennis* can survive the winter at temperatures well below freezing. In laboratory conditions, it has been found that the average temperature that pre-pupae can tolerate is minus 30° C (Crosthwaite et al., 2011). In another study, larvae collected from infested trees were found to withstand an average temperature of minus 25°C (Venette and Abrahamson, 2010), moreover, the pest established itself in the Moscow region, where winter temperatures often reach minus 30° C.

A. planipennis has a wide distribution covering most climatic zones in Europe. This pest spends a large part of its life cycle protected from extreme changes in climatic conditions (i.e. inside the trunk), which allows it to develop under unfavorable conditions and for longer periods of time.

The distribution of *A. planipennis* probably depends more on the presence of host plants than on local climatic conditions. Low temperatures do not appear to be a limiting factor for the survival of the pest in winter, and it occurs in cold regions such as the northeastern United States, central Canada, the Moscow region, and northeastern China.

Bulgaria falls in the transition zone between two climatic regions of Europe – European-continental and continental-Mediterranean climatic region (Zh. Galabov, 1982; L. Sabev, Sv. Stanev, 1959). This geographical location is characterized by significant air temperature fluctuations. The average annual temperature for most of Bulgaria is between 10° and 14° C, but it varies greatly in different areas of the country.

Since the end of the 1970s, a warming trend has been observed in Bulgaria.

In the period 1988 – 2020, the average annual air temperature for the low part of the country (for the regions with an altitude of up to 800 m) fluctuated within the limits of 10.6° C to 13.3° C with a stable positive trend of this change indicator (+0.035° C/year).

In 2020, the average annual temperature for the low part of the country is 13.0° C, which is 1.1° C above the norm. This is the second warmest year in the period 1988 – 2020, and the month of December is the warmest for the entire period - on average 3.2° C above the monthly norm (from +1.8° C in the villages of Gramada and Belogradchik to +4.6° C in Bozhurishte).

The spatial distribution of the average annual temperature anomaly by administrative regions (for the regions with an altitude of up to 800 m) is presented in Fig. 4. The deviations from the norm are the largest in North-Eastern Bulgaria (+1.6° C in the districts of Silistra and Varna), and the smallest – in the districts of Kyustendil, Blagoevgrad and Gabrovo (+0.5° C).

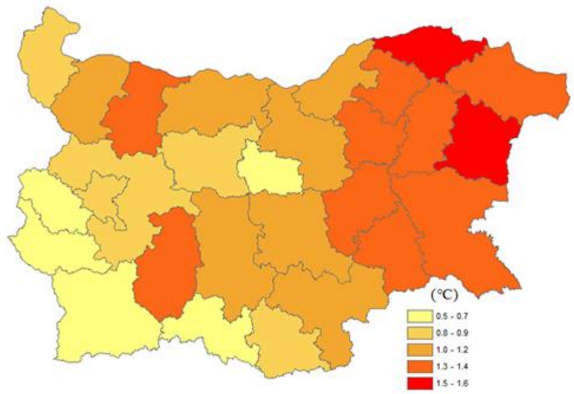

Figure 4. Deviations of the average annual air temperature (in °C) in 2018 compared to the climate norms for the period 1961 – 1990, source: Department of Weather Forecasts - NIMH, https://eea.government.bg/bg/soer/2020/climate/climate0

Climatic scenarios for Bulgaria

Climatic scenarios for Bulgaria are simulated by applying the ALADIN regional model (Forecasts and Information Service of NIMH – https://weather.bg/0index.php?koiFail=S1center&lng=0)), and the conclusions about climate changes in Bulgaria are:

- Ice days will decrease, and the high temperature will affect the vernalization in winter of a number of agricultural crops;
- The current summer conditions will gradually disappear as it will be hotter with average maximum air temperatures above 30°C mostly in the flat areas of the country;
- The number of summer days will increase to 90 days in the period 2021 – 2050. The percentage of summer days is expected to increase by 18 – 20% over 40% in most flat places in Southern Bulgaria;
- The number of hot days will increase by up to 30% by the end of the 21st century.

In conclusion, low winter temperatures are not expected to have a negative impact on the establishment and spread of *A. planipennis* in Bulgaria, as this species has established itself in areas with much lower temperatures than those in the country.

Given the climate changes in Bulgaria and the trend towards warming in most regions of the country, and the forecast for milder winters in the coming decades, it is assumed that the conditions will be increasingly suitable.

After its establishment, the local spread of *A. planipennis* is mainly through the flight of the adult beetles.

