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Commodity risk assessment of ash logs from the US treated with sulfuryl fluoride to prevent the entry of the emerald ash borer *Agrilus planipennis*

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Abstract

The European Commission submitted to the EFSA Panel on Plant Health a dossier by USDA proposing to use sulfuryl fluoride on ash log shipments to treat *Agrilus planipennis* for phytosanitary certification. After collecting additional evidence from USDA APHIS, external experts and literature, the Panel performed a quantitative assessment on the likelihood of pest freedom from *A. planipennis,* at the point of entry in the EU, of two different commodities fumigated with sulfuryl fluoride: (a) ash logs with bark; and (b) debarked ash logs. An expert judgement is given on the likelihood of pest freedom taking into consideration the measures acting on the pest, including uncertainties associated with the assessment. The likelihood of pest freedom from *A. planipennis* is lower for ash logs with bark compared with debarked ash logs. With 95% certainty, the Panel concludes that between 9,740 and 10,000 containers of ash logs with bark per 10,000 and between 9,989 and 10,000 containers of debarked ash logs per 10,000 will be free from *A. planipennis,* when fumigated with sulfuryl fluoride at the specific treatment regime proposed by the USDA APHIS.

Keywords: bark, beetle, EAB, *Fraxinus* spp., fumigant, SF, treatment

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1. Introduction

1.1. Background and Terms of Reference as provided by European Commission

1.1.1. Background

The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, is listed in Annex II to Regulation (EU) 2019/2072[1] as a Union Quarantine Pest. It is known to be present in the United States (US). Therefore, special requirements apply to the introduction of host plants of *A. planipennis* coming from, amongst other countries, the US. These requirements include wood from *Fraxinus* L. (ash). Annex VII, point 87 to Regulation 2019/2072 provides that wood other than chips, particles, sawdust, shavings, wood waste and scrap and other than wood packaging material may only be introduced:

- from areas recognised as free from *A. planipennis*; or
- after the bark and at least 2.5 cm of the sapwood are removed; or
- after the wood has undergone ionizing irradiation to achieve a minimum dose of 1 kGy.

In June 2021, the US introduced a request to use sulfuryl fluoride (SF) on ash log shipments to treat *A. planipennis* for phytosanitary certification. To this end, a specific treatment regime was proposed. It is noted by the Commission, that this regime has similarities with the regime set out in the International Standard for Phytosanitary Measures (ISPM) No 28, Annex 22 'Sulfuryl fluoride fumigation treatment for insects in debarked wood' (FAO, 2017a). It is further noted, that *A. planipennis* is not explicitly mentioned as a target in the mentioned standard and that the request from the US is not limited to debarked wood.

In support of the request, several background documents, including scientific publications, were submitted.

1.1.2. Terms of reference

EFSA is requested, pursuant to Article 29 of Regulation (EC) No 178/2002[2], to provide a scientific opinion.

In particular, EFSA is requested to assess, based on the information provided by the US, the likelihood of pest freedom from *A. planipennis* for the ash logs treated as proposed by the US.

The assessment shall include ash logs with bark, where bark and sapwood have not been removed, and debarked ash logs, where sapwood has not been removed.

In this assessment, EFSA shall take into account the available scientific information and, in particular, the scientific and technical information provided by the US, as well as existing international and regional phytosanitary standards. If necessary to complete its assessment, EFSA may ask additional technical information or clarifications regarding the US request to use sulfuryl fluoride on ash log shipments to treat *A. planipennis* for phytosanitary certification. Following the provision of such information, EFSA shall proceed with the assessment.

1.2. Interpretation of the Terms of Reference

The EFSA Panel on Plant Health (hereafter referred to as 'the Panel') assessed the likelihood of pest freedom from *A. planipennis* after fumigation proposed by the US with sulfuryl fluoride of the following two commodities:

- ash logs with bark, where bark and sapwood have not been removed,
- debarked ash logs, where sapwood has not been removed.

[1] Commission Implementing Regulation (EU) 2019/2072 of 28 November 2019 establishing uniform conditions for the implementation of Regulation (EU) 2016/2031 of the European Parliament and the Council, as regards protective measures against pests of plants, and repealing Commission Regulation (EC) No 690/2008 and amending Commission Implementing Regulation (EU) 2018/2019. OJ L 319, 10.12.2019, pp. 1–279.

[2] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31, 1.2.2002, pp. 1–24.

In its evaluation the Panel:

- Reviewed the information provided by USDA APHIS in the original Dossier and additional correspondence.
- Reviewed the pertinent literature on the efficacy of sulfuryl fluoride.
- Consulted external experts on wood industry.

Based on the above activities, the Panel provided a rating for the likelihood of pest freedom from *A. planipennis* of the above commodities at the point of entry in the EU.

2. Data and methodologies

2.1. Data

2.1.1. Data provided by USDA APHIS

The Panel considered all the data and information provided in the Dossier received together with the mandate letter, including the additional material provided by USDA APHIS in successive email exchanges. The Dossier and supplementary material are stored and accessible by EFSA.

The structure and overview of the Dossier is shown in Table 1.

Table 1: Structure and overview of the information provided by USDA APHIS

Dossier Section	Overview of contents	Filename
1.0	Dossier prepared by USDA APHIS and received from DG SANTE with the mandate.	Annex II.
2.0	Additional information provided by USDA APHIS in response to EFSA requests.	ESFA.ASH.Responses

The data and supporting information provided by USDA APHIS formed the basis of this commodity risk assessment.

2.1.2. Literature searches performed by EFSA

Literature searches were undertaken by EFSA to complete the knowledge gaps concerning (i) the pest *Agrilus planipennis*, mostly with reference to larval density and adult emergence; (ii) the fumigant sulfuryl fluoride, mostly with reference to its efficacy against *A. planipennis* and other wood boring beetles in all stages of development; and (iii) the commodities of ash logs with bark and debarked ash logs.

Systematic literature review on points (i) and (ii) was performed applying an *ad hoc* search string run between April and May 2022. In Appendix B, the search strategy, results and an extraction table summarising the main evidence are provided.

Additional searches, limited to retrieve documents, were run when developing the opinion. The available scientific information, including previous EFSA opinions on the relevant pest and relevant fumigant (e.g. EFSA, 2020; EFSA PLH Panel, 2020), was considered.

2.1.3. Further information provided by experts and national authorities

In order to integrate information concerning logs processing and ash logs production, the Panel involved the hearing expert Roberto Zanuttini, professor of wood technology at the University of Turin.

Additional information was asked to private companies in Italy in charge of fumigating wood logs with bark using sulfuryl fluoride for international trade outside the EU.

2.2. Methodologies

While developing the opinion, the Panel followed the EFSA Guidance on commodity risk assessment for the evaluation of high-risk plant dossiers (EFSA PLH Panel, 2019).

2.2.1. Pest data

The pest survey card on *A. planipennis* (EFSA, 2020) was the reference document used in this assessment.

2.2.2. Commodity data

The characteristics of the commodity were summarised mainly based on the information provided in the Dossier Sections 1.0 and 2.0.

2.2.3. Evaluation of efficacy of sulfuryl fluoride

A systematic literature review has been conducted on the efficacy of sulfuryl fluoride against *A. planipennis* and other wood pests either under laboratory conditions or inside wood with bark or debarked. The systematic literature review has been condensed in Table B.1 included in Appendix B.

Information on the efficacy of sulfuryl fluoride against pests in wood logs were also gathered from EFSA PLH Panel (2020).

2.2.4. Quantitative assessment of likelihood of freedom based on expert knowledge elicitation

To estimate the pest freedom of the commodity up to the point of entry in the EU, an expert knowledge elicitation (EKE) was performed following EFSA Guidance (Annex B.8 of EFSA Scientific Committee, 2018). The two commodities exported to the EU are ash logs with bark and debarked ash logs, charged in containers where they are submitted to fumigation. For this reason, the selected unit is the container, where the conditions within can be considered well defined and can differ from another container even when treated in the same way. Additionally, it is assumed that all logs of a container will arrive at the same customer and may result in a single outbreak after import. The whole container is considered infested when at least one of the transported logs is infested by at least one living pest individual. Therefore, the specific question for the EKE was: 'Taking into account: (i) the information provided by the US and (ii) other relevant information, how many of 10,000 containers of either ash logs with bark or debarked ash logs will be infested with *A. planipennis* when arriving in the EU?'

