Alien species in Belgium: a fact sheet for

Agrilus planipennis

François Mayer (Université Libre de Bruxelles)
Jean-Claude Grégoire (Université Libre de Bruxelles)
& Bram D'hondt (Belgian Biodiversity Platform)

Version 2013-09-22

This fact sheet was created as part of the project *Alien Alert*, which aims at developing an integrated quick-screening tool for emerging pests and invasive species in Belgium. This BELSPO-funded project involves eight scientific institutions. Coordination is provided through the Belgian Biodiversity Platform.

The objective of this fact sheet is to support the identification of potentially invasive non-native species for Belgium and neighbouring areas. Organisms that qualify for this fact sheet are species that are not present in Belgium but likely to become so in the near future, or that are present but not widely distributed, and are likely to cause environmental and/or socio-economic harm.

The scheme of this risk assessment is based upon the International Standards for Phytosanitary Measures, which are endorsed by the Food and Agriculture Organization of the United Nations (FAO 2004). It consecutively assesses the stages of entry, establishment, spread & ecological and/or economic impacts.

(Reference: FAO (2004) International Standard for Phytosanitary Measures No. 11: *Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms.*)

(Cover picture taken from http://commons.wikimedia.org.)

Table of contents

1 ORGANISM IDENTITY AND DISTRIBUTION

1.1 ORGANISM IDENTITY

Scientific name:	*Agrilus planipennis* (Fairmaire 1888)
Synonyms:	*Agrilus feretrius*, *Agrilus marcopoli*
Common names:	essenprachtkever (Dutch), emerald ash borer (English), agrile du frêne (French), Asiatische Eschenprachtkäfer (German)
Taxonomic position:	Arthropoda > Insecta > Coleoptera > Buprestidae

1.2 SHORT DESCRIPTION

The emerald ash borer is a phloem-feeding beetle with a metallic green colour.

The different stages may be characterized as follows:

eggs - Small (1,5 mm), oval with a colour that turns from light yellow to brownish yellow before hatching.

larvae – 2,6–3,2 cm long, segmented and creamy white in colour. The body is flat and broad. The head is small and brown and it is retracted into the prothorax, exposing only the mouthparts.

pupae – 1,0–1,4 cm long and creamy white in colour. The antennae stretch back to the base of the elytra.

adults – Adults have a metallic emerald colour. The body is narrow and elongate with a length of 0,8–1,4 cm. Eyes are prominent, kidney-shaped and somewhat bronze-coloured. The prothorax is slightly wider than the head (Canadian Food Inspection Agency 2012).

1.3 ORGANISM DISTRIBUTION

A/ Native range

Its native range is located in Far-east Asia in the following regions; northeastern China (provinces of Heilongjiang, Jilin, Liaoning, Shandong, Inner Mongolia, Hebei, Tianjin), Taiwan, Mongolia, Japan (provinces of Hokkaido, Honshu, Kyushu, Shikoku), South and North Korea (Haack et al., 2002) and Far-east Russia (Primorsky, Khabarovsk) (Baranchikov et al. 2008). *A. planipennis* was also mentioned in Laos by Jendek and Grebennikov (2011). However, it is now established that the specimens examined for the purpose of this latter study belonged to another related species, *Agrilus tomentipennis* (Jendek and Chamorro 2012).

B/ Introduced range

Belgium

Agrilus planipennis is absent from Belgium.

Rest of Europe

In western Russia; only present in the Moscow suburban area (Baranchikov et al. 2008). In 2009, numerous site surveys were performed resulting in the demarcation of the Emerald Ash Borer distribution area by the cities of Mytiszhi in the North (20 km from Moscow); Bykovo in the East (30 km from Moscow); Serpukhov in the South (90 km from Moscow); and Mozhaisk in the West (95 km from Moscow) (Baranchikov et al. 2011).

Other continents

The species is currently established in North America, in 18 states of the U.S. (Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Massashussets, Michigan, Minnesota, Missouri, New-York, Ohio, Pennsylvania,Tennessee, Virginia, Wisconsin, West Virginia) and 2 provinces of Canada (Québec and Ontario; Cooperative Emerald Ash Borer Project 2012). In Asia, surveys in parks of three cities of central Russia (Krasnoyarsk, Abakan, Yekateringburg) found no evidence of the presence of the pest (Baranchikov et al. 2008).

2 RISK ASSESSMENT

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD

2.1.1 Present status in Belgium

Absent. The species was never intercepted at any stage of invasion.

2.1.2 Present status in neighbouring countries

The species is not known to be present in any of the neighbouring countries.