The distribution of *A. planipennis* is characterized by both short- and long-distance movements (Siergert et al., 2015). Dispersal can occur naturally by flight of the adults or by accidental human-assisted transport (movement of infested material from host plant).

Laboratory studies have shown that adults, especially fertilized females, are relatively strong fliers, with an average flight of over 3 km observed when supplementary feeding between flights, 20% of fertilized females were capable of flying over 10 km in 24 hours, and 1 % of them over 20 km (Taylor et al., 2010). Field observations have shown that in areas where ash is densely wooded, adults fly a shorter distance – less than 200 m (Siergert et al., 2015).

Long-distance dispersal occurs with human assistance through the movement of plants and wood products (including wood, wood packaging, sawdust, and firewood) containing bark strips moving in local and international trade. In addition, the movement of adult beetles "hitchhiking" on or inside vehicles is considered to be the main means of long-distance dispersal.

In the EPPO area, the pest is expected to spread slowly but steadily to the west from where it is found in the Moscow region. Since its introduction in the late 1980s, *A. planipennis* has spread 250 km west of Moscow.

Human-assisted dispersal may lead to multiple areas of establishment in different parts of the EPPO region, but in the next decade, the probability of natural spread of *A. planipennis* in most EPPO countries is low.

Potential economic impacts of the pest for Bulgaria

A. planipennis is likely to cause huge direct economic losses, environmental and urban impacts as it causes high ash mortality in parkland, nurseries, urban areas and forests. It is assumed that if *A. planipennis* becomes established in Europe, its impact is expected to be similar to that in the European part of Russia or that in North America. The pest is difficult to detect and may take several years before symptoms appear, resulting in high population densities of the pest and difficult to control.

In its native area, *A. planipennis* prefers to attack stressed trees, although it also attacks healthy trees, especially in the introduced range. In addition to direct damage, this species also has an impact on the environment (ecosystem services, landscape) and social impacts (need to remove trees, impact on culture and traditions, reduced value of sites, loss of aesthetic value due to the removal of attacked ornamental trees in the landscape etc.) (Kovacs et al. 2010; Lyons & Scarr, 2010).

In the USA (Michigan and Ohio), *A. planipennis* has killed tens of millions of ash trees (Mc Cullough et al., 2011). In forested areas of Ohio, Michigan, and Pennsylvania, ash mortality in study areas reached nearly 100%, regardless of initial tree density, size, habitat, or species diversity. Similar levels of almost 100% tree mortality have occurred in Ontario (Canada), where by the end of 2011, approximately 63,000 hectares of forest and wooded areas were affected (Scarr et al., 2012).

In the USA, through simulations of the distribution in 2009-2019, it is estimated that the infested trees will be more than 17 million, and the cost of removing, replacing and treating them with plant protection products will amount to almost 8 billion euros (Kovacs et al., 2010).

In Canada, the estimated cost of removing and replacing affected trees will be €195-868 million (depending on distribution and treatment) over 30 years, and if trees used as park vegetation are included (Eastern Canada - 545,000 ash and Western Canada - 684,000 units), then the costs would swell to 332 - 1476 million euros (McKenney et al., 2012).

The native species *F. excelsior*, *F. angustifolia* and *F. ornus* are susceptible to *A. planipennis*, and several North American species known as especially susceptible are also used in the EPPO region as ornamentals. The susceptibility of other European species (*F. raibocarpa* and *F. xanthoxyloides*) is unknown but, but they are likely to be susceptible as well.

In the EPPO region, ash is used in riparian and mountain areas for water management, erosion prevention and conservation purposes. These areas will also be affected, and the use of pesticides can have an impact on the environment. In forests, the possible measures (cutting down attacked trees, clear cutting) can affect the functioning of the ecosystem.

The establishment of *A. planipennis* could lead to the potential loss of certain recreational areas such as parks or forests. The aesthetic value of the infested trees will be affected, which may lead to their felling and replacement with another species. Cutting down the infested trees near the buildings will lead to higher air conditioning costs.

The additional costs likely to be incurred following the introduction of *A. planipennis* (other than the direct costs associated with the impacts above) are:

- Additional costs will be incurred in forests for pest monitoring (including sampling), removal, destruction or treatment of infested trees, sanitary practices where applicable and possible phytosanitary measures applied to export timber, specifically for *A. planipennis*;
- In nurseries – control operations, destruction of attacked trees, loss of markets for trees already in production, initial costs of shifting to producing alternative species;
- In gardens and landscapes – additional costs for monitoring, removing and destroying infested trees, costs for their replacement;
- Possible loss of export markets;
- Mass-rearing and release of natural enemies (including pre-release risk assessment) and wasps for biosurveys.
- Costs of *A. planipennis* public awareness campaigns.

