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Agrilus planipennis
Pest Report to support ranking of EU candidate priority pests

EFSA (European Food Safety Authority),
Baker R, Gilioli G, Behring C, Candiani D, Gogin A, Kaluski T, Kinkar M, Mosbach-Schulz O, Neri FM, Preti S, Rosace MC, Siligato R, Stancanelli G and Tramontini S

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Correspondence: alpha@efsa.europa.eu

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1. Introduction to the report

This document is one of the 28 Pest Reports produced by the EFSA Working Group on EU Priority Pests under task 3 of the mandate M-2017-0136. It supports the corresponding Pest Datasheet published together on Zenodo[1] and applies the methodology described in the Methodology Report published on the EFSA Journal (EFSA, 2019).

This Pest Report has five sections. In addition to this introduction, a conclusion and references, there are two key sections, sections 2 and 3.

Section 2 first summarises the relevant information on the pest related to its biology and taxonomy. The second part of Section 2 provides a review of the host range and the hosts present in the EU in order to select the hosts that will be evaluated in the expert elicitations on yield and quality losses. The third part of Section 2 identifies the area of potential distribution in the EU based on the pest's current distribution and assessments of the area where hosts are present, the climate is suitable for establishment and transient populations may be present. The fourth part of Section 2 assesses the extent to which the presence of the pest in the EU is likely to result in increased treatments of plant protection products. The fifth part of section 2 reviews additional potential effects due to increases in mycotoxin contamination or the transmission of pathogens.

In Section 3, the expert elicitations that assess potential yield losses, quality losses, the spread rate and the time to detection are described in detail. For each elicitation, the general and specific assumptions are outlined, the parameters to be estimated are selected, the question is defined, the evidence is reviewed, and uncertainties are identified. The elicited values for the five quantiles are then given and compared to a fitted distribution both in a table and with graphs to show more clearly, for example, the magnitude and distribution of uncertainty. A short conclusion is then provided.

The report has two appendices. Appendix A contains a host list created by amalgamating the host lists in the EPPO Global Database (EPPO, online) and the CABI Crop Protection Compendium (CABI, 2018a). Appendix B provides a summary of the evidence used in the expert elicitations.

It should be noted that this report is based on information available up to the last day of the meeting[2] that the Priority Pests WG dedicated to the assessment of this specific pest. Therefore, more recent information has not been taken into account.

For *Agrilus planipennis*, the following documents were used as key references: pest risk analyses (PRAs) by EPPO (2013a) and Norway (VKM, 2014) and a contingency plan developed by Mainprize (2017) for the UK.

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[1] Open-access repository developed under the European OpenAIRE program and operated by CERN, https://about.zenodo.org/

[2] The minutes of the Working Group on EU Priority Pests are available at http://www.efsa.europa.eu/sites/default/files/wgs/plant-health/wg-plh-EU_Priority_pests.pdf

2. The biology, ecology and distribution of the pest

2.1. Summary of the biology and taxonomy

Emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire, 1888, *Coleoptera: Buprestidae*) is a single taxonomic entity. It originates from Far-East Asia and it was detected in 2002 in North America (USA and Canada) and in 2005 in the European part of Russia (Moscow region), causing extensive ash mortality in both areas of invasion (e.g. Haack et al., 2002; Baranchikov et al., 2008).

Time required to complete 1 generation:

- One year: adults begin to emerge in late spring or early summer → larvae develop in summer and autumn → the pest overwinters as fourth instar larvae or prepupae → pupation occurs in spring of the following year. The pest completes 1 generation in one year when frost free days are over 150 per year (Wei et al., 2007).
- Two years: young larvae (first to third instars) overwinter in the cambial area and resume feeding in spring of the following year → these individuals overwinter a second time as fourth instars or prepupae, and then pupate and emerge as adults the next year. The pest completes one generation in two years when frost free days are below 150 per year (Wei et al., 2007).

The proportion of individuals completing their development in more than one year depends on when the eggs were laid during the summer months, the local climate, host condition, larval density in the tree. For example, Siegert et al. (2010).

2.2. Host plants

2.2.1. List of hosts

The host range of EAB includes cultivated, ornamental and wild plants. The only verified larval host plants of *A. planipennis* are those from the genus *Fraxinus* (Jendek and Poláková 2014), the white fringe tree (*Chionanthus virginicus L.,* Oleaceae) (Cipollini, 2015), *Olea europaea* subsp. *europaea* (Cipollini et al., 2017). *Olea* could become an alternative host where ash foliage is available nearby for adults to consume in order to complete sexual maturation (Cipollini and Peterson, 2018).

Susceptible species: *F. americana, F. excelsior, F. angustifolia* (syn = *F. oxycarpa*), *F. mandshurica, F. chinensis, Fraxinus latifolia, F. ornus, F. pennsylvanica, F. quadrangulata* and *F. velutina* (EPPO, 2013a).

Other species from the literature not confirmed as larval hosts: *Fraxinus lanuginosa, F. nigra x mandshurica, F. profunda, F. uhdei, F. mandshurica* var. *japonica, Juglans ailanthifolia* (syn. *J. mandshurica var. sieboldiana, J. sieboldiana, J. cordiformis*, and *J. mandshurica var. sachalinensis*), *J. mandshurica, J. mandshurica* var. *japonica Pterocarya rhoifolia Ulmus propinqua* (=*Ulmus davidiana* var. *japonica*) (EFSA, 2011; EPPO, 2013a).

North American ash species are susceptible to EAB even when healthy, whereas Asian species (*F. chinensis, F. mandshurica, F. rhynchophylla*) are susceptible only when stressed (EPPO, 2013a; Poland et al., 2015). Of the North American ash species, blue ash (*F. quadrangulata*) is clearly the least susceptible, and white ash (*F. americana*) is somewhat less preferred than black ash (*F. nigra*) and green ash (*F. pennsylvanica*) (McCullough and Siegert, 2007; Herms and McCullough, 2014).

Species present in the assessment area:

- *F. excelsior*: this species is widely present in the planted and natural forests of Europe. It is found in: Austria, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Macedonia, The Netherlands, Norway, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, ex-Yugoslavia and United Kingdom (EFSA, 2011; EPPO, 2013a). In particular, this species is found at the EU border with Russia, Belarus and Ukraine where the beetle might first enter the EU (Beck et al., 2016).
- *F. ornus* and *F. angustifolia*: these species have a more southerly distribution than *F. excelsior* (Caudullo and de Rigo, 2016; Caudullo and Houston Durrant, 2016).

When combining the distribution of the three species, susceptible *Fraxinus* hosts to *A. planipennis* can be found throughout the European Union (EFSA, 2011).

- *F. americana*: present as sub-spontaneous tree in Bulgaria, France, Hungary, Lithuania (DAISIE, online) and Romania (Sîrbu et al., 2011).
- ornamental plants such as *Fraxinus latifolia*, *F. mandshurica*, *F. nigra*, *F. pennsylvanica*, *F. quadrangulata* and *F. velutina* (EPPO, 2013a; EFSA, 2011).

Appendix A provides the full list of hosts.