2.1.3 Introduction in Belgium

The pathway of introductions in invaded areas is not fully resolved (Baranchikov et al. 2008), but transport with wood packaging or dunnage and firewood are likely to be the main pathways of introduction. The International Standard for Phytosanitary Measures ISPM-15 implements a norm for heat treatment at 56°C for 30 min (FAO 2008). However it has been shown that *A. planipennis* can survive at 55 °C for 120 min, at 56 °C for 60 min and at 60 ºC for 30 min (Myers et al. 2009). EFSA panel opinion recommends a heat treatment of 60 min at a higher temperature than 70 °C to ensure a high control level (EFSA Panel on Plant Health 2011).

It is thought that *A. planipennis* has been introduced in North America with imported woody material (Haack 2002; Canadian Food Inspection Agency website 2011). Between 1985 and 2000, 38 interceptions of *Agrilus* spp. were made at points of entry in the U.S.; 28 on dunnage, 4 on crates, 4 on leaves, 1 from a cutting and 1 in ship's hold (Haack et al. 2002).

Transportation of firewood or nursery stock is also responsible of trans-national movements (Cappaert et al. 2005). In 2010, the first interception of *A. planipennis* at a port of entry was done by the U.S. Customs and Border Protection in Sault Ste. Marie, Michigan (USCBP website 2010) on a camper crossing the border between Canada and U.S. with infested firewood. The rapid spread of infestations into the U.S. is most probably the result of inadvertent movement of firewood, logs and nursery stock (Haack et al. 2006; Kean et al. 2012). Despite the dryness of cut logs, it was estimated that at least some beetles can emerge from ash material that died or was cut during the preceding 12 months (Petrice and Haack 2006). The frequency of wood material vectors is estimated moderate because despite the potential to survive heat treatment of the ISPM-15 norm, interceptions of *Agrilus* species at entry ports are scarce events.

A second potential pathway of introduction is the import of plant for planting. It was suggested that the emerald ash borer was probably imported to western Russia (in

Moscow) along with plants for planting from Canada, an intensive trade of ornamental ash tree between both countries being present in the 1990s (Izhevskii and Mozolevskaya 2010; Izhevsky et Maslyakov 2010).

In Europe, there have not been any report of *A. planipennis* intercepted in plants for plantings, wood packaging or dunnage, OEPP bulletins only mention an interception of *Agrilus* spp. with wood from Ukraine to Poland in 1998 (OEPP 1999/8).

To estimate the frequency of the plant for planting vectors, we obtained data from Antwerp (Belgium) and the Netherlands since 2008. No ash was imported to Antwerp but 2065 plants were imported to the Netherlands from both Canada and China; 465 plants from Canada in 2008, 600 plants from China in 2009 and 1000 plants from China in 2010 (Ludovic Rigaux ISEFOR project, pers. comm.).

2.1.4 Establishment capacity and endangered area

A/ Life-cycle and reproduction

Depending on climate, maturity is reached in one or two years. Adults emerge by the end of spring or at the beginning of summer and feed during 3 weeks on leaves, period during which mating takes place. Females lay eggs in bark cracks and hatching occurs from 7 to 9 days late. Larvae feed under the bark. In case of suitable conditions, imaginal moult occurs directly after overwintering, in spring. Otherwise, development continues until summer (Cappaert et al. 2005).

B/ Climatic requirements

The climatic requirements of the beetle are presently unclear. As the current distribution of the emerald ash borer is mainly in continental climates, it suggests that Northern, Central and Eastern Europe could be more at risk than Western and Southern Europe (Baranchikov et al. 2008).

The emerald ash borer is particularly tolerant to low temperature with an average low January temperature between -40°C to -18°C (Venette and Abrahamson n.d.). During winter, *A. planipennis* exhibits extremely low Super Cooling Points (SCP). The prepupae are frost resistant, the super cooling points (SCP) to which body fluids freeze is particularly low and at temperatures superior to that point most of the individuals still survive (Crosthwaite et al. 2011). The literature reports the following SCPs. In China, the larval SCP is comprised between -26.38° C and -23.04° C (Wang et al. 2010). In Minnesota, the larval SCP is comprised between -18°C and -14°C for non-acclimated larvae or between -28°C and -25°C for acclimated larvae (Venette and Abrahamson n.d.). In Ontario, the mean SCP of acclimated larvae was estimated at -30.6°C (Crosthwaite et al. 2011) with lowest SCPs recorded in November (-34.1°C in 2008 and -35.3°C in 2009) and higher SCPs in March (-18.2°C in 2009 and -11.3°C).

Adult emergence begins when cumulative growing degree days reach 400-500 degree days over 10°C with a peak activity occurring at approximately 1000 growing degree days (USDA-APHIS 2008).

C/ Habitat preferences

In its native range, on mainland Asia, *A. planipennis* was only observed feeding on ashes *Fraxinus chinensis* (syn. *F. rhynchophylla*, *F. alnuginosa* and *F. mandshurica*) and *F. japonica* (Anulewicz et al. 2008). However in Japan, the sub-species *A. planipennis ulmi* was also reported on other genera: *Ulmus* L., *Juglans* L. and *Pterocarya* Kunth. (Haack et al. 2002).