The uncertainties associated with each EKE were taken into account and quantified in the probability distribution applying the semi-formal method described in Section 3.5.2 of the EFSA Guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018). Finally, the results were reported in terms of the likelihood of pest freedom. The lower 5% percentile of the uncertainty distribution reflects the opinion that pest freedom is with 95% certainty above this limit.

3. The pest

3.1. Biology of *Agrilus planipennis*

The emerald ash borer (EAB), *A. planipennis*, is a buprestid native to eastern Asia and introduced to North America (US and Canada, in 2002) (Haack et al., 2002) and to Europe (Russia, in 2003; Ukraine, in 2019) (Kucheryavenko et al., 2020; Orlova-Bienkowskaja et al., 2020).

3.1.1. Tree colonisation and life cycle

The life cycle of *A. planipennis* in North America typically lasts 1 year, but a 2-year life cycle is frequently observed in part of the population (Cappaert et al., 2005; Tluczek et al., 2011).

From early May to August, with a peak in the second half of June, adults emerge from 3 to 4 mm diameter semicircular exit holes (so-called D-shaped holes) bored in the stem and branches of infested ashes. Before mating, the adults require a short maturation feeding period on the edges of the ash leaves, causing only minimal defoliation. After maturation feeding, males locate virgin females on host plants by visual/olfactory cues and by contact pheromones; long-distance pheromones have not been reported to date (Herms and McCullough, 2014). After mating, females usually lay 40–70 eggs, exceptionally up to 200. Eggs are laid in cracks/crevices in the bark or beneath the bark flakes and hatch in 1–2 weeks (Herms and McCullough, 2014; McCullough, 2019). Larval development occurs in four instars during summer and autumn. Most of the larvae (> 80%) stop feeding in October–November; the overwintering stage is the mature fourth instar larva in a prepupal cell in the outer bark or sapwood about 1 cm deep (4–16 mm) (Cappaert et al., 2005; EFSA PLH Panel, 2011). Pupation and adult emergence occur from mid-April to summer (Cappaert et al., 2005). In trees with thin bark, pupal cells are typically found in the sapwood, while in those with thicker bark they are mostly found in the outer bark (EPPO, 2013). It is not fully clear why some of the larvae overwinter in the second/third instar and then complete their development only during the following summer, so that the adults emerge only in the spring of the following year (2-year life cycle) (McCullough, 2019). This is most readily observed in trees with low larval densities, or when oviposition occurs in late summer; however, other factors, such as low temperatures, host defence reactions or low nutrient levels may also be involved (Cappaert et al., 2005). In China, the 2-year cycle has been found in areas where temperatures below 0°C last for more than 150 days per year (EFSA PLH Panel, 2011, citing Wei et al., 2007).

3.1.2. Host suitability

While in its native range *A. planipennis* is a secondary species infesting mainly stressed or dying ashes, and only rarely becoming a harmful pest (Wang et al., 2010; Herms and McCullough, 2014), in North America, it is now threatening to cause ash tree extinction from large areas and is considered to be the most destructive forest insect in the history of the US, where it is currently present in 35 states (USDA-APHIS, 2020; Poland et al., 2021). All 16 North American ash species are more or less susceptible to *A. planipennis* colonisation, but *Fraxinus americana* (white ash), *F. pennsylvanica* (green ash) and *F. nigra* (black ash) are the most vulnerable ones, all widespread and of considerable economic and ecological importance for North American deciduous forests and urban areas where ashes have been intensively planted in the past (Klooster et al., 2013; Poland et al., 2021).

In the US, *A. planipennis* can attack both stressed and healthy trees and the host condition is not a discriminating factor in the risk assessment (MacQuarrie, 2020). *A. planipennis* usually lays eggs on live plants; larvae hatched from eggs laid on freshly cut logs can only rarely develop (Petrice and Haack, 2007; Anulewicz et al., 2008). On large trees, the attack first occurs in the upper part of the stem and on branches, and this makes it difficult to detect infestations at early stages; sometimes symptoms of the attack become evident only after 2–3 years (EPPO, 2013). On trees 13–15 m in height and 30 cm in diameter, attacks occur mainly above 2 m high (Cappaert et al., 2005).

3.1.3. Adult dispersal

The adult lifespan is 43–63 days, but some females can live up to 120 days (EPPO, 2013). Adults are active in sunlight with relatively high temperatures, 23–25°C (EPPO, 2013). They are considered strong fliers, capable of covering distances between 3 and 20 km per day in natural conditions, although most of the dispersal remains within 100 m from the emergency point where host plants are largely available (Mercader et al., 2009; Taylor et al., 2010); the effect of the wind on the flight distance is still unclear (Siegert et al., 2010). Annual spread rates of 2.5–80 and 13–41 km were reported in North America and European Russia, respectively (EFSA, 2020). A maximum flight distance of 1,600 m per year has been estimated and might occur for the EU regions where ash is present (EFSA, 2019). *A. planipennis* can also move by passive transportation over long distances. The main pathways are ash wood (firewood and logs) with bark or debarked; plants for planting/nursery stock; waste wood, bark and hardwood chips; wood packaging; hitchhiking by vehicles (McCullough and Mercader, 2011; USDA-APHIS, 2015; Evans et al., 2020).

Additional information on *A. planipennis* biology and exhaustive summary tables on spread rate is available in EFSA (2019) (Appendix B - Evidence Tables) and EFSA (2020).

3.1.4. Infestation symptoms

The newly hatched larvae bore the outer bark and begin feeding in serpentine or winding tunnels in the phloem and cambium. The spreading of larval galleries within phloem can extend to the circumference of the branches and stems, so disrupting the circulation of water, saps and nutrients, and causing decay and death of the host. Trees infested by large number of beetles, recognisable by crown thinning and branch decay, die in 2–4 years (Herms and McCullough, 2014).

3.1.5. Insect survival

Although most of the life cycle is spent in the larval stage within bark and sapwood, the wood of ash infested by *A. planipennis* can contain all the stages of the pest at different times. Overwintering larvae are able to tolerate low temperatures, down to −30°C, thanks to the increased body concentration of glycerol (up to 17% of the fresh mass), the presence of antifreeze agents in the haemolymph and cuticular waxes that protect against external ice (Crosthwaite et al., 2011). On the other hand, the survival of larvae can be possibly limited by strong fluctuations in winter temperatures, which can rise up to 10–15°C, rapidly reducing the concentration of glycerol and other antifreeze agents (Sobek et al., 2011).

According to Petrice and Haack (2006a), the time of cutting infested trees (but not debarked) can remarkably affect the larval mortality, since logs cut from July to August show a significant higher mortality than logs cut later, probably as consequence of more advanced larval development, which is less affected by changes in food quality and intraspecific competition; beetle survival was also significantly reduced in logs stored uncovered by tarps both in sunny or shady sites. Furthermore, it has been shown that even from small logs of firewood cut in the summer, adults of *A. planipennis* can emerge up to 2 years after cutting (Petrice and Haack, 2007).

3.1.6. Larval density and adult emergence

The larval density and the number of adults that can emerge, seems to partly depend on the bark texture: trees with rough bark, with many cracks and crevices that favour oviposition of the beetle have shown a density of 458 larval galleries/m^2, while 137/m^2 were observed in ash tree stems with smooth bark (Anulewicz et al., 2008). As reported in the Dossier Section 2.0, on trees with more than 90% dieback, the density of exit holes and woodpecker attacks ranged from 60 to 155 per m^2 (6–14 per ft^2) (Anulewicz et al., 2007). An increased tree mortality strictly related to increasing bark roughness was also shown by Marshall et al. (2013). However, the main factor on which the larval density and the number of emerging adults of *A. planipennis* depends is the phloem availability.

Petrice and Haack (2006a) tested the larval density of *A. planipennis* in logs 40 cm long and 6–37 cm in diameter, from July to December finding a number of larvae ranging from 16.7 to 270/m^2. The same authors find an average density of 108 adults/m^2 emerging from untreated logs in an efficacy test of three insecticides (Petrice and Haack, 2006b).