2.2.2. Selection of hosts for the evaluation

All the European ash species (*F. angustifolia, F. excelsior* and *F. ornus*) seem to be highly susceptible to EAB attack even when healthy (Herms, 2015, Baranshikov et al., 2014). These three *Fraxinus* species are considered to be the main hosts for EAB in the EU. Details on their ecology and their distribution in Europe are provided for *F. excelsior* by Beck et al. (2016), for *F. angustifolia* by Caudullo et al. (2016) and for *F. ornus* by Caudullo and de Rigo (2016).

2.2.3. Conclusions on the hosts selected for the evaluation

The three common native European *Fraxinus* species (*F. angustifolia*, *F. excelsior* and *F. ornus*) were assessed together for impact since they are all known to have high susceptibilities and, taken together, they can be found throughout the EU.

2.3. Area of potential distribution

2.3.1. Area of current distribution

Figure 1 provides an overview of the current area of distribution of the pest. In the EU no outbreaks have yet been reported.

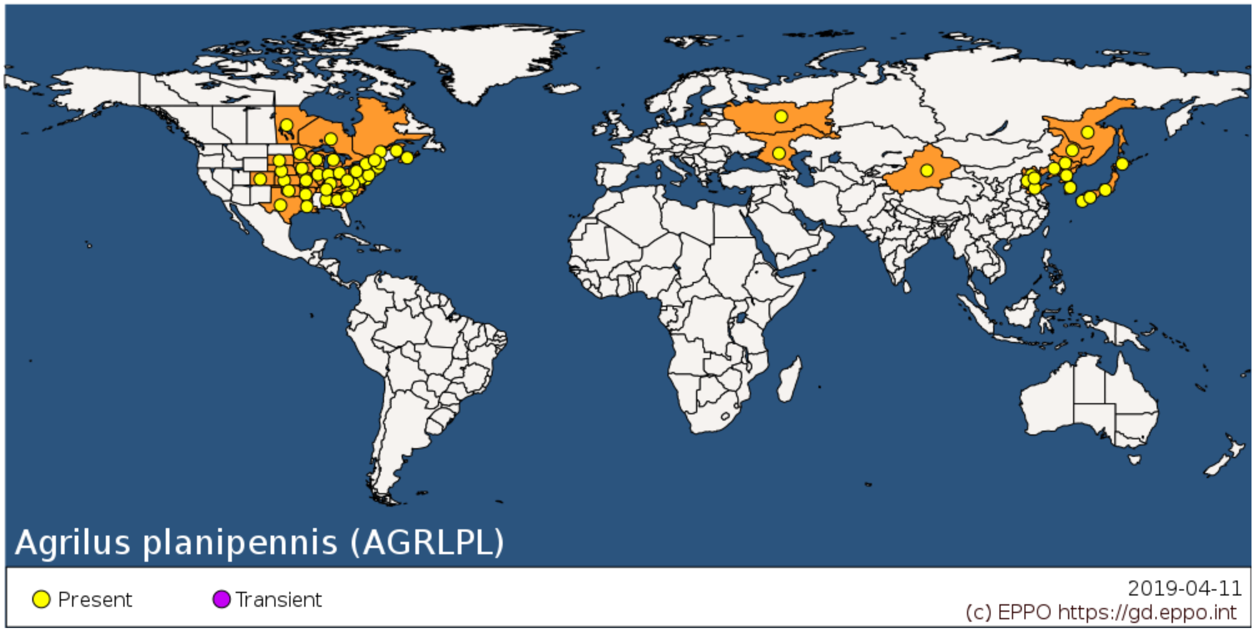

Figure 1 Distribution map of *Agrilus planipennis* from the EPPO Global Database accessed 11/04/2019.

2.3.2. Area of potential establishment

The wide distribution of *A. planipennis* covers most of the Köppen-Geiger climates present in the EU: large part of its life cycle is completed inside the trunk, where it is protected from extreme meteorological conditions, and can be extended over longer periods of time, in case of unfavourable conditions. This explains its establishment in Moscow, where winter temperatures often reach below −30°C.

Field observations identified the lethal temperature for larvae (−25°C on average; Venette and Abrahamson, 2010) and laboratory studies for prepupae (−30°C on average; Crosthwaite et al., 2011). No data are instead available on the development thresholds for adult emergence and the temperature-based control of the adult flight: adults are active in strong sunlight and at temperatures above 25°C (Wang et al., 2010). In experimental conditions, *A. planipennis* adults fly at room temperatures of 23°C (Taylor et al., 2010) and express their maximum flying capacity at 27.9 °C (Fahrner et al., 2015).

2.3.3. Transient populations

Agrilus planipennis is not expected to form transient populations in the EU (for "transient" see the definition in EFSA, 2019).

2.3.4. Conclusions on the area of potential distribution

The area of potential distribution for *A. planipennis* is considered to be the whole of the EU because: (i) all three European *Fraxinus* species are highly susceptible, (ii) taken together, these species occur throughout the EU and (iii) it is assumed that the whole of the EU is climatically suitable for *A. planipennis* (Figure 2).