Availability of suitable hosts in Bulgaria

All three species of European ash are found on the territory of Bulgaria: *F. excelsior*, *F. angustifolia* (synonyms: *F. oxycarpa* and *F. oxyphylla*) and *F. ornus*.

Mountain ash (*F. excelsior*) is not protected by the Biodiversity Act, but is a key habitat 91E0 "Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Pandion, Alnion incanae, Salicion albae)" which is a priority for conservation in the European network "NATURE 2000". In Bulgaria, *F. excelsior* is distributed in the Balkan Mountains (Stara Planina), the Rhodope Mountains, the Danube Plain, North-Eastern Bulgaria, the Pre-Balkans, the Tundzhan Hilly Plain, the Western Border Mountains, Belasitsa, Znepolski District and the Struma Valley, at an altitude of 0 to 1500 meters.

In Bulgaria, *F. oxycarpa* is not protected by the Biodiversity Act. This species is distributed along the Black Sea coast, the Danube Plain, the eastern part of the Balkan Mountains, the eastern part of the Rhodope Mountains, the Upper Thracian Plain and the Tundzhan Hilly Plain at an altitude of 0 to 800 meters.

F. ornus is also not protected by the Biodiversity Act, and in Bulgaria it is distributed throughout the country from 0 to 1500 m above sea level.

Taking them into account the temperature range and host plants necessary for the establishment and development of *A. planipennis,* it can be assumed that the territory of the whole country will be suitable for the establishment and development of A. planipennis.

In case of possible introduction of *A. planipennis* on the territory of the EU and Bulgaria, a direct economic impact can be expected both on the yield and quality of European ash species, as well as an impact on the environment and urban conditions.

Pest risk assessment

- **Table 1.** Presence of the pest – **Low risk**

High risk	The pest is found on the Balkan Peninsula
Medium risk	The pest is found in the EU
Low risk	**The pest is not found in the EU**

A. planipennis is found in North America and the European part of Russia, and at the moment there is no evidence that this pest is present on the territory of the EU.

- **Table 2.** Pest entry pathways – **Medium risk**

High risk	It is known that there are pathways for the pest to enter Bulgaria
Medium risk	**Pathways for the pest to enter Bulgaria are possible, but none are known to exist**
Low risk	The pathways for the pest to enter Bulgaria are unlikely

A. planipennis spreads naturally and through human-assisted pathways, such as infested ash logs, firewood and nursery plants. Other potential pathways of entry have been identified, such as: wood, sawdust, mulch (composted and non-composted)

- **Table 3.** Capacity for natural entry of the pest – **Low risk**

High risk	Maximum recorded distribution – 500 – 250 km per year
Medium risk	Maximum recorded distribution 100 – 250 km per year
Low risk	**Maximum recorded spread 1 – 100 km per year (wind dispersal; flowing water)**

The distribution of *A. planipennis* is characterized by both short- and long-distance movements (Siergert et al., 2015). Dispersal can occur naturally by flight of the adults or by accidental human-assisted transport (movement of infested material from host plant).

Natural spread

Laboratory and field observations indicate that the flight of adults is limited to a few kilometers per year (Siergert et al., 2015). Laboratory studies have shown that adults, especially fertilized females, are relatively strong fliers, with an average flight of over 3 km observed when additional feeding between flights, 20% of fertilized females were capable of flying over 10 km in 24 hours, and 1% of them over 20 km (Taylor et al., 2010).

In real conditions, the rate of spread of *A. planipennis* has been found to be between 2.5 and 80 km per year, which suggests that this pest will reach Central Europe within 15 – 20 years.

- **Table 4.** Climatic conditions for establishing the pest – **High risk**

High risk	**It is supposed that >40% of the territory of Bulgaria is suitable for establishing the pest**
Medium risk	It is supposed that >20% of the territory of Bulgaria is suitable for establishing the pest
Low risk	It is supposed that >0 to 20% of the territory of Bulgaria is suitable for establishing the pest

Considering current distribution in North America and European Russia, as well as its natural area in Asia, it has been suggested that *A. planipennis* can survive the winter at temperatures well below freezing (minus 30° C).

- **Table 5.** Presence of host plants – **High risk**

High risk	**>10% of host plants are found in Bulgaria**
Medium risk	>1 to 10% of host plants are found in Bulgaria
Low risk	>0 to 1% of the host plants are found in Bulgaria

The main hosts of *A. planipennis* are trees of the genus *Fraxinus, Oleaceae* (Jendek and Poláková, 2014).