McCullough and Siegert (2007) found an average density of 89 adult beetles/m^2 for diameters ranging from 2.5 to > 60 cm in two study areas in Michigan (105/m^2 for diameters $\geq$ 13 cm). In the range of diameter $\geq$ 26 cm, i.e. the most interesting commercially (merchantable size) the density was 106 (26–42 cm), 102 (42–60 cm) and 94 (> 60 cm) per m^2, respectively. It has also been estimated that ash logs $\geq$ 26 cm support the reproduction of 55–65% of beetles representing only 6% of the trees present in the study areas, while logs $\leq$ 13 cm which are 75–80% of total trees, contribute only 12% (McCullough and Siegert, 2007). As reported in the Dossier Section 2.0, McCullough and Siegert (2007) sampled 71 green and white ash trees killed by *A. planipennis* and reported that, on average, roughly 89 to 105 *A. planipennis* could develop per m^2 (8–10 per ft^2). Larval density on untreated control trees at the Seven Lakes site averaged 134.0 $\pm$ 80.47 emerald ash borer per m^2 (Mccullough et al., 2011).

Tests carried out on young ash trees attacked by *A. planipennis* in nurseries have shown larval densities per m^2 from 51.6 to 145.7 on stem diameters 6–8 cm (Anulewicz et al., 2008). On ash logs 60 cm long and 13 cm in diameter, exposed on steel poles, a maximum density of 110/m^2 was found, while similar logs attached to the stem of infested trees showed density from 17 to 195.5/m^2 (Anulewicz et al., 2008).

In laboratory tests on ash logs 70–72 cm in length and diameter up to 30 cm, adult emergence from 28.65/m^2 to 57.7/m^2 were observed at temperatures 10–15.6°C and up to 124.2/m^2 at temperatures 21.1°C (Barak et al., 2010).

Larval densities per m^2 ranging from 0 to 265.7 were found in ash trees up to 8 m high and 10.8 cm in diameter, with some differences between girdled trees treated with stress elicitor methyl jasmonate and untreated trees. The highest densities (211.9–265.7/m^2) were observed on girdled trees, stem height from 2 to 5 m. Overall, no significant differences were found in trees treated with methyl-jasmonate and untreated trees (2.7–50.9/m^2 at 2–5 m height) (Tluczek et al., 2011).

The density of *A. planipennis* galleries on branches of asymptomatic ash urban trees was studied by Turgeon et al. (2016), finding densities per m^2r ranging from 0 to 126 in branches of 8.8 cm in diameter at the base.

A summary of information available on *A. planipennis* density in trees and logs is provided in Table 2.

Table 2: Evidence table summarising the study results on *A. planipennis* life stages densities on ash trees and logs

Tree/Log size			**Life stage density**				**References**	**Notes**
Ash species	**Diameter cm**	**Length cm**	**Nr. eggs/ m^2**	**Nr. larval galleries/ m^2**	**Nr. larvae/ m^2**	**Nr. exit holes or emerged adults/ m^2**		
Fraxinus pennsylvanica/ *F. americana*	15	40			23.2–158.0	19.1–90.6 exit holes/ m^2	Petrice and Haack, 2006a	Test on firewood logs from ash trees cut from July to December during the seasons 2002–2003 and 2003–2004
	10	40			16.7–270.7	9.3–78.0 exit holes/ m^2		
Fraxinus sp.	12	50				108 emerged adults/ m^2	Petrice and Haack, 2006b	Adult emergence from untreated logs in insecticide efficacy test
Fraxinus pennsylvanica/ *F. americana*	2.5–13					68.8 emerged adults/ m^2	McCullough and Siegert, 2007	Length of the log sections not specified; surface area was calculated. All size combined density: 88.9 exit holes/ m^2; density high enough to cause tree death. One larva requires approx. 10 c m^2 of phloem to complete development. ≥26 cm diameter is threshold for merchantable size.
	14–25					108.3 emerged adults/ m^2		
	26–42					106.2 emerged adults/ m^2		
	43–60					102.0 emerged adults/ m^2		
	> 60					94.3 emerged adults/ m^2		
Fraxinus pennsylvanica	13.1	60	14.1	39.6			Anulewicz et al., 2008	Test on logs attached to steel poles
Fraxinus americana			21.7	36.5				
Fraxinus pennsylvanica	11.9		47.1–4.9	195.5–17.0–97.4				Test on logs attached to infested ash trees
Fraxinus americana			28.1	143.6–70.0				
Fraxinus pennsylvanica	6–8			145.7–58.9				Test on nursery trees
Fraxinus americana				76.5–51.6				

Tree/Log size			Life stage density				References	Notes
Ash species	**Diameter cm**	**Length cm**	**Nr. eggs/ m^2**	**Nr. larval galleries/ m^2**	**Nr. larvae/ m^2**	**Nr. exit holes or emerged adults/ m^2**		
Fraxinus sp.	≤ 30	70–72				14.4–124.2 emerged adults/ m^2	Barak et al., 2010	Adult emergence from untreated logs in Sulfuryl fluoride fumigation efficacy test
Fraxinus pennsylvanica	10.8	≤ 800			1.1–50.9		Tluczek et al., 2011	Control untreated trees
					0.0–39.1			Trees treated with stress elicitor methyl jasmonate
					14.67–265.7			Girdled trees
Fraxinus pennsylvanica	8.8	300		0–126			Turgeon et al., 2016	Test on branch samples
Fraxinus nigra	4.29			235.9		40.1 exit holes/ m^2	Tanis and McCullough, 2015	Young trees in ash plantations fertilised or treated with paclobrutazol growth regulator
Fraxinus pennsylvanica	6.27			220.1		30.4 exit holes/ m^2		
Fraxinus americana	5.6			40.7		1.0 exit holes/ m^2		
Fraxinus quadrangulata	4.6			2.0		0.0 exit holes/ m^2		
Fraxinus pennsylvanica	13.1–13.3				28.2–14.0		Burr et al., 2018	Control trees 2010–2011 debarked from the base to 2 m
	15.1–14.5				57.7–63.3			Girdled trees 2010–2011 debarked from the base to 2 m
	6.4–5.0				5.1–6.7			Planted trees debarked from the base to 2 m
Fraxinus pennsylvanica	26.8			72.4			McCullough et al., 2018	Maximum density observed (2014) in control trees in insecticide efficacy test

3.1.7. Natural enemies and biological control

As reported in the Dossier Section 2.0, parasitoids of Asian origin are present and actively released by APHIS. Currently, APHIS is raising four parasitoids (*Oobius agrili* Zhang and Huang (Hymenoptera: Encyrtidae), *Spathius agrili* Yang and Huang (Hymenoptera: Braconidae), *Spathius galinae* Belokobylskij & Strazanac (Hymenoptera: Braconidae) and *Tetrastichus planipennisi* Yang and Huang (Hymenoptera: Eulophidae)) to control *A. planipennis*. For detail on the efficacy of those parasitoids please refer to Appendix A.