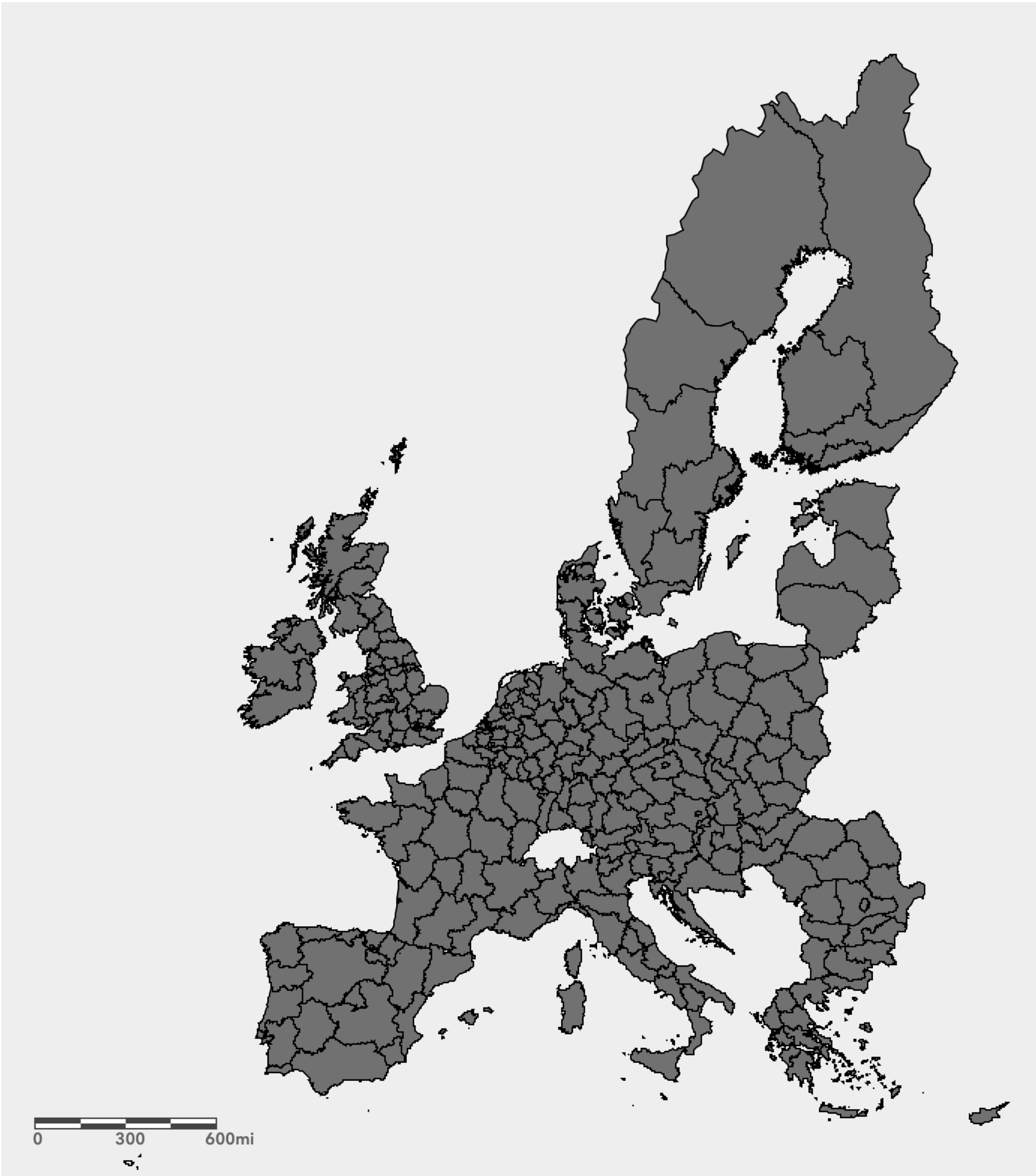

Figure 2 The potential distribution of the pest in the EU NUTS2 regions based on the scenarios established for assessing the impacts of the pest by the EFSA Working Group on EU Priority Pests (EFSA, 2019). This link provides an online interactive version of the map that can be used to explore the data further: https://arcg.is/18auzf

2.4. Expected change in the use of plant protection products

Chemical control is used mostly for high-value trees (e.g. urban trees and ornamentals). In these circumstances, injections or sprays are considered as valid methods to protect living and cut trees (Petrice and Haack, 2006; Herms et al., 2009; McCullough et al., 2011). Trunk or soil systemic injections or soil drenches could be used to prevent tree infestations (100% effective) or kill *A. planipennis* already present in trees though this is not 100% effective except for emamectin benzoate (Petrice and Haack, 2006). The efficacy of systemic products is also affected by the size of the tree.

In North America mass-rearing and release of Chinese parasitoids (the larval parasitoids *Spathius agrili* and *Tetrastichus planipennisi*, and the egg parasitoid *Oobius agrili*) to reduce the pest populations has been conducted. All three are currently established in the US but their impact on the populations of *A. planipennis* is not yet known. A number of other parasitoids reared from *Agrilus* are being investigated, such as *Spathius galinae* originating from the Russian Far-East (Belokobylski et al., 2012; Yang et al., 2012a). In North America and China several native species were also found attacking *A. planipennis* (Johny et al., 2012; Yang et al., 2012b) with highly variable parasitism rates (ranging from 1.2% to 40.7% according to Lyons, 2010).

In forested areas, chemical insecticidal control is neither economically viable nor environmentally desirable (Poland, 2007).

Due to the fact that no effective treatments with plant protection products (PPPs) are currently available, the most suitable PPP indicator is Case "A" and the category is "0" based on Table 2.

Table 1: Expected changes in the use of Plant Protection Products (PPPs) following *Agrilus planipennis* establishment in the EU in relation to four cases (A-D) and three level score (0-2) for the expected change in the use of PPPs.

Expected change in the use of PPPs	**Case**	**PPPs indicator**
PPPs effective against the pest are not available/feasible in the EU	**A**	**0**
PPPs applied against other pests in the risk assessment area are also effective against the pest, without increasing the amount/number of treatments	B	0
PPPs applied against other pests in the risk assessment area are also effective against the pest but only if the amount/number of treatments is increased	C	1
A significant increase in the use of PPPs is not sufficient to control the pest: only new integrated strategies combining different tactics are likely to be effective	D	2

2.5. Additional potential effects

2.5.1. Mycotoxins

The species is not known to be related to problems caused by mycotoxins.

2.5.2. Capacity to transmit pathogens

The species is not known to vector any plant pathogens.

3. Expert Knowledge Elicitation report

3.1. Yield and quality losses

3.1.1. Structured expert judgement

3.1.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the priority pests are listed in the section 2.4.1.1 of the Methodology Report (EFSA, 2019).

3.1.1.2. Specific scenario assumptions

- Susceptible hosts are living trees that would be killed by EAB.
- There are no differences in terms of pest preferences and host vulnerability between the different EU ash species
- The potential severity of impacts is considered to be the same in all the different climatic zones in the area of potential establishment
- Urban areas, natural forests and commercial plantations are assessed together
- The amount of stress that an ash tree is suffering is not expected to influence substantially its vulnerability to an EAB attack
- The effect of Chalara ash dieback does not influence the assessment
- The damage is to the outer layers so the wood quality is not affected. The use of reduced quality wood (e.g. pulp wood/fuel wood) has not been considered.
- Any infestation with EAB will cause 10-20% losses for hardwood/veneer production.
- The assessment only considers damage to the European ash species and does not take into account the potential losses to other ornamental, non-native ash species which are less widely grown.
- There is a uniform age distribution of ash trees, from very young to the end of rotation (100-120 years), in the area of potential establishment.

3.1.1.3. Selection of the parameter(s) estimated

No standards for reduced quality (e.g. pulp wood/fuel wood) are considered. All loss is covered by the proportion of yield loss.

3.1.1.4. Defined question(s)

What is the percentage yield loss in *Fraxinus* trees under the scenario assumptions in the area of the EU under assessment for *Agrilus planipennis*, as defined in the Pest Report?

3.1.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.1 in Appendix B) selecting the data and references used as the key evidence for the EKE on impact. A few reference publications were identified:

- Tanis and McCullough, 2012
- Knight et al., 2013,
- Burr and McCullough, 2014,

- Klooster et al., 2014,

3.1.1.6. Uncertainties identified

- Dead trees may still have a trunk large enough to provide relevant yield
- There may be some ash genotypes resistant to EAB
- Interactions with Chalara ash dieback
- Most of the data published come from observations at nurseries and where ash populations may be genetically homogeneous: a greater variability in responses to EAB attacks is expected in natural conditions
- Potential effect of native parasitoids (see Russia for example)

3.1.2. Elicited values for yield losses

What is the percentage yield loss in *Fraxinus* trees under the scenario assumptions in the area of the EU under assessment for *A. planipennis*, as defined in the Pest Report?

The five elicited values on yield loss in *Fraxinus* sp. on which the group agreed are reported in the table below.

Table 2: Summary of the 5 elicited values on yield loss (%) on *Fraxinus* plantations

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	50%	65%	75%	85%	99%

3.1.2.1. Justification for the elicited values for yield loss on *Fraxinus* sp.

Reasoning for a scenario which would lead to high yield loss (99th percentile / upper limit)

The upper value of yield loss is based on experiences in North America. Some ash genotypes could be more attractive or vulnerable to EAB attack. Native parasitoids have no effect. EAB attack will result in tree mortality and total loss of yield.