All native species of European ash – *F. excelsior*, F. angustifolia and F. ornus are confirmed as susceptible hosts (EFSA PLH Panel, 2011; EPPO, 2013a; Baranchikov et al., 2014; Herms, 2015) and are found on the territory of Bulgaria.

- **Table 6.** Spread of the pest after establishment – **Medium risk**

High risk	It is known that there are pathways for the spread of the pest in Bulgaria
Medium risk	**The pathways for the spread of the pest in Bulgaria are possible, but are not known to exist**
Low risk	The pathways for the spread of the pest in Bulgaria are unlikely

Dispersal of *A. planipennis* can occur naturally by adult flight or by accidental human-assisted transport (movement of infested material from host plant).

Laboratory and field observations indicate that adult flights are limited to a few kilometers per year (Siergert et al., 2015). Field observations have shown that in areas where ash is densely wooded, adults fly a shorter distance – less than 200 m (Siergert et al., 2015).

Long-distance dispersal occurs through human assistance, international trade, and the movement of adults "hitchhiking" on or inside vehicles.

- **Table 7.** Development (reproductive potential) of the pest after establishment – **Low risk**

High risk	The annual reproductive potential of a female is > 500 eggs
Medium risk	The annual reproductive potential of a female is from 100 to 500 eggs
Low risk	**The annual reproductive potential of a female is < 100 eggs**

Fertilized females lay individually or in small groups on the bark surface, but most often in bark cracks, with one female laying 68 to 90 eggs (Haack et al., 2002). Eggs are usually laid on living trees, but have occasionally been observed laying on freshly felled ash logs, although these larvae rarely complete their development (Petrice & Haack, 2007; Anulewicz et al. 2008).

- **Table 8.** Economic impact – **High risk**

High risk	**The pest appears as a problem in its native area and the areas where it has entered**
Medium risk	The pest appears as a problem only in areas where it has entered
Low risk	Not reported as a problem outside the place of origin

A. planipennis is likely to cause huge direct economic losses, environmental and urban impacts by causing high ash mortality in parkland, nurseries, urban areas and forests. It is assumed that its impact in Europe will be similar to that in places where it is already established. *A. planipennis* is difficult to detect before symptoms appear on infested host plants, resulting in high population densities of the pest, which in turn makes it difficult to control.

4. Level of risk

Based on the current phytosanitary legislation at the European and national level, **the risk of the pest entering the territory of the Republic of Bulgaria is low to medium.**

At the moment, for Bulgaria, **the risk of natural introduction of *A. planipennis* is low** since the species has not been established in neighboring countries, and field observations have shown that in areas where ash is densely wooded, adults fly a shorter distance – less than 200 m (Siergert et al., 2015).

Recorded dispersal rates of this species in North America are between 2.5 and 80 km per year and between 13 and 41 km per year in European Russia.

These data suggest that *A. planipennis* will reach Central Europe within 15 – 20 years (Valenta et al., 2017).

In the eventuality of *A. planipennis* entering the country, there is a real possibility that the pest will develop one generation per year, as winter temperatures are not expected to be a limiting factor for its establishment.

Therefore, the risk of **establishment of *A. planipennis* is assessed as high** due to the presence of susceptible host plants.

In the eventuality that *A. planipennis* is established in the country, **the risk of its subsequent spread is assessed as medium.**

In case of possible entry and spread of the pest in Bulgaria, it can have a negative economic impact, it is likely to have an impact on the environment and urban conditions, causing high mortality of ash trees in park spaces, nurseries, urban areas and forests. The pest is difficult to detect and may take several years before symptoms appear, resulting in high population densities of the pest and difficult to control.

The application of control measures in forests and urban environments is limited.

The use of chemicals to control *A. planipennis* can be effective, but it will be expensive and likely to have undesirable effects on the environment. Control by natural enemies and woodpeckers is expected to be insufficiently effective.

The establishment of *A. planipennis* could lead to the potential loss of certain recreational areas such as parks or forests. The aesthetic value of the attacked trees will be affected, which may lead to their felling and replacement with another species, **therefore the level of risk is defined as high.**

5. Pest risk management

Signs of *A. planipennis* attack include: D-shaped exit holes, larval galleries characteristic of the genus *Agrilus*, yellowing and subsequent premature browning of leaves, crown thinning, withered branches, longitudinal splitting of the bark with larval galleries underneath, injury from woodpeckers on infested trees. Except adults, all stages of the life cycle are hidden making them difficult to detect.