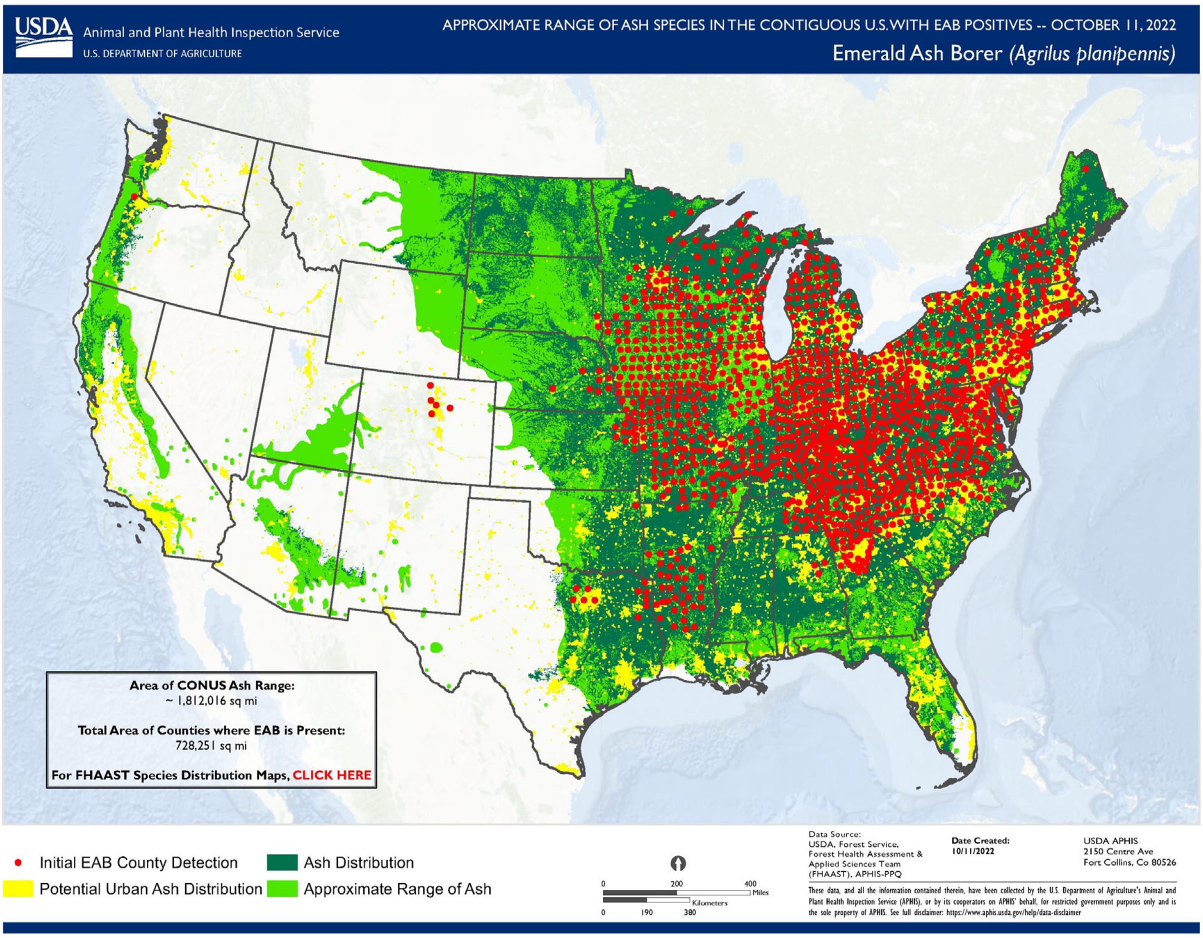
A. planipennis parasitoid releases began in 2007, researchers have found that *T. planipennisi* and *O. agrili* have established in many states and provinces, are dispersing from the release sites, and are responding to changes in *A. planipennis* density by increasing percentage parasitism. *Spathius agrili* is found periodically at some southerly release sites, but release in the south is still in the early stages. Release of *S. galinae* began in 2015, and its establishment and spread appear successful at long-term study sites in Connecticut, Massachusetts, Michigan and New York. Another species of *Oobius*, reared from *A. planipennis* eggs collected in Russia, is being evaluated as *A. planipennis* biocontrol agent for some regions of the US and Canada. Over the last 10 years, *A. planipennis* Biocontrol Rearing Facility in Brighton, Michigan has produced and released more than 6 million parasitoids. Releases have occurred in 29 states (Arkansas, Colorado, Connecticut, District of Columbia, Delaware, Iowa, Illinois, Indiana, Kansas, Kentucky, Louisiana, Massachusetts, Maryland, Maine, Michigan, Minnesota, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Dakota, Tennessee, Virginia, Wisconsin, and West Virginia) and 3 Canadian Provinces (New Brunswick, Ontario and Quebec) (Dossier Section 2.0).

3.2. Prevalence and incidence of *Agrilus planipennis* in the US

A. planipennis is widely distributed in North America mainly in the central and eastern US (USDA-APHIS, 2022), see Figure 1.

The maps of *A. planipennis* in the US can be found under this link https://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/eab-ash-range-map.pdf

Highly susceptible ashes (green, black and white ash) resulted in nearly 100% mortality rates in some forests near the invasion epicentre (Herms and McCullough, 2014).



Disclaimer: The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the European Food Safety Authority concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Figure 1: Distribution of ash trees and *Agrilus planipennis* in the US from October 2022 (USDA-APHIS, 2022). © USDA-APHIS

4. The commodity

4.1. Description

Two different commodities are considered: (1) ash logs with bark; (2) debarked ash logs.

According to the Dossier Section 2.0, the size of logs, which are valid for all hardwood, range from 0.3 to 1.17 m in diameter and 1.8–11.9 m in length. The moisture content of the commodities is $>$ 30%.

Concerning debarked logs, as described in the Dossier Section 2.0, for hardwood, debarking is always done down to the cambium layer. In addition, upon mechanical debarking, less than 2% bark is allowed to remain. After debarking, logs are reviewed by the log yard handlers and any remaining bark is removed by using hand tools. Fully debarked logs are inspected visually by USDA APHIS PPQ or the State Agriculture contracted by USDA APHIS PPQ. Shipments are rejected if tolerance for bark is exceeded.

As reported in Dossier Section 2.0, compared to other hardwood species (walnut, hickory, maple, bass wood, birch, and poplar), ash (*Fraxinus* spp.) logs are not of primary export interest. The total volume of ash logs exported from the US to the EU in 2021 was 465 m^3 out of 147,307 m^3 of hardwood logs, representing 0.3% of the traded volume (see table in the Dossier Section 2.0). The volumes of US hardwoods to the EU vary greatly from year to year and are likely to increase given recently disrupted supply chains in the Ukraine and Russia, however it is unknown if the likely increase will affect also ash.

4.2. Production areas and estimates of volume stocks

American ash trees grow commonly throughout the eastern US in mixed hardwood forests, from the north in New York State to the southern States along the Gulf of Mexico, and everywhere in between. They grow high in the mountains and low on the plains and coastal areas giving rise to great variety of character. With such widespread distribution in latitude, climate and soil conditions, there are significant variations in ash depending on location, in particular between the slower grown northern and faster grown southern trees (Dossier Section 2.0).

Of the hardwood timber produced in the US, only 17% derives from company owned lands or public forestlands, and the remainder comes from non-corporate, often small family-owned forests. There are more than four million individuals and other private entities that own the 110 million hectares of hardwood and mixed oak-pine forest types in the US (Dossier Section 2.0).

Based on the Dossier Section 2.0, Forest Inventory Analysis (FIA) data shows US ash growing stock is 657 million m^3, 4.5% of total US hardwood growing stock. American ash is growing 3.3 million m^3/ per year while the harvest is 6.9 million m^3 per year. Net volume (after harvest) is decreasing −3.5 million m^3 each year, between 2014 and 2018. Growing stock and growth to removal rates, by state, are available through the interactive forest map on the AHEC (www.americanhardwood.org) website.

4.3. Production and handling processes

4.3.1. Source of logs for export and growing conditions

American hardwoods – including ash – originate overwhelmingly from naturally regenerating mixed species forests east of the Mississippi River. With some very minor exceptions there is virtually no plantation forestry in the hardwood sector in the US (Dossier Section 2.0).

4.3.2. Production cycle

As previously mentioned, ash trees grow in mixed-naturally regenerated stands (Dossier Section 2.0).

According to the Dossier section 2.0, harvest time for hardwoods is generally September to April, depending upon the weather conditions. Hardwoods for export require that the sap not be running within the tree in order to avoid discoloration or staining during transportation. As weather warms from the US south to the US north, harvesting ends accordingly.

All hardwood trees are selectively harvested: selection is based on size and condition of the tree. Licensed foresters review that stands and mark trees for cutting that are both healthy and show no signs of *A. planipennis* if they meet the size requirement for harvest. Logs with *A. planipennis* are cut and destroyed on site or turned into pulp and they cannot be exported (Dossier Section 2.0).