Reasoning for a scenario which would lead to low yield loss (1st percentile / lower limit)

The lower value of yield loss is given mainly by the fact that genetic variability could cause some ash genotypes to be less attractive or vulnerable to EAB. This also takes into account what has been observed in the US where some wild ash survived colonization and could even recover (Aubin et al., 2015). Native parasitoids could have an impact on the EAB population.

There is more chance of tree recovery so that the attacked trees still provide relevant yield.

Reasoning for a central scenario equally likely to over- or underestimate the yield loss (50th percentile / median)

The median value of yield loss is given by the high expected mortality compensated by the capacity of some affected plants to recover.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision is mainly affected by uncertainty in the expected responses by EU ash species in the different habitats (from urban areas to wild forests).

3.1.2.2. Estimation of the uncertainty distribution for yield loss on *Fraxinus* sp.

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 3: Fitted values of the uncertainty distribution on the yield loss (%) on *Fraxinus* sp.

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	50%					65%		75%		85%					99%
Fitted distribution	49%	51%	53%	57%	61%	65%	69%	75%	82%	85%	88%	92%	95%	96%	98%

Fitted distribution: BetaGeneral (2.1392,1.6113,0.45,1), @RISK7.5

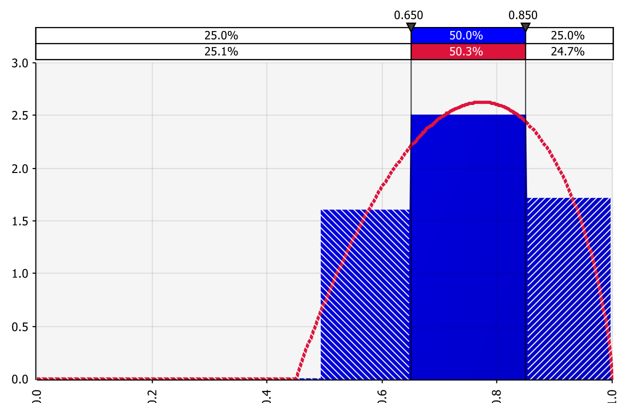

Figure 2 Comparison of judged values (histogram in blue) and fitted distribution (red line) for yield loss on *Fraxinus* sp.

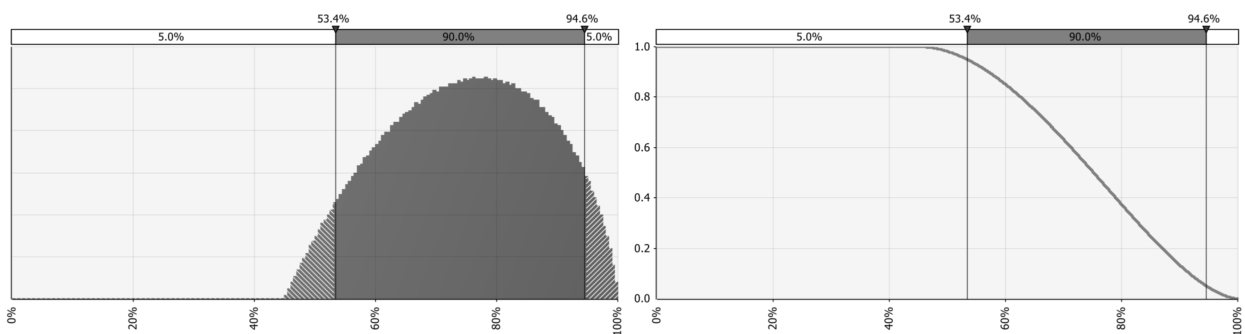

Figure 3 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for yield loss on *Fraxinus* sp.

3.1.3. Conclusions on yield and quality losses

Due to the assumption of homogeneous growing conditions for *Fraxinus* sp. plants in Europe no further spatial stratification due to climatic conditions or other factors affecting the potential establishment of the pest is made. This estimation of yield loss can therefore be applied to all EU NUTS2 regions where ashes are present.

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses (here with the meaning of mortality rate) is estimated to be 75% (with a 95% uncertainty range of 51 - 96%).

3.2. Spread rate

3.2.1. Structured expert judgement

3.2.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the different priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019).

3.2.1.2. Specific scenario assumptions

- Local displacement of logs is not considered to be important for short distance dispersal so the spread rate only takes into account the active and passive (wind supported) natural spread.
- Different ash species do not influence the spread rate.
- Hitchhiking is excluded as it is not confirmed to be a major component of spread

3.2.1.3. Selection of the parameter(s) estimated

The spread rate has been assessed as the number of metres per year.

3.2.1.4. Defined question(s)

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (Units: m/year)

3.2.1.5. Evidence selected

The experts reviewed the evidence obtained from the literature (see Table B.2 in Appendix B) selecting the data and references used as the key evidence for the EKE on spread rate. The main references considered are:

- McCullough et al., 2011,
- Mercader et al., 2012, 2016,
- Siegert et al., 2010,
- Taylor et al., 2010.

One general point was made: the speed of colonisation by *A. planipennis* in the EU might not be as the same as that observed in North America, since by the time it was first observed in North America, it had already spread away from the initial outbreak.

3.2.1.6. Uncertainties identified

- Flight-mill experiments overestimate the real flying capacity
- some of the papers have a component of human-assisted spread, being chronological reconstructions of invasion events (e.g. Siegert et al., 2014, Baranchikov et al., 2016)
- the effect of wind in the dispersal mechanism

3.2.2. Elicited values for the spread rate

What is the spread rate in 1 year for an isolated focus within this scenario based on average European conditions? (Units: m/year)

The five elicited values on time to detection on which the group agreed are reported in the table below.

Table 4: Summary of the 5 elicited values on spread rate (m/y)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	100	1,000	1,500	3,000	10,000

3.2.2.1. Justification for the elicited values of the spread rate

Reasoning for a scenario which would lead to wide spread (99th percentile / upper limit)

The upper value takes into account the fact that the values provided by flight-mill experiments are usually overestimations of the actual flight capacity of an insect but this consideration is counterbalanced by the potential effect of winds supporting passive dispersal mechanisms.

The widespread availability of preferred host plants will favour longer distances of spread.

Reasoning for a scenario, which would lead to limited spread (1st percentile / lower limit)

The lower value of spread rate is justified by the fact that, although in some cases individuals have been observed to move only to the next closest plant from one generation to the other, the biology of this pest supports spread even when it is not necessary just for finding food (McCullough et al., 2011).

The potential effect of wind is considered to be negligible.

Reasoning for a central scenario, equally likely to over- or underestimate the spread (50th percentile / median)

The median value is lower than some of the papers because the expert group considers an earlier stage of colonisation and not an invasion after 7 years or more as documented in many of the North American references (e.g. Siegert et al., 2014).

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision is given by the fact that the median value is a good estimate well supported by the experts with a long tail on the right.