Trees do not show obvious symptoms of infestation until they are heavily attacked, which can take 2-3 years. At this time there are no reliable methods for detecting low population levels of *A. planipennis*.

Methods for detecting *A. planipennis* include: trapping, visual inspection, branch and tree sampling and biosurveillance.

Biological control

In North America, the classic biological control of mass rearing and release of parasitoids has been used to reduce *A. planipennis* populations. 3 parasitoids (2 larval parasitoids – *Spathius agrili* and *Tetrastichus planipennisi* and 1 egg parasitoid - *Oobius agrili*) have been reared and released in the USA (Duan et al. 2012a), but the impact of these species on *A. planipennis* populations has not yet been known. A number of other parasitoids, such as *Spathius galinae*, originating from the Russian Far East, are also being studied (Yang et al., 2012; Belokobylski et al., 2012). In North America, the species *Leluthia astigma* (Kula et al., 2010), *Atanycolus* spp. (Duan et al., 2012b), as well as the fungi *Isaria farinosa* and *Purpureocillium lilacinum* also attack *A. planipennis*. Experiments are currently underway to inoculate adult male *A. planipennis* in the field with a strain of *Beauveria bassiana* with the aim of eventually inoculating and killing adult females (Lyons et al., 2012).

Chemical control

Chemical control is mostly used for high value trees (e.g. urban trees, ornamentals). Combining the different approaches together, the following methods are used in North America (Herms et al., 2009, referred to by EAB 2012 and CFIA 2012a; MDA, 2011; RA Haack and T Scarr, unpublished data):

- systemic insecticides for soil application or irrigation;
- systemic insecticides for trunk injection (trunk injection is currently the only method that protects trees for more than one year);
- treatment of the lower part of the trunk with systemic insecticides;
- a protective coating applied using sprays that are applied to the trunk, main branches, leaves, targeting the adults and young larvae of the pest.

Microbial insecticides were also investigated (*Beauveria bassiana*, *Metarhizium anisopliae*, (Baranchikov et al., 2008 citing Liu & Bauer, 2006; Wang et al., 2010), but *Beauveria bassiana* was ineffective in high populations of *Agrilus planipennis*.

A. planipennis has been added to the A2 list of pests recommended for regulation as quarantine for the EPPO region, meaning that the pest is locally present in the EPPO region.

Agrilus planipennis is a Union quarantine pest listed in part A of Annex II of Commission Implementing Regulation (EU) 2019/2072 and a priority pest under Commission Delegated Regulation (EU) 2019/1702, which obliges Member States to carry out annual studies.

In order to prevent the introduction of *A. planipennis* into the EU, in Annex VII, point 87 of Regulation 2019/2072 provides that wood other than wood chips, wood particles, sawdust, chipboard, wood waste and wood packaging material may to enter only:

- Pest free area of *A. planipennis* / from areas recognized as free from *A. planipennis*; or
- After removing the bark and at least 2.5 cm of the sapwood; or

- After the wood has been exposed to ionizing radiation, until reaching a minimum dose of 1 kGy in the wood.

6. Conclusion

A. planipennis is a phytophagous in the family *Buprestidae*, native to East Asia.

A. planipennis was accidentally introduced to North America and European Russia, and its native area includes China, the Russian Far East, and the Korean Peninsula.

A. planipennis is currently not known to occur in the EU, but this pest is present in the European part of Russia and eastern Ukraine, as well as North America and parts of Asia, therefore active monitoring is necessary in all parts of EU where this species can be established. Specifically, the EU's eastern borders, including Finland, Estonia, Latvia, Lithuania, Poland, Slovakia, Hungary and Romania.

A. planipennis has been added to list A2 of the pests recommended for regulation as quarantine for the EPPO region, which means that the pest is locally present in the EPPO region, it is also included in Part A of Annex II to the Implementing Regulation (EU) 2019/2072 of the Commission and Delegated Regulation (EU) 2019/1702 of the Commission, by which the Member States are obliged to conduct annual surveys for its presence.

In order to prevent the introduction of *A. planipennis* into the EU, Annex VII to Commission Implementing Regulation (EU) 2019/2072 sets out specific requirements for the import of plants, wood, wood products and bark of *Fraxinus* L., *Juglans ailantifolia* Carr., *Juglans mandshurica* Maxim., *Ulmus davidiana* Planch. and *Pterocarya rhoifolia* Siebold and Zucc from countries where *A. planipennis* is present.