At the production site, logs are graded, and often sorted by quality and destination. Logs are visually reviewed to identify defects; grade is marked with paint or chalk on the body or end of the log. They are scaled by measuring the end and the length of the section for the grade of that section of the tree. Measurements are recorded and log is tagged with a unique tag number if it is a saw log or better quality. Logs going to pulp, chips, or pallet are usually not tagged as they are sold by weight or volume (Dossier Section 2.0).

Normal cutting activity would have the logs moved to the mill/export yard within 30 days or less. Logs must be fresh as possible for the best manufacturing results. Target for getting logs in the container within 60 days. However, if temperatures are below 4.4°C it could be as long as 90 days. Once temperatures are above 4.4°C it is imperative to move quickly in order to avoid quality degrade.

4.3.3. Post-harvesting, export procedures including inspections

Logs are not inspected by competent authority for pests unless they are destined for export (Dossier Section 2.0).

Logs with any visual sign of *A. planipennis* cannot be exported and would be removed from the parcel prior to fumigation (Dossier Section 2.0).

Logs are inspected before loading in the container if going to fumigation facility to ensure no larva, pupa, or adult pests are present. Additional visual inspection is done at the end of the container after fumigation to make sure no pests are present.

USDA APHIS PPQ inspection is based on pass/fail. If there is failure in the lot, no phytosanitary certificate is issued and therefore, export is not possible. Phytosanitary certificates are issued only in cases where USDA has inspected and 'passed' the lot (Dossier Section 2.0).

According to Dossier Section 2.0, it could take between 30 and 90 days from harvest to loading container. It can be as little as 30 days and as much as 90 days, depending upon the weather and the availability for debarking and fumigation.

It could take between 30 and 90 days from loading container to arrival at the port of export. Fumigation can be done at origin or near port of export (Dossier Section 2.0).

Treated hardwood logs are all shipped by container without temperature or humidity controls (Dossier Section 2.0).

Time on dock is estimated between 3 and 12 days, while transit from US East Coast ports to the EU is estimated at 17–35 days (Dossier Section 2.0).

4.4. Overview of interceptions

According to EUROPHYT online (accessed on 21 December 2022) and TRACES-NT online (accessed on 21 December 2022), there were no interceptions of logs of *Fraxinus* spp. from US destinated to the EU Member States due to presence of harmful organisms between 1995 and December 2022.

5. Fumigation with sulfuryl fluoride

5.1. Efficacy of sulfuryl fluoride against emerald ash borer and other wood boring insects

The systematic literature review on the efficacy of sulfuryl fluoride against emerald ash borer and other wood boring insects is summarised in Appendix B.

In summary, sulfuryl fluoride displays high efficacy against a wide range of insect species including emerald ash borer at all stages with exception of eggs (Mizobuti et al., 1996; Soma et al., 1996; Zhang, 2006; Barak et al., 2010).

5.2. Description of the fumigation procedure proposed by the US

Fumigation of logs is performed inside the shipping containers just prior to delivery to the seaport for exporting. If fumigation is at or near port of export, containers are sealed and held in the custody of the railroad until transferred to the licensed fumigation facility or port. Containers are trucked to the fumigation facility and opened under licensed fumigators supervision. Times, temperatures, fumigant use, and duration of exposure and aeration are recorded. Post fumigation, containers are sealed with new security seal (Dossier Section 2.0).

Logs are stacked in bunks. Length and height of bunks depends on the height of the container, diameters and lengths of the logs, and weight of the logs. Some space is required to be left at the top of the container to allow for fumigation equipment to be inserted. Containers are required to have the weight evenly distributed across the chassis axles. With hardwoods, maximum weight is usually reached before maximum space in the container is reached. There is no packaging in log containers (Dossier Section 2.0).

Moisture content of logs is not measured prior to fumigation (Dossier Section 2.0).

The fumigation conditions proposed are reported in Table 3 (Dossier Section 1.0).

Table 3: Proposed treatment with sulfuryl fluoride by the USDA APHIS

Temperature (°C)	Applied dose (g/m^3)	Minimum concentration (g/m^3) at time indicated (h)					Required CxT exposure (g-h/m^3)
		0.5	2	4	24	48	
15.6	144	187	181	170	137	–	3,723
15.6	128	177	165	156	120	102	6,072
21.1	128	168	156	147	109	–	3,172
21.1	104	129	119	112	82	66	4,210

Fumigation (including trucking in and out and heating time) is expected to last 5–10 days (Dossier Section 2.0). Information on how heating will occur has not been provided.

When ambient temperatures are forecast to be lower than the mandated requirements, fumigations will be postponed. If the ambient forecast for the intended exposure period is predicting to be 10-degree Fahrenheit (approximately 5.6-degree Celsius) away from the minimum temperature requirement, data loggers are used (Dossier Section 2.0).

Ambient temperature forecasting is a daily requirement for fumigators and to remain compliant with the label, and USDA/APHIS-PPQ compliance agreement regulations. Fumigators forecasts include the fumigant exposure period and are recorded in the record of treatment in the USDA database by container and booking (Dossier Section 2.0).

The data logger probe will be placed in the lowest location inside the container. Recorded data will be uploaded into the record of treatment per container at the end of the exposure period. The unit is placed outside the container and is weather protected. Some of the data loggers used have wireless capabilities (Dossier Section 2.0).

When the log shipments arrive to the fumigation yards during cold weather, the core temperature of each log is taken and recorded. The log core temperature must be at, or above the minimum temperature listed (Dossier Section 2.0).

If environmental temperatures are above 4.4°C, logs with bark are waxed on the ends if fumigated. Wax is applied to the body and ends if logs are debarked (Dossier Section 2.0).

Standard wax used is ANCHORSEAL® (https://uccoatings.com/products/anchorseal-end-grain-sealer/) (Dossier Section 2.0).

When fumigations occur, fumigators must adhere to the USDA compliance agreement mandates and record the data in the USDA database. Each month fumigators compile all record of treatments from the prior month and furnishes them to the USDA. After fumigation, USDA officers follow the checklist to ensure licensed fumigators are following the mandates set forth in the compliance agreements (Dossier Section 2.0).

6. Likelihood of the pest freedom from *A. planipennis* of ash logs from the US treated with sulfuryl fluoride at the point of entry in the EU

An overview of the evaluation of pest freedom from *A. planipennis* of the two commodities from the US treated with sulfuryl fluoride at the point of entry in the EU is given in the sections below (Sections 6.1 and 6.2). The outcome of the EKE regarding pest freedom after the evaluation of the currently proposed measures is summarised in Section 6.3.

6.1. Overview of the evaluation of *Agrilus planipennis* on ash logs with bark

Rating of the likelihood of pest freedom	Extremely frequently pest free (based on the Median).				
Percentile of the distribution	5%	25%	Median	75%	95%
Proportion of pest free containers	**9,740** out of 10,000 containers	**9,885** out of 10,000 containers	**9,945** out of 10,000 containers	**9,977** out of 10,000 containers	**9,993** out of 10,000 containers
Percentile of the distribution	5%	25%	Median	75%	95%
Proportion of infested containers	**7** out of 10,000 containers	**23** out of 10,000 containers	**55** out of 10,000 containers	**115** out of 10,000 containers	**260** out of 10,000 containers
Summary of the information used for the evaluation	**Possibility that the pest could become associated with the commodity** *Agrilus planipennis* is widespread in the US. The most important and commercialised ash tree species in the US are highly susceptible to the pest. Although infested ash trees are generally recognisable mainly based on symptoms on the crown, some trees infested by the pest at the larval and pupal stages could go undetected, especially if these have been recently colonised. The presence of the bark hampers the prompt detection of signs of the pest consisting of larval galleries.				