3.2.2.2. *Estimation of the uncertainty distribution for the spread rate*

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 5: Fitted values of the uncertainty distribution on the spread rate (m/y)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	100					1,000		1,500		3,000					10,000
Fitted distribution	236	320	416	562	729	930	1,138	1,627	2,325	2,846	3,628	4,708	6,362	8,262	11,196

Fitted distribution: Gamma (0.94924,2093), @RISK7.5

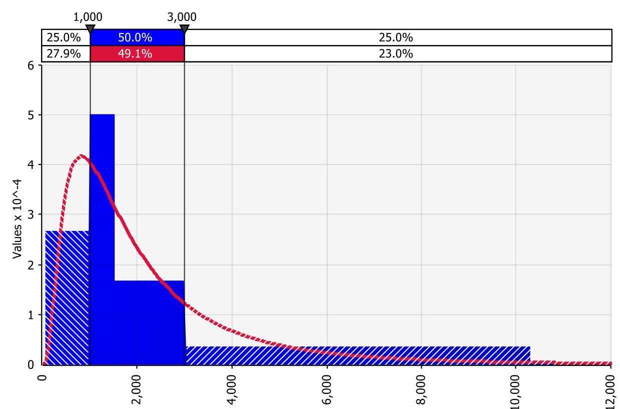

Figure 4 Comparison of judged values (histogram in blue) and fitted distribution (red line) for spread rate.

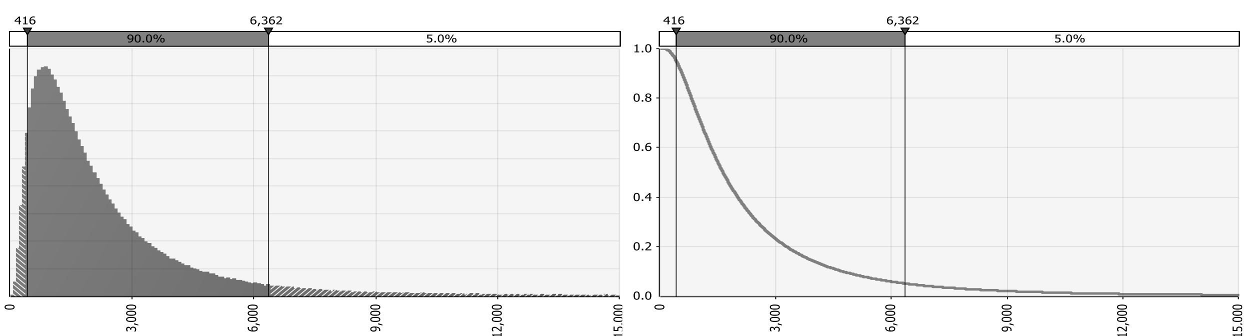

Figure 5 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for spread rate.

3.2.3. Conclusions on the spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *A. planipennis* is approximately 1,600 m (with a 95% uncertainty range of 320 – 8,262 m).

Due to the assumption of homogeneous growing conditions for *Fraxinus* sp. plants in Europe, this estimation can be applied to all EU NUTS2 regions where ash trees are present.

3.3. Time to detection

3.3.1. Structured expert judgement

3.3.1.1. Generic scenario assumptions

All the generic scenario assumptions common to the assessments of all the different priority pests are listed in the section 2.4.2.1 of the Methodology Report (EFSA, 2019).

3.3.1.2. Specific scenario assumptions

No specific assumptions are introduced for the assessment of the time to detection.

3.3.1.3. Selection of the parameter(s) estimated

The time for detection has been assessed as the number of years between the first event of pest transfer to a suitable host and its detection.

3.3.1.4. Defined question(s)

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (Unit: years)

3.3.1.5. Evidence selected

- Size of the adults and its habit of remaining in the canopy make this species hard to be seen in spite of the attractive colors. Visual inspection is the main method for detection in the EU.
- Current traps are not fully effective, and no long-range pheromone traps are available
- Most new EAB infestations have been at least 6-10 years-old before being identified.

3.3.1.6. Uncertainties identified

- Visibility of exit holes
- Possible confusion between EAB and Chalara ash dieback symptoms. Other metallic green buprestid beetles could also be confused with EAB.
- Overall awareness of the phytosanitary services and the general public – the capacity of people to observe EAB and be so interested by its presence that they contact phytosanitary services

3.3.2. Elicited values for the time to detection

What is the time between the event of pest transfer to a suitable host and its first detection within this scenario based on average European conditions? (Unit: years)

The five elicited values on time to detection on which the group agreed are reported in the table below.

Table 6: Summary of the 5 elicited values on time to detection (years)

Percentile	**1%**	**25%**	**50%**	**75%**	**99%**
Expert elicitation	2%	7%	10%	15%	20%

3.3.2.1. Justification for the elicited values of the time to detection

Reasoning for a scenario which would lead to a long time for detection (99th percentile / upper limit)

The upper value takes into account the experience with Chalara ash dieback: it took many years to be noticed and identified, in addition, dieback could hide the presence of EAB. In this case there is already a damage scenario. Exit holes are very hard to be seen. The two-year life cycle delays symptom development. Forest inventories are assumed to occur every 4 years.

Reasoning for a scenario which would lead to a short time for detection (1st percentile / lower limit)

The lower value of 2 years is based: on somebody seeing the beetle, e.g. in a private garden or when surveillance activity is undertaken to detect Chalara ash dieback or peeling bark symptoms are detected on a tree attacked by EAB during the first year (when larvae are already present). Ash is a common urban tree in the EU where the symptoms of EAB can be more easily seen than in forests.

Reasoning for a central scenario, equally likely to over- or underestimate the time for detection (50th percentile / median)

The median value is related to the fact that the current survey and detection activity is very unlikely to find a new outbreak and social involvement and knowledge on this pest is still low. Most new EAB infestations have occurred for at least 6-10 years before being detected. Invasive pests frequently take 10 years to be detected.

Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile / interquartile range)

The precision is mainly driven by the assumption that forest inventories in the EU are conducted every 4 years on average (Hauk, 2007). However, the values closer to Q1 are more representative of a scenario in urban areas while Q3 is more related to detection in forests.

3.3.2.2. Estimation of the uncertainty distribution for the time to detection

The comparison between the fitted values of the uncertainty distribution and the values agreed by the group of experts is reported in the table below.

Table 7: Fitted values of the uncertainty distribution on the time to detection (years)

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Expert elicitation	2					7		10		15					20
Fitted distributio n	1.6	2.1	2.8	3.9	5.2	6.6	8.0	10.6	13.2	14.6	16.2	17.5	18.8	19.6	20.2

Fitted distribution: BetaGeneral (1.3141,1.5198,3,19), @RISK7.5

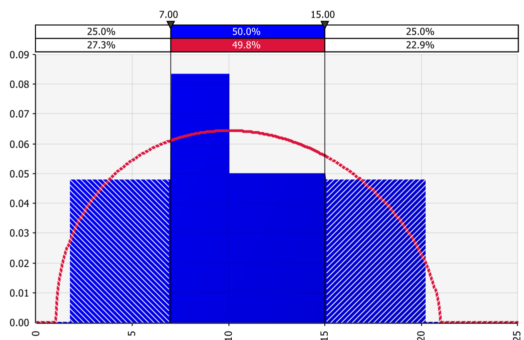

Figure 6 Comparison of judged values (histogram in blue) and fitted distribution (red line) for time to detection.