Low temperatures are not a limiting factor for the establishment and spread of *A. planipennis* in Bulgaria, moreover, considering climate changes in the country, it is assumed that in the coming decades the conditions for the establishment of *A. planipennis* in the country will be more and more suitable.

It is important for Europe and Bulgaria that all three European species *Fraxinus excelsior*, *F. ornus* and *F. angustifolia* are suitable hosts.

In case of possible introduction of *A. planipennis* on the territory of the EU and Bulgaria, a direct economic impact on the yield and quality of European ash species can be expected, as well as a negative impact on the environment and urban conditions.

Based on the above, the most adequate measure that can be applied is monitoring. At this stage, this is the most easily applicable and economically effective measure, which aims to take timely measures to limit and eliminate any outbreak that may occur, should the pest be identified.

References

1. Anulewicz AC, Mccullough DG, Cappaert DL and Poland TM, 2008. Host range of the emerald ash borer (Agrilus planipennis Fairmaire) (Coleoptera: Buprestidae) in North America: results of multiple-choice field experiments. Environmental Entomology, 37(1), 230–241.
2. Baranchikov Y, 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(2), 233–238.
3. Baranchikov YN, Seraya LG and Grinash MN, 2014. All European ash species are susceptible to emerald ash borer Agrilus planipennis Fairmaire (Coleoptera: Buprestidae) – a far eastern invader. Siberian Journal of Forest Sciences, 6, 80–85.
4. Belokobylskij, S.A., Yurchenko, G.I., Zaldívar-Riverón, A., Strazanac, J., and Mastro, V. 2012. A new emerald ash borer (Coleoptera: Buprestidae) parasitoid species of Spathius Nees (Hymenoptera: Braconidae: Doryctinae) from the Russian Far East and South Korea. Annals of the Entomological Society of America, 105: 165–178.
5. CABI (Centre for Agriculture and Bioscience International), 2019a. Invasive species compendium – Agrilus planipennis (emerald ash borer) datasheet. Available online: https://www.cabi.org/isc/datasheet/3780 [Accessed: 9 October 2020]
6. Cappaert D, McCullough DG, Poland TM and Siegert NW, 2005. Emerald ash borer in North America; a research and regulatory challenge. American Entomologist, 51(3), 152-165.
7. Cipollini D and Peterson DL, 2018. The potential for host switching via ecological fitting in the emerald ash borer–host plant system. Oecologia, 187(2), 507–519.
8. Crosthwaite JC, Sobek S, Lyons DB, Bernards MA and Sinclair BJ, 2011. The overwintering physiology of the emerald ash borer, Agrilus planipennis fairmaire (coleoptera: buprestidae). Journal of Insect Physiology,57(1), 166-73. doi: 10.1016/j.jinsphys.2010.11.003
9. Duan, J.J., Bauer, L.S., Abell, K.J., Van Driesche, R., 2012a. Population responses of hymenopteran parasitoids to the emerald ash borer (Coleoptera: Buprestidae) in recently invaded areas in north central United States. BioControl 57, 199-209.
10. Duan, J.J., Yurchenko, G., Fuester, R., 2012b. Occurrence of emerald ash borer (Coleoptera: Buprestidae) and biotic factors affecting its immature stages in the Russian Far East.Environ. Entomol. 41, 245-254.
11. EFSA PLH Panel (EFSA Panel on Plant Health), 2011. Scientific Opinion on a technical file submitted by the US Authorities to support a request to list a new option among the EU import requirements for wood of Agrilus planipennis host plants. EFSA Journal, 9(7), 2185, 51 pp. doi: 10.2903/j.efsa.2011.2185
12. EPPO (European and Mediterranean Plant Protection Organization), 2013a. Pest risk analysis for Agrilus planipennis. EPPO Bulletin, 43, 1–68. Available at http://www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRA_intro.htm [Accessed: 9 October 2020]
13. EPPO (European and Mediterranean Plant Protection Organization), 2020. EPPO Global Database. Agrilus planipennis. Distribution details in Ukraine. Available online: https://gd.eppo.int/taxon/AGRLPL/distribution/UA [Accessed 1 October 2020]
14. Evans HF, Williams D, Hoch G, Loomans A and Marzano M, 2020. Developing a European toolbox to manage potential invasion by emerald ash borer (Agrilus planipennis) and bronze birch borer (Agrilus anxius), important pests of ash and birch. Forestry, 93(2), 187–196.
15. Haack RA, Jendek E, Liu H, Marchant KR, Petrice TR, Poland TM, and YE H, 2002. The emerald ash borer: A new exotic pest in North America. Newsletter of Michigan Entomological Society, 47(3&4), 1–5.
16. Herms DA and McCullough DG, 2014. Emerald ash borer invasion of North America: history, biology, ecology, impacts, and management. Annual Review of Entomology, 59, 13–30. Doi: 10.1146/annurev-ento-011613-162051.