	Measures taken against the pest and their efficacy The measures consist of (a) biological control using natural enemies; (b) selective cutting aimed at cutting only healthy-looking trees; (c) inspections of logs and (d) fumigation with sulfuryl fluoride. Biological control using parasitoids is in place in the US and it is expected to play a role in reducing the populations of the pest in sites where the parasitoids are well established. However, the efficacy of biological control is not expected to be very high especially in the case of parasitoids of larvae. Selective cutting is expected to be effective in preventing the trading of infested logs because that operation is performed by licensed foresters. Concerning inspections of logs, the presence of the bark will not allow the detection of the galleries. In addition, entry holes are hardly detectable and exit holes may be overlooked. Fumigation with sulfuryl fluoride displays high efficacy against a wide range of insect species including emerald ash borer at all stages with exception of eggs. However, eggs are not expected to be present on the commodity when fumigation is performed. **Interception records** In the EUROPHYT/TRACES-NT database, there are no records of notification of *Fraxinus* logs neither from the US nor from other countries due to the presence of *A. planipennis* between the years 1995 and January 2023 (EUROPHYT/TRACES-NT, online). **Shortcomings of current measures/procedures** None. **Main uncertainties** – Whether pheromone traps are used to monitor the presence and abundance of the pest. – How accurate may be the detection of symptoms in the upper parts of the crown based on observation from the ground. – How the temperature inside containers during fumigation step is managed.

6.2. Overview of the evaluation of *Agrilus planipennis* on debarked ash logs

Rating of the likelihood of pest freedom	Almost always pest free (based on the Median).				
Percentile of the distribution	5%	25%	Median	75%	95%
Proportion of pest free containers	**9,989** out of 10,000 containers	**9,994** out of 10,000 containers	**9,996** out of 10,000 containers	**9,998** out of 10,000 containers	**9,999.4** out of 10,000 containers
Percentile of the distribution	5%	25%	Median	75%	95%
Proportion of infested containers	**0.6** out of 10,000 containers	**2** out of 10,000 containers	**4** out of 10,000 containers	**6** out of 10,000 containers	**11** out of 10,000 containers
Summary of the information used for the evaluation	**Possibility that the pest could become associated with the commodity** *Agrilus planipennis* is widespread in the US. The most important and commercialised ash tree species in the US are highly susceptible to the pest. Although infested ash trees are generally recognisable mainly based on symptoms on the crown, some trees infested by the pest at the larval and pupal stages could go undetected, especially if these have been recently colonised. However, the bark removal is expected to reduce the pest population in logs and to make the observation of larval galleries possible.				

	Measures taken against the pest and their efficacy The measures consist of (a) biological control using natural enemies; (b) selective cutting aimed at cutting only healthy-looking trees; (c) debarking; (d) inspections of logs; and (e) fumigation with sulfuryl fluoride. Biological control using parasitoids is in place in the US and it is expected to play a role in reducing the populations of the pest in sites where the parasitoids are well established. However, the efficacy of biological control is not expected to be very high especially in the case of parasitoids of larvae. Selective cutting is expected to be effective in preventing the trading of infested logs because that operation is performed by licensed foresters. Debarking is expected to reduce the number of living individuals by killing those present under the bark. It is also expected to make visible the typical galleries of the pest under the bark, making the detection of infested logs more likely during inspections. Fumigation with sulfuryl fluoride displays high efficacy against a wide range of insect species including emerald ash borer at all stages with exception of eggs. However, eggs are not expected to be present on the commodity when fumigation is performed. **Interception records** In the EUROPHYT/TRACES-NT database, there are no records of notification of *Fraxinus* logs neither from the US nor from other countries due to the presence of *A. planipennis* between the years 1995 and January 2023 (EUROPHYT/TRACES-NT, online). **Shortcomings of current measures/procedures** None. **Main uncertainties** – Whether pheromone traps are used to monitor the presence and abundance of the pest. – How accurate may be the detection of symptoms in the upper parts of the crown based on observation from the ground. – How the temperature inside containers during fumigation step is managed.

6.3. Outcome of expert knowledge elicitation

Table 4 and Figure 2 show the outcome of the EKE regarding pest freedom of *A. planipennis* after the evaluation of the currently proposed measures for the two ash logs commodities. Figure 3 provides an explanation of the descending distribution function describing the likelihood of pest freedom after the evaluation of the currently proposed fumigation with sulfuryl fluoride for *A. planipennis* on logs with bark.

Table 4: Assessment of the likelihood of pest freedom following evaluation of proposed fumigation with sulfuryl fluoride against *Agrilus planipennis* on two different ash logs commodities designated for export to the EU. In panel A, the median value for the assessed level of pest freedom for each pest is indicated by 'M', the 5% percentile is indicated by 'L', and the 95% percentile is indicated by 'U'. The percentiles together span the 90% uncertainty range regarding pest freedom. The pest freedom categories are defined in panel B of the table

Number	Ash commodity	Sometimes pest free	More often than not pest free	Frequently pest free	Very frequently pest free	Extremely frequently pest free	Pest free with some exceptional cases	Pest free with few exceptional cases	Almost always pest free
1	Ash logs with bark				**L**	**M**		**U**	
2	Debarked ash logs						**L**		**MU**

PANEL A

	Pest freedom category	Pest-free containers out of 10,000
	Sometimes pest free	≤ 5,000
	More often than not pest free	5,000 – ≤ 9,000
	Frequently pest free	9,000 – ≤ 9,500
	Very frequently pest free	9,500 – ≤ 9,900
	Extremely frequently pest free	9,900 – ≤ 9,950
	Pest free with some exceptional cases	9,950 – ≤ 9,990
	Pest free with few exceptional cases	9,990 – ≤ 9,995
	Almost always pest free	9,995 – ≤ 10,000

PANEL B

Legend of pest freedom categories	
L	Pest freedom category includes the elicited lower bound of the 90% uncertainty range
M	Pest freedom category includes the elicited median
U	Pest freedom category includes the elicited upper bound of the 90% uncertainty range