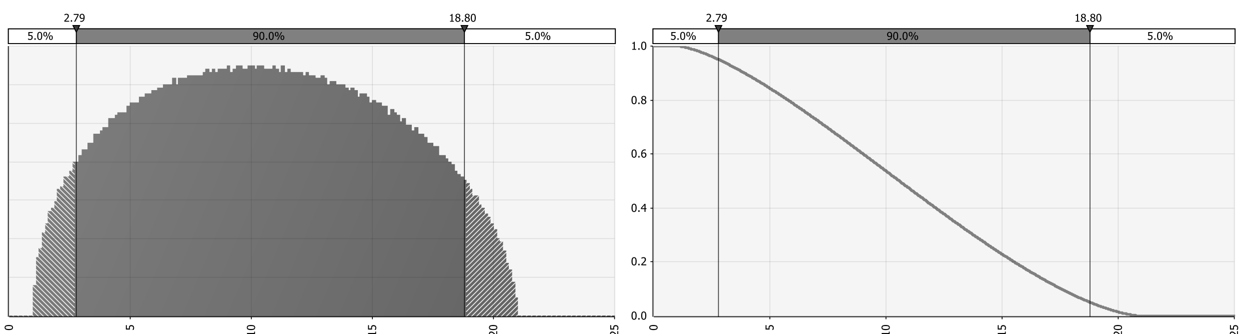

Figure 7 Fitted density function to describe the uncertainties with 90% uncertainty interval (left) and fitted descending distribution function showing the likelihood (y-axis) that a given proportion (x-axis) maybe exceeded (right) for time to detection.

3.3.3. Conclusions on the time to detection

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be 10 years (with a 95% uncertainty range of 2 – 19 years).

4. Conclusions

Hosts selection

The three common native European *Fraxinus* species (*F. angustifolia*, *F. excelsior* and *F. ornus*) were assessed together for impact since they are all known to have high susceptibilities and, taken together, they can be found throughout the EU.

Area of potential distribution

The area of potential distribution for *A. planipennis* is considered to be the whole of the EU because: (i) all three European *Fraxinus* species are highly susceptible, (ii) taken together, these species occur throughout the EU and (iii) it is assumed that the whole of the EU is climatically suitable for *A. planipennis.*

Expected change in the use of plant protection products

Due to the fact that no effective treatments with plant protection products (PPPs) are currently available, the most suitable PPP indicator is Case "A" and the category is "0".

Yield loss

Due to the assumption of homogeneous growing conditions for *Fraxinus* sp. plants in Europe no further spatial stratification due to climatic conditions or other factors affecting the potential establishment of the pest is made. This estimation of yield loss can therefore be applied to all EU NUTS2 regions where ashes are present.

Based on the general and specific scenarios considered in this assessment, the proportion (in %) of yield losses (here with the meaning of mortality rate) is estimated to be 75% (with a 95% uncertainty range of 51 - 96%).

Spread rate

Based on the general and specific scenarios considered in this assessment, the maximum distance expected to be covered in one year by *A. anxius* is approximately 1,600 m (with a 95% uncertainty range of 320 – 8,262 m).

Due to the assumption of homogeneous growing conditions for *Fraxinus* sp. plants in Europe, this estimation can be applied to all EU NUTS2 regions where ash trees are present.

Time for detection after entry

Based on the general and specific scenarios considered in this assessment, the time between the event of pest transfer to a suitable host and its detection is estimated to be 10 years (with a 95% uncertainty range of 2 – 19 years).

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Appendix A – CABI/EPPO host list

The following list, defined in the Methodology Report (EFSA, 2019) as the full list of host plants, is compiled merging the information from the most recent PRAs, the CABI Crop Protection Compendium and the EPPO Global Database. Hosts from the CABI list classified as 'Unknown', as well as hosts from the EPPO list classified as 'Alternate', 'Artificial', or 'Incidental' have been excluded from the list.

Genus	**Species epithet**
Chionanthus	*virginicus*
Fraxinus	
Fraxinus	*americana*
Fraxinus	*angustifolia*
Fraxinus	*chinensis*
Fraxinus	*excelsior*
Fraxinus	*japonica*
Fraxinus	*lanuginosa*
Fraxinus	*mandshurica*
Fraxinus	*nigra*
Fraxinus	*ornus*
Fraxinus	*pennsylvanica*
Fraxinus	*profunda*
Fraxinus	*quadrangulata*
Fraxinus	*rhynchophylla*
Fraxinus	*uhdei*
Fraxinus	*velutina*
Juglans	*mandshurica*
Olea	*europaea*
Pterocarya	*rhoifolia*
Ulmus	*davidiana*

Appendix B – Evidence tables

B.1 Summary on the evidence supporting the elicitation of yield and quality losses

Susceptibility	Infestation	Symptoms	Impact	Additional information	Reference	Limitations/ uncertainties
	Incidence	***Severity***	***Losses***			
Fraxinus americana, *F. pennsylvanica*, *F. nigra*, *F. profunda*, and *F. quadrangulata*			Mortality rate: nearly 100%	Ohio, Michigan and Pennsylvania, 2004-2010. Monitoring plots (>250) to track decline and mortality of ash trees and saplings (>4500) in forests. Mortality reached about 100% in all areas and plots.	Knight et al., 2010	
F. americana L. (~28%), *F. nigra* Marsh. (~5%), *F. pennsylvanica* Marsh. (~70%)			Reduction in average ash volume: 75% in five years	Historical spread of EAB in Michigan and neighbouring States (data: FIA program). Data are for growing-stock trees (live trees, >12.7 cm DBH) on timberland. The 75% decrease is for the 'core' area (<50 km of the epicenter of the EAB invasion) in the period 2004-2009. Average ash volume decreased from 12.7 to 3.2 m^3 ha^{-1}=75%.	Pugh et al., 2011	
F. quadrangulata, *F. americana*			Percentage of dead trees: *F. quadrangulata*: 29-37% *F. americana*: 84-100%	Survival of two ash species in two south-eastern Michigan woodlots, surveyed several years after the *A. planipennis* invasion (EAB population peak ~2005).	Tanis and McCullough, 2012	
F. americana, *F. pennsylvanica*, *F. nigra*, *F. profunda*, and *F. quadrangulata*			Mortality rate from the estimated time of infestation: 25% (after 3y), 50% (4y), 75% (5y) and >99% (6y)	Field study. Naturally infested tree stands (N = 31) in forested areas in EAB-infested counties, Ohio.	Knight et al., 2013	
All native ash species	Incidence: • In the whole area: 16.9% • Core areas (close to the epicentre): 21.2% • Non-core areas: 12.9%		Mortality rate: • In the whole area: 4.8% • Core areas (close to the epicentre): 7.8%; • Non-core areas: 2.1%.	Aerial and on-ground surveys. Study area: Northern Indiana, southern Michigan and northern Ohio (estimated ash population: 318 million trees). Estimates are from 432 sample plots (1436 trees). Incidence: % of standing ash trees >5cm DBH attacked by EAB. Data on killed trees as % of symptomatic trees: 29% (study area); 36.6% (core areas); 16.3% (non-core areas).	Marshall et al., 2013	