In neo-colonized areas, *A. planipennis* completes its cycle exclusively on ash trees. In North America, *F. pennsylvanica* Marsh., *F. americana* L., *F.nigra* Marsh, *F. quadrangulata* Michx and *F. profunda* species have been killed (Anulewicz et al. 2008).

In Europe, at least three ash species occur naturally and should be highly suitable for establishment of *A. planipennis*. *F. excelsior* is the most widespread of the three species; the two other species, *F. ornus* and *F. angustifolia*, have a Mediterranean distribution. For the purpose of this study, distribution maps of the three *Fraxinus* species are available for the European Union (stricto sensu) from Koble and Seufert (2001) (Figure 1). The Grid layer provided in annex was reprojected to a geographic WGS84 system and resampled to approximately 1 km resolution by William Wint from Oxford.

Moreover, a 1 x1 km distribution map of *Fraxinus* spp. in the EU (also extended to countries of the Balkans) is also available from Brus et al. 2011 (Figure 2).

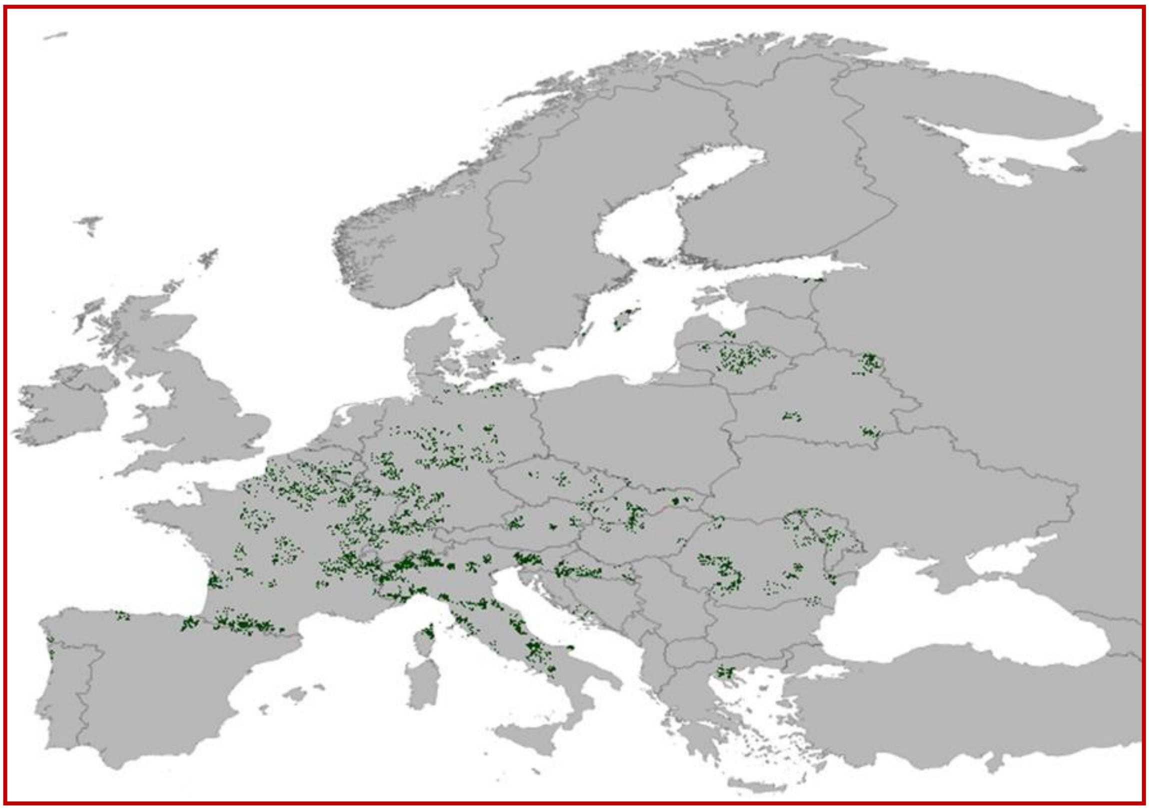


Figure 1 - Map of the present distribution of Fraxinus spp. in Europe according to Koble and Seufert (2001)