17. Herms DA, 2015. Host range and host resistance. In: Van Driesche RG and Reardon RD (eds.). Biology and control of emerald ash borer. FHTET-2014–09. USDA Forest Service, Forest Health Technology Enterprise Team, Morgantown. pp. 65–73.
18. Herms DA, McCullough DG, Clifford CS, Smitley DR, Miller FD and Cranshaw W, 2019. Insecticide options for protecting ash trees from emerald ash borer. North Central IPM Center Bulletin. 3rd Edition. 16 pp. Available online: http://www.emeraldashborer.info/documents/Multistate_EAB_Insecticide_Fact_Sheet.pdf [Accessed: 10 September 2020]
19. Jendek E and Poláková J, 2014. Host Plants of World Agrilus (Coleoptera, Buprestidae). A Critical Review. Springer, Cham. 706 pp.
20. Kovacs, K. F., Haight, R. G., McCullough, D. G., Mercader, R. J., Siegert, N. W., Liebhold, A. M., 2010. Cost of potential emerald ash borer damage in U.S. communities, 2009-2019.Ecological Economics, 69(3) 569-578. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VDY-4X8VB83-1&_user=10&_coverDate=01%2F15%2F2010&_rdoc=16&_fmt=high&_orig=browse&_srch=doc-info(%23toc%235995%232010%23999309996%231577610%23FLA%23display%23Volume)&_cdi=5995&_sort=d&_docanchor=&_ct=27&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=4a1b8e45306f2965facfa968321b5fe7
21. Kula, R.R., Knight, K.S., Rebbeck, J., Cappaert, D., Bauer, L.S., and Gandhi, K.J.K. 2010. Leluthia astigma (Ashmead) (Hymenoptera: Braconidae: Doryctinae) as a parasitoid of Agrilus planipennis Fairmaire (Coleoptera: Buprestidae: Agrilinae), with an assessment of host associations for Nearctic species of Leluthia Cameron. Proceedings of the Entomological Society of Washington, 112: 246–257.
22. Lyons and Scarr, 2010, Workshop Proceedings: Guiding Principles for Managing the Emerald Ash Borer in Urban Environments - https://cfs.nrcan.gc.ca/publications?id=32017
23. Lyons, D. B., R. Lavallée, G. Kyei-Poku, K. Van Frankenhuyzen, S. Johny, C. Guertin, J. A. Francese, G. C. Jones, and M. Blais. 2012. Towards the development of an autocontamination trap system to manage populations of emerald ash borer (Coleoptera: Buprestidae) with the native entomopathogenic fungus, Beauveria bassiana. Journal of Economic Entomology 105: 1929–1939.
24. Liu H, Bauer LS, Gao R, Zhao T, Petrice TR and Haack RA, 2003. Exploratory survey for the emerald ash borer, Agrilus planipennis (Coleoptera: Buprestidae), and its natural enemies in China. The Great Lakes Entomologist, 36 (3&4), 191–204.
25. McCullough DG, Siegert NW, Poland TM, Pierce SJ and Ahn SZ, 2011. Effects of trap type, placement and ash distribution on emerald ash borer captures in a low density site. Environmental Entomology, 40(5), 1239–1252.
26. McKenney et al., 2012, Estimates of the potential cost of emerald ash borer (Agrilus planipennis Fairmaire) in Canadian municipalities. – https://cfs.nrcan.gc.ca/publications?id=33763
27. Orlova-Bienkowskaja MJ and Bieńkowski AO, 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.
28. Orlova-Bienkowskaja MJ and Volkovitsh MG, 2018. Are native ranges of the most destructive invasive pests well known? A case study of the native range of the emerald ash borer, Agrilus planipennis (Coleoptera: Buprestidae) Biological Invasions, 20(5), 1275–1286. doi: 10.1007/s10530-017-1626-7
29. Orlova-Bienkowskaja MJ and Bieńkowski AO, 2020. Minimum winter temperature as a limiting factor of the potential spread of Agrilus planipennis, an alien pest of ash trees, in Europe. Insects, 11(4), 258.
30. Petrice TR, Haack RA, 2006. Efficacy of three insecticides applied to bark to control Agrilus planipennis (Coleoptera: Buprestidae). Great Lakes Entomologist, 39(1/2):27-33.