<table>
<tr><td>F. pennsylvanica
(medium-large size trees: DBH 10–65 cm)</td><td>Incidence: 98%</td><td>Distribution in damage categories
(0=healthy; 7=dead)
<table><tr><td>Damage category</td><td>No. of trees</td></tr><tr><td>0</td><td>7</td></tr><tr><td>1</td><td>9</td></tr><tr><td>2</td><td>22</td></tr><tr><td>3</td><td>118</td></tr><tr><td>4</td><td>340</td></tr><tr><td>5</td><td>424</td></tr><tr><td>6</td><td>9</td></tr><tr><td>7</td><td>11</td></tr><tr><td>Total</td><td>940</td></tr></table></td><td>Mortality rate: 2%
(at the time of survey)</td><td>Survey, city of Moscow.
F. pennsylvanica was the most abundant ash species in the city.
Small trees (DBH <10 cm) were generally in very good condition. Some data also for F. excelsior (not included here: very few trees in the area).
<u>Incidence</u>: ratio of all categories but 0 and 1 to the total.
<u>Mortality rate</u>: ratio of categories 6 and 7 to the total.</td><td>Straw et al., 2013</td><td></td></tr>
<tr><td>• European ash species: F. excelsior, F. angustifolia and F. ornus
• American ash species: F. pennsylvanica and F. americana
• Asian ash species: F. mandshurica, F. chinensis</td><td></td><td></td><td>% killed by EAB:
• European ash species: 70-100%
• American ash species: 81-90%
• Asian ash species: 0%</td><td>EAB infestation in the Main Botanical Garden of the Russian Academy of Sciences, Moscow. Russia.
EAB first registered at the garden in 2011. The data refer to trees killed during the period 2010–2014.</td><td>Baranchikov et al., 2014</td><td></td></tr>
<tr><td>Major component of F. pennsylvanica</td><td></td><td></td><td>killed by EAB (% of the total ash basal area): 14-87%</td><td>A. planipennis invasion wave across southern Michigan.
Survey in 24 forested sites, each categorised as being part of the ‘Core’, ‘Crest’ or ‘Cusp’ of the invasion. The loss in 2011 was 87%, 57% and 14% in the Core, Crest and Cusp sites, respectively.</td><td>Burr and McCullough, 2014</td><td>First year of invasion is not provided?</td></tr>
<tr><td>F. americana,
F. pennsylvanica and
F. nigra</td><td></td><td></td><td>Cumulative mortality rate:
• Michigan: 99.7 %
• Ohio: varying, up to 100% (higher in sites infected for longer)</td><td>Ash monitoring plots in two areas: (1) SE Michigan (2004-2010) – 38 forested stands; area with high mortality (Upper Huron River watershed); (2) Ohio (2005-2008), 62 forested stands; levels of ash mortality heterogeneous and varying in time; non-infested sites included.

In Michigan, cumulative ash mortality increased from 40% in 2005 to 99.7% in 2009.</td><td>Klooster et al., 2014</td><td></td></tr>
</table>

European ash species: *F. excelsior*, *F. ornus* and *F. angustifolia* subsp. *oxycarpa* American ash species: *F. americana*, *F. latifolia*, *F. nigra*, *F. pennsylvanica* and *F. quadrangulata* Asian ash species: *F. mandshurica* Hybrid: *F. nigra* x *mandshurica*			Mortality rates (% initial population) European: • *F. excelsior*: 95% • *F. ornus*: 100% • *F. angustifolia* subsp. *Oxycarpa*: 100% American: • *F. Americana*: 55-80% • *F. latifolia*: 100% • *F. nigra*: 95-100% • *F. pennsylvanica*: 65-100% • *F. quadrangulata*: 35% Asian/hybrid: • *F. mandshurica*: 20% • *F. nigra* x *mandshurica*: 20%	Common garden study (established in 2004) in southeast Michigan. Each taxon replicated 20 times in a randomised complete block design. Mortality rates (cumulative) are those recorded in 2014.	Herms, 2015	
F. americana, *F. pennsylvanica*, *F. nigra*, *F. profunda*, and *F. quadrangulata*			Decrease in ash volume: up to 81% in five years. Ash mortality rate (on a per-volume basis): • For old infestations: up to 23.6%/year • For more recent infestations: *increasing* by up to 2.7 % /year	Study area: 22 States in the eastern US. Forest inventory data used to quantify trends in ash mortality rate and volume per hectare in the period 2009-2014 relative to the year of initial EAB detection. For areas where detection occurred in 2003-2008 (Table 2, green frame), there was an overall decrease in ash volume between 2009 and 2014. The 81% loss is for detection years 2003-2004: 1.6 m^3/ha (year 2014)/ 8.4 m^3/ha (year 2009) = 81%. For older infestations (detection year <2003), major losses had probably already depleted the population by 2009. Tables 1 and 2 at pages 707 and 708 from Morin et al., 2017	Morin et al., 2017	The authors point out that there is a time lag between EAB detection and impacts on mortality: e.g. there was no consistent trend in volume loss for more recent detection years (2009 and later).
Fraxinus americana, F. pennsylvanica, F. nigra			76% fallen dead ash trees from 2008 to 2012.		Perry et al., 2018	

B.2 Summary on the evidence supporting the elicitation of the spread rate

Spread	**Additional information**	**Reference**	**Uncertainty**
Max flight distance in a year: up to 750 m	Data collected from two newly-colonized sites in Michigan (naturally / artificially infested). Estimate of larval density on trees as a function of distance from the source of infestation. Infestation occurred less than 1 year earlier. • 88.9% and 90.3% larvae within 100 m • 100% and 97.8% within 300 m • One larva at one site at 750 m	Mercader et al., 2009	There may have been dispersal >750 m, but sampling was conducted only up to 750-800 m
Rate of expansion of infestation front: 20 km/year	Estimate of historical spread in Ohio, 1998-2006. Rate of expansion estimated using a spatially explicit model with 'stratified' dispersal: a combination of short-range (insect flight) and long-range dispersal (human-facilitated, e.g. on or in vehicles, plant or wood material).	Prasad et al., 2010	
Max flight distance in a year: 180-638 m	Sampling conducted at two sites (Michigan; mixed land cover types) where infestation originated 1 yr and 3 yr earlier from infested nursery trees. *A. planipennis* dispersal assessed by locating galleries constructed by the progeny of dispersing EAB adults. Colonised trees were found out to 638 and 540 m from the epicenters at the 1 yr and 3 yr sites, respectively.	Siegert et al., 2010	
Distance flown by mated females in a day: >3 km (median) >10 km (20%) >20 km (1%)	Free-flight distances estimated from results of flight-mill experiments.	Taylor et al., 2010	How these observations translate to field settings is unknown (Mercader et al., 2012)
< 200 m/y	The vast majority of eggs laid by *A. planipennis* females are within 200 m of their emergence point (Mercader et al., 2009, Siegert et al., 2010)	Mercader et al., 2012	