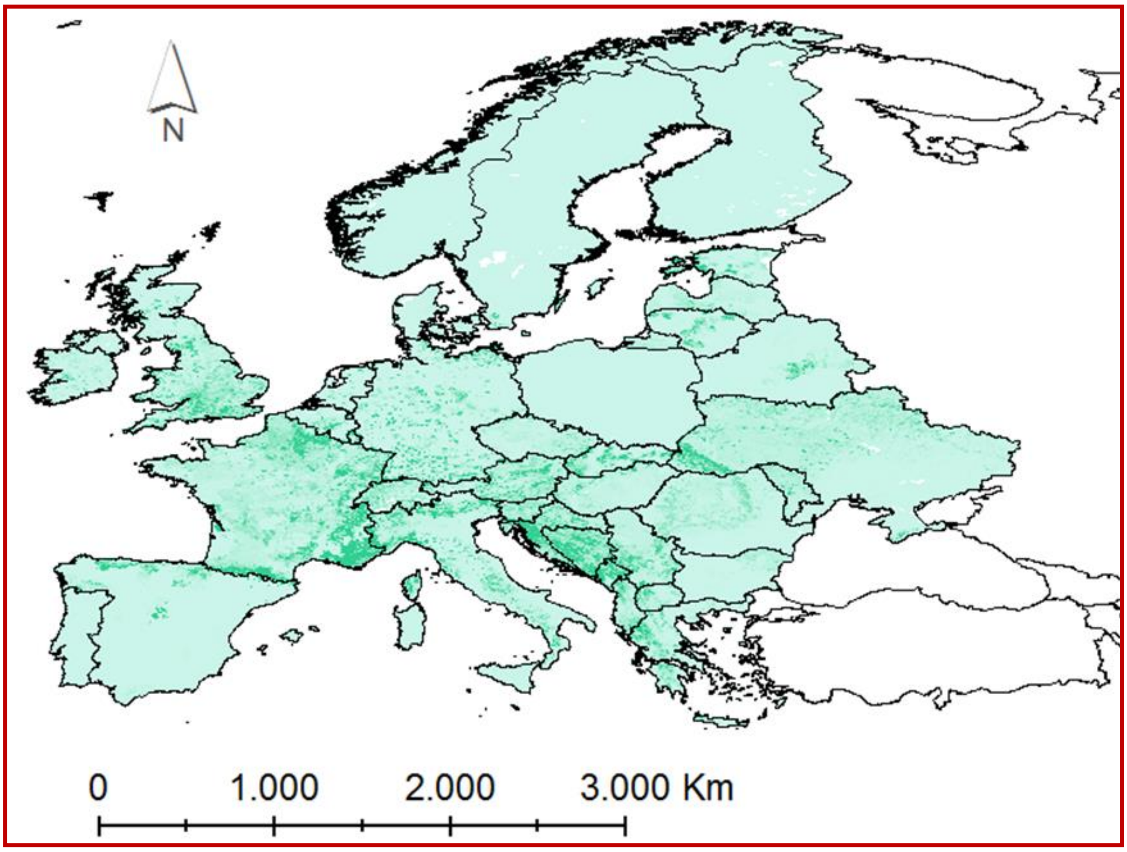


Figure 2 - Map of the present distribution of *Fraxinus* spp. in Europe according to Brus et al. (2011)

D/ Feeding habits

Larvae feed in the phloem, cambium and outer sapwood of healthy or declining ash trees (*Fraxinus* sp.) producing S-shaped galleries.

The emerald ash borer is oligophagous, feeding exclusively on ashes (except for the Japanese sub-species, quite polyphagous, but only present in Japan, never reported as invasive). Larvae feed through the bark on the phloem and sometimes also on the outer surface of the sapwood of healthy or declining ash trees (*Fraxinus* sp.) (USDA–APHIS 2011). Adults also feed briefly on leaves during their lifespan but damages are minor compared to those caused by larvae (Wang et al. 2010).

E/ Control agents

The effectiveness of control agents is Europe is estimated low.

In its native range, the main control agents of the Emerald ash borer are several parasitoid species of wasps. The three most effective are *Oobius agrili* (Hymenoptera: Encyrtidae) that causes 56,3-61,5% mortality (Liu et al. 2007), *Spatius agrili* (Yang et al. 2006) that causes 30-90% mortality and *Tetrastichus planipennisi* that causes 32-65% (Liu et al. 2003 in Baranchikov et al. 2008).

In North America, Ichneumonid parasitoid wasps (*Atanycolus* sp.) and Braconids (*Spathius* sp.) are quite ineffective on the emerald ash borer populations, only 1% of the hatched larvae are parasitized by wasps (Duan et al. 2011 in Moraal 2011). Generalist predators may also occasionally impact the emerald ash borer populations. The generalist predators are woodpeckers (Anulewicz et al. 2007), *Enoclerus* sp. (Coleoptera: Cleridae), *Catagenus rufus* F. (Coleoptera: Passandridae) and *Tenebroides* sp. (Coleoptera: Trogossitidae) (Moraal 2011), among them woodpeckers may affect significantly the emerald ash borer (Anulewicz et al. 2007).