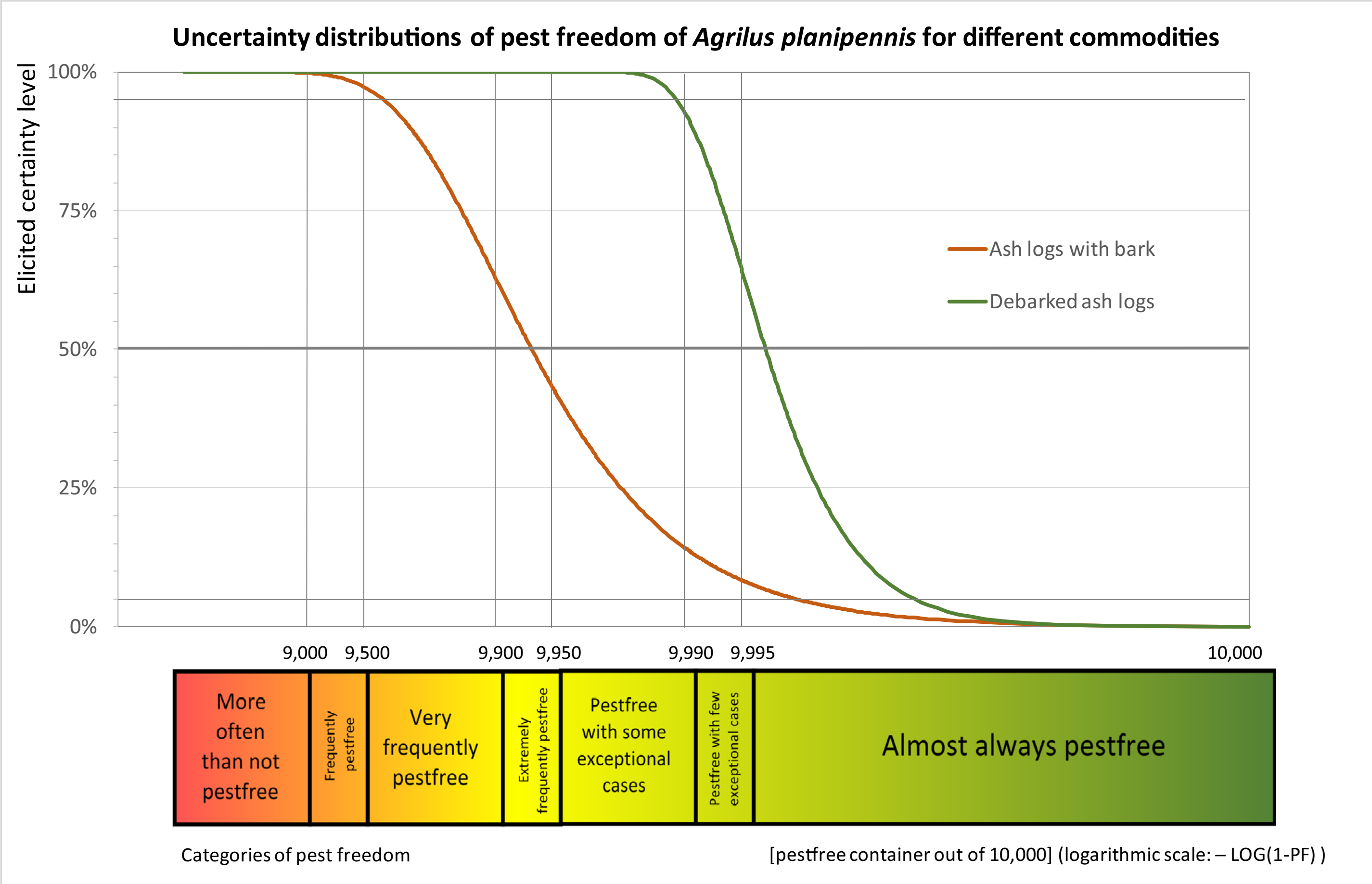


Figure 2: Elicited certainty (y-axis) of the number of pest-free containers of ash logs (x-axis; log-scaled) out of 10,000 containers designated for export to the EU from the US for *Agrilus planipennis* visualised as descending distribution function. Horizontal lines indicate the percentiles (starting from the bottom 5%, 25%, 50%, 75%, 95%)

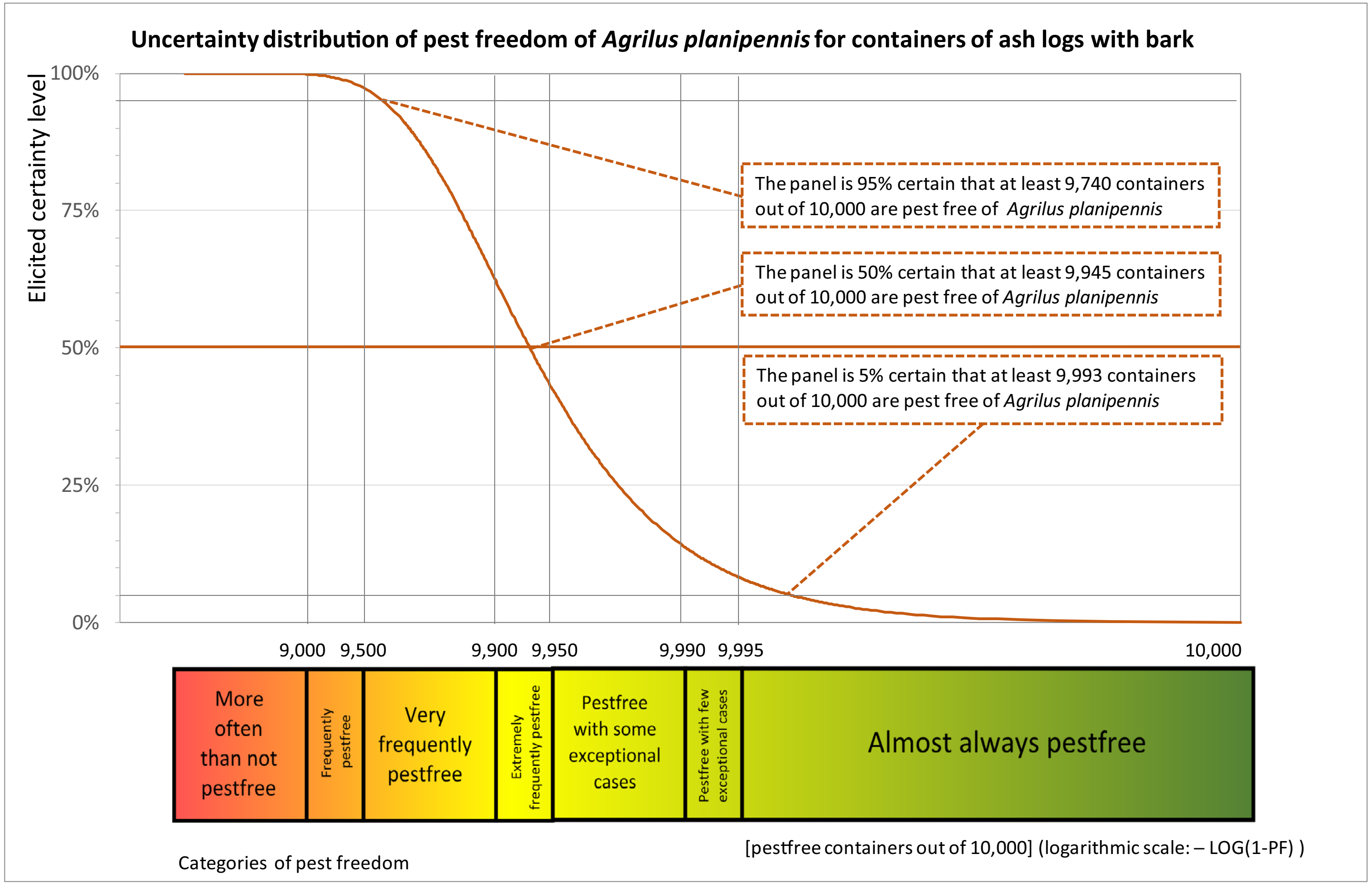


Figure 3: Explanation of the descending distribution function describing the likelihood of pest freedom after the evaluation of the currently proposed fumigation with sulfuryl fluoride for *Agrilus planipennis* on logs with bark

7. Conclusions

The risk associated with the importation into the EU of ash logs with bark and debarked ash logs from US in relation to the presence of *A. planipennis* using fumigation with sulfuryl fluoride as proposed by USDA APHIS was assessed.

The likelihood of pest freedom from *A. planipennis* of ash logs with bark from the US was estimated as 'extremely frequently pest free' with the 90% uncertainty range reaching from 'very frequently pest free' to 'pest free with few exceptional cases'. For ash logs with bark coming from the US, the EKE indicated with 95% certainty that between 9,740 and 10,000 containers per 10,000 will be free from *A. planipennis*.

The likelihood of pest freedom from *A. planipennis* of debarked ash logs from the US was estimated as 'almost always pest free' with the 90% uncertainty range reaching from 'pest free with some exceptional cases' to 'almost always pest free'. For debarked ash logs coming from the US, the EKE indicated with 95% certainty that between 9,989 and 10,000 containers per 10,000 will be free from *A. planipennis*.

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Abbreviations

EAB	Emerald Ash Borer
EKE	Expert Knowledge Elicitation
EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization
ISPM	International Standards for Phytosanitary Measures
PLH	Plant Health
SF	Sulfuryl Fluoride
USDA APHIS	Animal and Plant Health Inspection Service of United States Department of Agriculture

Glossary

Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 1995, 2017b).

Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO, 2017b).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2017b).
Impact (of a pest)	The impact of the pest on the crop output and quality and on the environment in the occupied spatial units.
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO, 2017b).
Measures	Control (of a pest) is defined in ISPM 5 (FAO, 2017b) as 'Suppression, containment or eradication of a pest population' (FAO, 1995). Control measures are measures that have a direct effect on pest abundance. Supporting measures are organisational measures or procedures supporting the choice of appropriate risk mitigation measures that do not directly affect pest abundance.
Pathway	Any means that allows the entry or spread of a pest (FAO, 2017b).
Phytosanitary measures	Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2017b).
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2017b).
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO, 2017b)

Appendix A – Natural enemies and biological control agents of *A. planipennis*

As reported in the Dossier Section 2.0, parasitoids of Asian origin are present and actively released by APHIS. Currently APHIS is raising four parasitoids (*Oobius agrili*, *Spathius agrili*, *Spathius galinae* and *Tetrastichus planipennisi*) to control the emerald ash borer (EAB) *A. planipennis*.