Two rates (short/long range) Expansion rate of the main invasion front: • 3.84 km/year (1998-2001) • 12.97 km/year (2001-2003) 'Jump distance' of new satellite colonies (formed each year): • average 27.4 km • maximum 64.7 km	Dendrochronological reconstruction of early spread of EAB in Michigan. Study area (> 15000 km^2) included urban and residential areas, forested parks, small woodlots and agricultural fields. Progression of ash mortality (1997-2003) reconstructed from estimated dates of tree death and used as a surrogate for the spread of EAB. Spread mechanism: combination of natural EAB dispersal and human-assisted transport of infested ash material.	Siegert et al., 2014	The switch to a faster rate of expansion of the main front (12.97 km/year) is not linked to changes in the spread mechanism. It occurred because growing satellite colonies coalesced with the primary population: as a result, the main front (defined as the edge of the primary population) suddenly expanded.
Spread rate: • 0.4–0.7 km/year (recent infestation) • 1.2–1.7 km/year (older infestation)	Spread rates of EAB (2008-2011) in two recently established EAB infestations sites in Michigan (one larger, presumably older; the other one smaller, presumably more recent). The area included forestland, a state park, small municipality with street trees. Estimates were based on larval presence in girdled detection trees. Spread mechanism: mainly natural spread. According to the authors, it is unlikely that human-assisted spread played a major role.	Mercader et al., 2016	
Rate of expansion of infestation front: 10-12 km/year	Dendrochronological reconstruction of the expansion of the western front of the EAB invasion in the European part of Russia.	Baranchikov et al., 2016 (in Russian; discussed in Musolin et al., 2017)	

B.3 Summary on the evidence supporting the elicitation of the time to detection

Reference	Case	Results / evidence
Detection methods		
Haack et al., 2002; EPPO, 2005; de Groot et al. 2006; CFIA, 2015; USDA-APHIS, 2012	Visual symptoms	• D-shaped exit holes produced by emerging adults • Larval galleries, which are typical for the genus *Agrilus*. • Symptoms of infested trees: yellowing then premature browning of the foliage, thinning of crowns, dying of branches, longitudinal bark splits with larval galleries underneath, epicormic branches and shoots often along the lower trunk, dead branches. • Woodpecker injury is commonly observed in North America and European Russia on infested trees. Woodpeckers remove small patches of bark or create small holes in the bark to extract developing *A. planipennis*. On heavily infested trees, woodpeckers in search of *A. planipennis* can flake off large areas of outer bark, which can accumulate at the base of the tree. This also leaves the trunk with large areas of light brown or whitish bark after the flakes of bark have been removed. • Dieback and dead trees.
EPPO, 2013a	Reliability	No reliable single method to detect low level populations. Monitoring usually relies on several methods, most commonly a combination of trapping, visual inspection of trees, and branch or tree sampling.
Chamorro et al., 2012	Identification	First detailed description of the egg, larval instars I–IV, prepupa, and pupa of *A. planipennis* and comparison with other7 *Agrilus* species to determine its affinity
EPPO, 2013b	Official procedures	EU standard for official control available
McCullough et al., 2011	Traps efficiency	• Purple double-decker traps: 65% of all EAB captured • green double-decker traps: 18% of the beetles • whereas sticky bands on girdled trees: 11% Purple traps differently baited and suspended in the trees canopy: 5%
McCullough et al., 2011	Use of girdled trees	Mean N of EAB larvae/m2 of ash phloem on girdled (12.2) and nongirdled (2.6) ash trees
Mercader et al., 2012	Use of girdled trees	The probability of detecting low density populations by sampling nongirdled trees is very low (even when detection tools are assumed to have three-fold higher detection probabilities than nongirdled trees)
Mercader et al., 2012	Number of sampled trees	Sampling at 1,000 m from the epicentre 1 tree → 55-60% error 5 trees → 5-7% error Sampling at 3,000 m from the epicentre 1 tree → 99% error 5 trees → 95% error
Biology of the pest		
Brown-Rytlewski and Wilson, 2005	Pest life cycle	after accumulation of 230-260 degree-days base 10°C, adults emerge

Siegert et al., 2010; Villari et al., 2016	Pest life cycle	Prolonged larval development (2yr) is more common in healthy trees, in northern habitats, and when there are low densities of *A. planipennis* infesting a tree. In stressed trees, nearly all EAB develop within 1 yr Although all instars can overwinter, pupation does not occur until after prepupae have overwintered
Mercader et al., 2012	Larval population density	Very difficult to delineate the extent of the distribution of localized EAB populations, particularly when a small proportion of the population was assumed to have a higher propensity for dispersal
Rutledge and Keena, 2012	Pest reproduction	BBB males > successful at transferring a spermatophore > EAB males, with BBB males succeeding in 47/48 attempts > 43/52 attempts of EAB 45% of singly mated EAB females failed to lay any eggs > 12% of singly mated BBB BBB shows also < mate discrimination than EAB
EPPO, 2013a	Pest life cycle	Eggs: laid individually or in small groups on the bark surface, usually inside bark cracks and crevices (68-90 eggs per female; Haack et al., 2002). Normally oviposition is on live trees; occasionally on freshly cut ash logs, although larvae emerging from such eggs rarely complete their development (Petrice and Haack, 2007, citing others; Anulewicz et al., 2008)
EPPO, 2013a	Pest life cycle	Larvae: 4 instars. First-instar larvae tunnel through the bark to the cambium, then feed in the inner bark and outer sapwood. They produce galleries (up to 26-32 cm long), which are S- shaped and filled with frass
EPPO, 2013a	Pest life cycle	Pupae: at the end of the larval gallery, predominantly in the sapwood when the bark is thin, otherwise in the outer bark when the bark is thick
EPPO, 2013a	Pest life cycle	Callow adults: under the bark for 1-2 weeks, then exit through D-shaped holes (3-4 mm wide)
EPPO, 2013a	Feeding and flying behaviour	Adults are active during the day and rest on foliage at night. When conditions are not favourable for flight, adults rest in bark cracks and on foliage. They feed on the foliage of their host throughout their lives, starting to feed and fly soon after emergence
EPPO, 2013a, citing Bauer and Miller, unpublished	Lifespan	Female: 28-120 (average 63) days, lying 1-307 (average 74) eggs Male: 12-83 (average 43) days
EPPO, 2013a	Infestation progress	On large trees it starts in the canopy, progresses down the tree finally infesting the base of the tree and surface roots. Favoured: 5-10 cm diameter
Host conditions during the period of potential detection		
Knight et al., 2010	Host size	EAB populations kill small ash saplings as they reach susceptible size (3-cm diameter at breast height).
McCullough et al., 2011	Effects on symptom expression	Infestations from ash nursery trees, logs, or firewood are typically discovered at least 4-6 years after establishment, when declining canopies of heavily infested ash trees are noticed
McCullough and Mercader, 2012	Effects on symptom expression	To date, most *A. planipennis* outlier populations have been discovered at least 3-4 years after establishment, when *A. planipennis* densities are high enough for the tree to exhibit external signs of infestation. Trees with low densities of *A. planipennis* exhibit few, if any, external symptoms