In Moscow, no parasitoids were identified (Baranchikov et al. 2008). In Belgium, wasps specific to native *Agrilus* sp. could perhaps parasitize the emerald ash borer, such as species from the families Ichneumonidae (*Atanycolus* sp.) and Braconidae (*Spathius* sp.) (Kenis and Hilszczanski 2004). Generalist species of woodpeckers and predator coleopterans (e.g. the generalist *Thanasimus formicarius* (Cleridae)) should have a moderate impact on emerald ash borer populations.

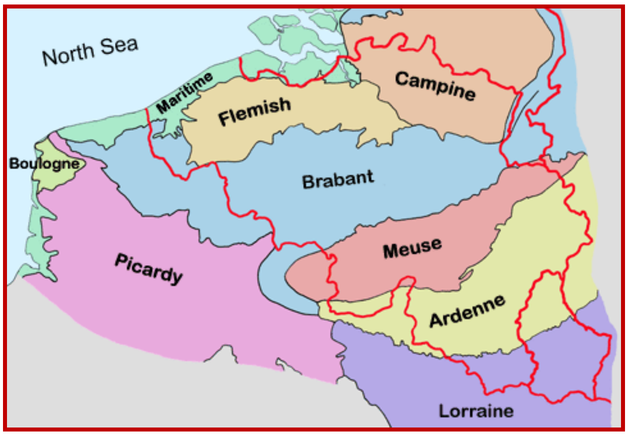
F/ Establishment capacity in Belgium

Future establishment of the emerald ash borer is considered to be likely in Belgium because of suitable climatic conditions and availability of a suitable host tree, *Fraxinus excelsior* (Koble and Seufert 2001, Brus et al. 2011).

G/ Endangered areas in Belgium

As climatic requirements are likely to be encountered everywhere in Belgium, the most important factor for establishment in the country is the abundance of suitable hosts. Ash trees are naturally abundant in the Brabant, Meuse and Ardenne (Basse Ardenne) districts (Brus et al. 2011, Koble and Seufert 2001). Moreover ash trees are commonly used as ornamental or shade trees in urban areas e.g. in Brussels, 200 ashes are listed on the inventory of remarkable trees (MRBC 2012). The Flandrian district which is particularly urbanized with two big cities (Ghent and Antwerp) and several regional cities (Brugge, Sint-Niklaas and Mechelen), and also connected to potential entry ports (Zeebrugge, Antwerp; Luyten and Van Hecke, 2007) is also likely to present optimal environmental conditions for the establishment of the emerald ash borer.

The establishment capacity for the different Belgian geographic districts is deemed as follows:



Districts	**Establishment conditions**
Maritime	Suboptimal
Flandrian	Optimal
Brabant	Optimal
Kempen	Suboptimal
Meuse	Optimal
Ardenne	Optimal
Lorraine	Suboptimal

Map taken from Diederich & Ries, lichenology.info

2.1.5 Dispersal capacity

A/ Natural spread

The natural spread is a short-range spread as beetles fly to new hosts (Caeppaert et al. 2005). Natural spread rate is estimated as quite low, with a mean rate around 1 km/year (McCullough et al. 2005; Taylor et al. 2004). Relative long dispersal events are occasional. They occur by flights of more than 1 km (Haack et al. 2002) and probably by wind because adults are small and subjected to dispersal by air currents. Flight capability was also evaluated in the laboratory by flight mills with an average of 1,3 km/day and 10% of females flying more than 7 km/day (Taylor et al. 2010).

B/ Human assistance

Human-mediated transport occurs over long distance (Muirhead et al. 2006). Part of the population of the emerald ash borer can survive 1-2 months in cut logs (Petrice et al. 2007). Therefore, human mediated-dispersal results from movement of infested materials such as firewood or cut logs.

Despite never formally observed, a second potential pathway of movements within the country could be the transport of plants for planting from plant nursery stocks (EPPO 2005). Most of plant nurseries are located in eastern Flanders (around Ghent), in western Flanders (around Antwerp) and in Limburg provinces. A few nurseries are also located in Brabant provinces (Rigaux ISEFOR, pers. comm.).

2.2 EFFECTS OF ESTABLISHMENT

2.2.1 Environmental impacts

A/ Competition [Low]

Competition with native species is supposed low; Evans et al. (2004) mention 8 native buprestid species of *Agrilus* spp. and species of the genus *Coraebus* and *Melanophila*, all colonizing broadleaved trees in Europe, but none of them are regular colonizers of ashes.

B/ Predation/herbivory [High]

In Belgium and neighbouring areas, the main host is *Fraxinus excelsior* (Koble and Seufert 2001). Little is known about the susceptibility of this species to the emerald ash borer, but at least one report of *F. excelsior* infested was done in western Russia (Baranchikov et al. 2008).