31. Petrice, T. R., and R. A. Haack. 2007. Can emerald ash borer, Agrilus planipennis (Coleoptera: Buprestidae), emerge from logs two summers after infested trees are cut? Great Lakes Entomol. 40: 92–95.
32. Galabov Zh. Report on ecological assessment of a medium-term operational program for the implementation of the road infrastructure development strategy in the Republic of Bulgaria 2014 - 2020, , Physical geography Natural conditions and resources, 1982.
33. Sabev L., St. Stanev , Climatic regions of Bulgaria and their climate, 1959. – http://www.api.bg/files/6814/2623/0793/Doklad_EO_SOPISRPIBG.pdf
34. Ryall KL, Fidgen JG and Turgeon JJ, 2011. Detectability of the emerald ash borer (Coleoptera: Buprestidae) in asymptomatic urban trees by using branch samples. Environmental Entomology, 40(3), 679–688.
35. Scarr, T. A., Ryall, K. L., and Hodge, P. (2012). Forest Health Conditions in Ontario, 2011. Available online at: https://www.ontario.ca/document/forest-health-conditions-2011
36. Siegert, N. W., McCullough, D. G., Williams, D. W., Fraser, I., Poland, T. M., Pierce, S. J., 2010. Dispersal of Agrilus planipennis (Coleoptera: Buprestidae) from discrete epicenters in two outlier sites.Environmental Entomology, 39(2) 253-265. http://www.bioone.org/doi/full/10.1603/EN09029
37. Siegert, N. W., Mercader, R. J., McCullough, D. G., 2015. Spread and dispersal of emerald ash borer (Coleoptera: Buprestidae): Estimating the spatial dynamics of a difficult-to-detect invasive forest pest. Canadian Entomologist, 147(3) 338-348.
38. Taylor, R. A. J., Bauer, L. S., Poland, T. M., Windell, K. N., 2010. Flight performance of Agrilus planipennis (Coleoptera: Buprestidae) on a flight mill and in free flight.Journal of Insect Behavior, 23(2) 128-148. http://www.springerlink.com/link.asp?id=104914
39. USDA APHIS PPQ, 2018. EAB Trapping Protocols 2018 Emerald Ash Borer Survey guidelines United States Department of Agriculture. Available online: https://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/TrappingProtocols.pdf [Accessed: 12 September 2020]
40. USDA APHIS PPQ, 2020. Initial county EAB detections in North America – August 3, 2020. Cooperative Emerald Ash Borer Project, United States Department of Agriculture. Available online: http://www.emeraldashborer.info/documents/MultiState_EABpos.pdf [Accessed 13 August 2020]
41. Valenta V, Moser D, Kapeller S and Essl F, 2017. A new forest pest in Europe: A review of Emerald ash borer (Agrilus planipennis) invasion. Journal of Applied Entomology, 141(7), 507–526.
42. Venette & Abrahamson, Cold hardiness of emerald ash borer, agrilus planipennis: a new perspective – https://jwcdaily.com/YZdKg/wp-content/uploads/2014/02/cold-hardiness-of-eab1.pdf
43. Volkovitsh, M.G.; Suslov, D.V. The first record of the emerald ash borer, Agrilus planipennis Fairmaire (Coleoptera: Buprestidae),in Saint Petersburg signals a real threat to the palace and park ensembles of Peterhof and Oranienbaum. In Dendrobiotic Invertebratesand Fungi and their Role in Forest Ecosystems. The Kataev Memorial Readings—XI. In Proceedings of the All-Russia Conference withInternational Participation, Saint Petersburg, Russia, 24–27 November 2020 –
44. Wei X, Reardon RD, Sun TH, Lu M and Sun JH, 2007. Biology and damage traits of emerald ash borer (Agrilus planipennis Fairmaire) in China. Insect Science, 14(5), 367–373.
45. Yang, Z.Q., Wang, X.Y., Yao, Y.X., Gould, J.R., and Cao, L.M. 2012. A new species of Sclerodermus (Hymenoptera: Bethylidae) parasitizing Agrilus planipennis (Coleoptera: Buprestidae) from China, with a key to Chinese species in the genus. Annals of the Entomological Society of America, 105: 619–627.
46. Yu C, 1992. Agrilus marcopoli Obenbarger. In: Xiao G, ed. Forest Insects of China. Beijing, China: China Publishing House, 400-401.