If adults only cause little damages to host trees by feeding on leaves, larvae are particularly destructive. Symptoms depend on the density of attacks. *Agrilus planipennis* can persist at low density level without inducing significant symptoms (e.g. no crown dieback, no epicormic sprouting) (Marshall et al. 2009). At high density, the most severe symptom is the decline of ashes, caused by a gradual reduction in the size of tree crown (Pontius et al. 2008). In less than 10 years, the consequences of the emerald ash borer establishment on the US forest were dramatic with millions of ash trees killed. In 2006, 15 million trees were killed in Michigan (Poland and McCullough 2006) and in 2007, 53 million killed trees were recorded across Michigan, Indiana and Ohio (Smith et al. submitted for publication, in Koch et al. 2012).

C/ Genetic effects and hybridization [Low]

Hybridization with other buprestids has never been reported. Despite several *Agrilus* species being present in Belgium (Hastir & Gaspar 2002), in the absence of a comprehensive phylogeny it seems difficult to estimate the potential for *A. planipennis* to hybridize with endemic species.

D/ Pathogen pollution [Very low]

So far, the emerald ash borer has not been reported to favour the spread of any native or exotic pathogen.

E/ Effects on ecosystem functions [High]

F. excelsior is particularly abundant on calcic and polytrophic mulls (Duliere et al. 1995) and most common in wet sites such as riparian areas or swamps (Pautasso et al. 2013). Disappearance of ashes would have serious consequences for native biodiversity and riparian forest ecosystems. Because of the emergence of ash dieback caused by *Chalara fraxinea* (Delhaye et al. 2010), *F. excelsior* populations are already threatened in Belgium. The attack of the emerald ash borer should superimpose to the fungi's impact and result in a complete decline of ashes.

Ashes play also a role in nutrient and water cycling and their decline should alter nutrient concentration and soil moisture content of natural habitats (Fissore et al. 2012). Ashes also provide food and shelter for birds, insects, mammals and rare epiphytic lichens (Orłowski and Nowak 2007; Pautasso et al. 2013). The abundance of ashes has been also shown associated with greater mollusc diversity (Rüetschi 1999, in Pautasso et al. 2013). If on the short term, the decline of ash trees could promote the abundance of saproxylic beetles and animals such as woodpeckers or cavity-nesting birds, on the long term, disappearance of ashes should increase the risk of associated species becoming extinct. Canopy gaps and open areas created by dying ash trees could also make it easier for invasive plants to establish (Herms et al. 2008).

2.2.2 **Animal health impacts** [Very low]

No impact on animal health is expected.

2.2.3 **Plant health impacts** [Moderate to High]

In Belgium, the trade based on ash is moderate with, in Wallonia, 20 000 ha of standing trees and around 12 000 m³ felled each year (around 5% of the broadleaved wood trade), but the price of ash wood is quite high. Because of its strength and elasticity, it is used for furniture, veneer, flooring, composite wood, tool handles and sport equipments (Baranchikov et al. 2008, Pautasso et al. 2013). In 2011, a price of 90 Euro per m³ was not uncommon (Delahaye et al. 2011).

2.2.4 **Human health impacts** [Very low]

No impact on human health is expected.

2.2.5 **Other impacts** [Low to Moderate]

Eradication programs generate heavy costs; in the US, for the period 2009-2019, a global cost of nearly $1 billion per year was estimated for the treatment, removal, and replacement of trees (Kovacs et al. 2009).

A loss in landscape value in urban areas where *F. excelsior* is planted as shade or ornamental trees is also likely to occur. For example, in the Brussels Region, 200 ash trees are listed on the inventory of remarkable trees (MRBC 2012).

F. excelsior constitutes a potential resource for future pharmacological developments. The exudates of ashes ('manna') have medical properties (Baranchikov et al. 2008); e.g. in-vitro experiments have shown that, extracts of ash bark have anti-malarial properties by inhibiting the development of asexual stages of *Plasmodium falciparum* (Aydin-Schmidt et al. 2010).

3 SUMMARY: *AGRILUS PLANIPENNIS* IN BELGIUM

ENTRY – *Moderate* - The entry in Belgium by direct import from a native area or an already invaded area is estimated moderate first because intercept of *Agrilus planipennis* with wood-packing material is scarce and second because the ashes for planting seems rarely imported to Belgium.

Introduction of infested material via neighbouring countries (e.g. the Netherlands) would be likely if the species became established in one of these countries.

ESTABLISHMENT – *High* - The emerald ash borer is likely to establish self-sustaining populations in Belgium and neighbouring areas because appropriate climatic conditions and patches of suitable host tree are both encountered.

SPREAD – *Moderate to High* - Natural dispersion is quite low but occasional dispersal at long distance may occur by wind. The emerald ash borer can be spread by human activities through infested logs or firewood. A quite high empirical rate of spread of 20 km/year was estimated (Prasad et al. 2010).

IMPACTS – *High* - Environmental impacts of the spread of the emerald ash borer are estimated as high, because it is likely that the spread of *Agrilus planipennis* will contribute to the decline of *Fraxinus excelsior* in Belgium and neighbouring countries, already weakened by *Chalara fraxinea*. Despite ash wood only constituting 5% of broadleaved wood exchanged each year, its monetary value is high and a potential for use in pharmacology exist. Therefore, economic impacts are estimated moderate to high.

LIST OF REFERENCES

Anulewicz et al. (2007) Emerald ash borer (*Agrilus planipennis*) density and canopy dieback in three North American ash species. Arboric. Urban For. 33: 338-349

Anulewicz et al. (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: 230–241

Aydin-Schmidt et al. (2010) Carolus Linnaeus, the ash, worm-wood and other anti-malarial plants. Scand. J. Infect. Dis. 42: 941–942

Baranchikov et al. (2008) Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. Bulletin OEPP/EPPO Bulletin 38: 233–238

Baranchikov et al. (2011) Emerald ash borer in Russia: 2009 situation update. In: McManus et al. (eds.). 2010. Proceedings. 21st U.S. Department of Agriculture interagency research forum on invasive species 2010; 2010 January 12-15; Annapolis, MD. Gen. Tech. Rep. NRS-P-75. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 66-67

Brus et al. (2011) Statistical mapping of tree species over Europe. European Journal of Forest Research 131: 145–157

Cappaert et al. (2005) Emerald ash borer in North America: a research and regulatory challenge. American Entomologist 51: 152-165

CFIA website (2011) http://www.inspection.gc.ca/english/plaveg/for/cwpc/wdpkgqae.shtml, consultation November 2012

Cooperative Emerald Ash Borer Project (2012) http://www.emeraldashborer.info/files/multistate_eabpos.pdf, accessed November 2012

Crosthwaite et al. (2011) The overwintering physiology of the emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae). Journal of Insect Physiology 75: 166–173

Delhaye et al. (2010) Sylva Belgica 117: 24-29

Delahaye et al. (2011) La chalarose du frêne en Wallonie : état des lieux, septembre 2011. Forêt Wallonne 114: 37-44

Duliere et al. (1996) Répertoire des groupes écologiques du fichier écologique des essences. Ministère de la Région wallonne, Jambes (B). 320 pp.

EFSA (2011) Panel on Plant Health (PLH); 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: 2185. [51 pp.] doi:10.2903/j.efsa.2011.2185.

EPPO (2005) Data sheets on quarantine pests: *Agrilus planipennis*. Bulletin OEPP/EPPO Bulletin 35: 436–438

Evans et al. (2004) Buprestidae and Cerambycidae. In: Bark and wood boring insects in living trees in Europe, a synthesis. Lieutier et al. (eds.). Dordrecht: Kluwer.

FAO (2008) International standards for phytosanitary measures: Revision of ISPM No15, Regulating wood packaging material in international trade, Draft Publ. No. 15. Food and Agriculture Organization of the United Nations, Rome, Italy

Haack et al. (2002) The emerald ash borer: a new exotic pest in North America. Newsletter of the Michigan Entomological Society 47: 1-5

Haack (2006) Exotic bark- and wood-boring Coleoptera in the United States: recent establishments and interceptions. Canadian J. For. Res. 36: 269-288

Hastir & Gaspar (2002) Les « richards » (Coleoptera – Buprestidae) de la faune de Belgique: éthologie, phénologie, classification et systématique. Notes fauniques de Gembloux 47: 3-40

Herms et al. (2008) Impacts of emerald ash borer-induced gap formation on forest communities. In: Mastro et al. (eds.) Proceedings of the emerald ash borer and Asian longhorned beetle research and technology development meeting, Pittsburgh, Pennsylvania, 23–24 Oct 2007, p 10.

IzhevskiI & Mozolevskaya (2008) *Agrilus planipennis* in Moscow. Russian journal of biological invasions 1: 20-25

IzhevskiI & Maslyakov (2010) New invasions of alien insects into the European part of Russia

1: 68-73

Jendek & Grebennikov (2011) *Agrilus* (Coleoptera, Buprestidae) of East Asia. Jan Farkac, Prague, 362 pp.

Jendek & Chamorro (2012) Six new species of *Agrilus* Curtis, 1825 (Coleoptera, Buprestidae, Agrilinae) from the Oriental Region related to the emerald ash borer, *A. planipennis* Fairmaire, 1888 and synonymy of Sarawakita Obenberger, 1924. ZooKeys 239: 71–94

Kean et al. (2012) Global eradication and response database. http://b3.net.nz/gerda. Accessed 3 December 2012

Kenis & Hilszczański (2004) Natural enemies of Cerambycidae and Buprestidae in Europe. In: European bark and wood boring insects in living trees: a synthesis. Lieutier et al. (eds.). Kluwer: 475-498

Köble & Seufert (2001) Novel maps for forest tree species in Europe. Proceedings of the 8th European Symposium on the Physico-Chemical Behaviour of Air Pollutants: "A Changing Atmosphere!", Torino (It) 17-20 September 2001

Koch et al. (2012) Breeding Strategies for the Development of Emerald Ash Borer-Resistant North American Ash: general technical report PSW-GTR-240. In Proceedings of the 4th International Workshop on Genetics of Host-Parasite Interactions in Forestry 235-239

Kovacs et al. (2009) Cost of potential emerald ash borer damage in U.S. communities. Ecol Econ 2009–2019

Luyten S & Van Hecke (2007) De belgische stadsgewesten 2001, Instituut voor Sociale en Economische Geografie, K.U.Leuven, SPF Economie, Algemene Directie Statistiek en Economische Informatie

Liu et al. (2007) Seasonal abundance of *Agrilus planipennis* (Coleoptera: Buprestidae) and its natural enemies *Oobius agrili* (Hymenoptera: Encyrtidae) and *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in China. Biol. Control 42: 61-71

Marshall et al. (2010) Efficacy of trap and lure types for detection of *Agrilus planipennis* (Col., Buprestidae) at low density. Journal of Applied Entomology 134: 296–302. doi: 10.1111/j.1439-0418.2009.01455.x

McCullough et al. (2005) Dispersal of emerald ash borer at outlier sites: three case studies. In: Mastro & Reardon (eds.). Emerald ash borer research and technology development meeting, FHTET 2004-15, USDA Forest Service, Morgantown, WV, pp 58-59

Moraal (2011) Biologische bestrijding van de essenprachtkever *Agrilus planipennis*: een literatuurstudie. Wageningen: Alterra Wageningen UR, 2011 Alterra-rapport (ISSN 1566-7197; 2188)

MRBC (2012) http://arbres-inventaire.irisnet.be/ last consultation on February 2012

Myers et al. (2009) Evaluation of heat treatment schedules for Emerald Ash Borer (Coleoptera: Buprestidae). Journal of Economic Entomology 102: 2048-2055

Pautasso et al. (2013) European ash (*Fraxinus excelsior*) dieback – a conservation biology challenge. Biological Conservation 158: 37-49. doi:10.1016/j.biocon.2012.08.026.

Petrice & 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

Poland & McCullough (2006) Emerald ash borer: invasion of the urban forest and the threat to North America's ash resource. J. For. 104:118–24

Pontius et al. (2008) Ash decline assessment in emerald ash borer-infested regions: A test of tree-level, hyperspectral technologies. Remote Sensing of Environment, 112, 2665−2676

Prasad et al. (2010) Modeling the invasive emerald ash borer risk of spread using a spatially explicit cellular model. Landscape Ecology, 25, 353–369

Sobek-Swant et al. (2012) Potential distribution of emerald ash borer: what can we learn from ecological niche models using Maxent and GARP? Forest Ecology and Management. 281:23-31

Taylor et al. (2004) Emerald ash borer flight potential. In: Mastro & Reardon (eds.). Emerald ash borer research and technology development meeting, FHTET-2004-02, USDA Forest Service, Morgantown, WV, pp. 31-32

Taylor et al. (2010) Flight performance of *Agrilus planipennis* (Coleoptera: Buprestidae) on a flight mill and in free flight. J. Insect Behav. 23(2):128–148. doi:10.1007/s10905-010-9202-3.

USCBP website (2010) http://cbp.gov/archived/xp/cgov/newsroom/news_releases/archives/2010_news_releases/august_2010/08112010_4.xml.html. consultation on November 2012

USDA–APHIS (2008) New Pest Response Guidelines for the Emerald Ash Borer, *Agrilus planipennis* (Fairmaire) USDA–APHIS–PPQ–Emergency and Domestic Programs–Emergency Planning, Riverdale, Maryland

USDA–APHIS (2011) Emerald Ash Borer Program Manual, *Agrilus planipennis* (Fairmaire) USDA–APHIS–PPQ–Emergency and Domestic Programs–Emergency Planning, Riverdale, Maryland

Venette & Abrahamson (n.d.) Cold hardiness of emerald ash borer, *Agrilus planipennis*: A new perspective. 1-5. Retrieved from http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5191794.pdf

Wang et al. (2010) The biology and ecology of the emerald ash borer, *Agrilus planipennis*, in China. Journal of Insect Science 10, 28

Yang et al. (2006) A new species of emerald ash borer parasitoid from China belonging to the genus *Tetrastichus* Haliday (Hymenoptera: Eulophidae). Proc. Entomol. Soc. Wash. 108: 550-558