Oobius agrili parasitises up to 60% of EAB eggs laid during the summer in some areas of China. Tiny female *Oobius* accomplish this by searching the bark of ash trees for EAB eggs. When *Oobius* finds an EAB egg, it injects its own egg inside, where it will hatch, grow, and kill the host egg. All *Oobius* being released are females that reproduce without mating to produce only daughters. *Oobius* adults will emerge and repeat the cycle for at least two generations during the EAB egg-laying season. Each *Oobius* adult parasitises up to approximately 80 EAB eggs during its lifetime. *Oobius* spend the winter as larvae inside EAB eggs and emerge as adults the following spring.

Spathius agrili parasitises up to 90% of EAB larvae in ash trees east of Beijing in Tianjin, China, where the climate is relatively mild, thus releases of *S. agrili* are limited to EAB infestations in the south, where EAB also has a one-year life cycle like that of EAB in Tianjin, China. *Spathius agrili* is now released in areas where at least 50% of the EAB have a one-year life cycle which modelling predicts will be in areas that accumulate more than 3,500 GDD 50F. Female *Spathius* parasitise EAB larvae by drilling through the bark and laying an average of 8 eggs on the outside of its host while simultaneously paralysing the EAB. The hatching parasitoid larvae feed and develop on the EAB larva, causing its death. The cycle is repeated 1–2 times each summer and fall depending on climate. *Spathius agrili* overwinter as larvae or pupae and enter obligate diapause in the host gallery. Mature larvae spin silken cocoons in which they pupate and emerge as adults during the following summer.

Tetrastichus planipennisi is another larval parasitoid of EAB collected from China. The life cycle of *Tetrastichus* is similar to that of *Spathius*; however, the female parasitoid lays eggs inside EAB larvae where the parasitoid larvae grow, eventually killing their host. *Tetrastichus* completes several generations each year, and one EAB larva can produce up to 130 *Tetrastichus* adults. They survive the winter under the bark of ash trees as larvae inside their host or as prepupae in their host gallery. As the weather warms in spring, the overwintering larvae of *Tetrastichus* gradually pupate, develop into adults, emerge from small round exit holes chewed in the bark above the gallery, and seek EAB larvae to parasitise. Due to the short ovipositor of *Tetrastichus*, they are more successful in parasitising EAB larvae in small diameter ash sapling and trees up to approximately 6 in. in diameter at breast height (DBH). Research has shown that for *Tetrastichus* populations to persist they need EAB larvae to parasitise when they emerge in the spring. *Tetrastichus* is now preferentially released in areas where at least 25% of the EAB have a 2-year life cycle and where modelling predicts *Tetrastichus* will establish.

Spathius galinae has a biology similar to that of *S. agrili*, however, *S. galinae* originated in the Russian Far East and may complete two or more generations per year. The Russian Far East is more climatically similar to northern regions of North America than to the region of China where *S. agrili* was collected, thus *S. galinae* is more likely to establish further north than *S. agrili*. In addition, both *S. galinae* and *T. planipennisi* are more likely to establish in northern regions due to the availability of EAB larvae early in the spring when their adults emerge seeking hosts. *Spathius galinae* is expected to fill an important niche because its long ovipositor allows it to parasitise EAB larvae in large diameter ash trees (up to ~ 23 inches DBH).

The USDA APHIS PPQ Biological Control Production Facility in Brighton, MI produces EAB parasitoids for field release. These small parasitic wasps must be reared in EAB eggs or larvae, which are produced or harvested from ash trees felled and removed from EAB-infested woodlots. Although the parasitoids are reared and stockpiled throughout the year for release during the field season, the rearing methods are time and labor intensive. Research is ongoing on an artificial diet for EAB, but for now fresh logs and leaves are needed for production of EAB and its parasitoids. There are also challenges storing the *Spathius* species in chill for stockpiling prior to release. The EAB egg parasitoid, *O. agrili*, is reared in EAB eggs laid on paper by EAB adults. *Oobius* will be shipped to cooperators either as mature pupae inside EAB eggs on paper held inside pill vials with screening (Oobinators) or as adults in plastic cups with solid caps. *Oobius* pupae are released by attaching the Oobinators to ash trees, with the screen-side down, and removing the plastic cap. The *Oobius* adults will emerge and disperse naturally. *Oobius* adults are released from the plastic cups by opening the lids, inverting the cup, and tapping it gently against the trunks of EAB-infested ash trees at release sites. The three species of EAB larval parasitoid, *S. agrili*, *S. galinae*, and *T. planipennisi*, are reared in small ash bolts in which EAB larvae are grown from eggs applied to the bark. Although some *Spathius* and *Tetrastichus* adults may be shipped in plastic cups, most of the larval parasitoids are shipped as mature pupae in the small ash bolts. These bolts will be shipped with a small hole drilled through the top to provide a point of attachment to a release tree. Twine or zip ties are common materials used to attach release bolts. *Spathius galinae* will be shipped exclusively as adults in cups due to the difficulty in getting *S. galinae* to emerge from bolts that have been kept in storage for several months. *Spathius* or *Tetrastichus* adults are released from the plastic cups by opening the lids, removing the screening, inverting the cup, and tapping it gently against the trunks of EAB-infested ash trees at release sites.

Appendix B – Literature review on sulfuryl fluoride

The literature search was performed in Scopus and ResearchGate using the following strings.

In Table B.1, the search string for *Agrilus planipennis* and sulfuryl fluoride used in above mentioned databases is reported. Totally, 3 papers were retrieved, which were published between 1962 and 2022. Titles and abstracts were screened, and only 1 paper was considered relevant.

Table B.1: *Agrilus planipennis* and sulfuryl fluoride

TOPIC: ("Agrilus planipennis" OR "Emerald Ash Borer" OR "EAB")
AND
TOPIC: ("sulfuryl fluoride" OR "sulphuryl fluoride")

In Table B.2, the search string for sulfuryl fluoride used in used in above mentioned databases is reported. Totally, 118 papers were retrieved, which were published between 1962 and 2022. Titles and abstracts were screened, and 8 papers were considered relevant.

Table B.2: Sulfuryl fluoride and wood boring beetles

TOPIC: ("insects" OR "wood" OR "fumigation")
AND
TOPIC: ("sulfuryl fluoride" OR "sulphuryl fluoride")

Further references cited in the screened articles or belonging to the grey literature were included in a second phase.

Table B.3, which includes 10 papers, summarises all main evidence extracted from these references with specific reference to the relevance in support to this opinion.

Table B.3: Evidence table summarising the study results on sulfuryl fluoride fumigation efficacy on *Agrilus planipennis* and other wood boring beetles

Plant/Material	**Pest**	**Family**	**Life stage E = Eggs L = Larvae P = pupae A = adults**	**Type of samples**	**Type of fumigation container**	**C = Concentration [g/m³]**	**D = Duration [h]**	**T = Temperature [°C]**	**Wood moisture [%]**	**Mortality [%]**	**Reference**	**Limitations/ Uncertainties**
Fraxinus	***Agrilus planipennis***	Buprestidae	L	Logs with bark and large branches cut 70–72 cm up to 30 cm diameter	432 l fumigation chambers	104	48	15.6	32.75	99.9	Barak et al., 2010	
						104	48	21.1		100		
						112	48	10.0		99.9		
						128	48	15.6		100		
						128	24	21.1		100		
						136	24	15.6		100		
						144	24	10.0		99.9		
						144	24	15.6		100		
					Cargo container	104	48	26.0	no data	100		not tested at lower T
						128	24	23.5		100		
						128	48	24.8		100		
						144	24	23.9		100		
			E	eggs on filter paper	Glass fumatoria	79.3	48	21.1	not applicable	98.3		tested outside wood/bark
						94.9	48	21.1		100		
						129.6	24	21.1		91.7		
						145.5	24	21.1		93.5		
WPM *Populus*	***Anoplophora glabripennis***	Cerambycidae	L	timbers 10 × 10 × 115 cm	432 l fumigation chambers	68.8	24	21.1	44.4	99.9	Barak et al., 2006	debarked wood
						81–3						
						87.6						
						77.5		15.6				
						95.1						
						104.2						
						90.0		10.0				
						110–3						
						120.7						
						113.8		4.4				
						140.4						
						154.3						

Plant/Material	Pest	Family	Life stage E = Eggs L = Larvae P = pupae A = adults	Type of samples	Type of fumigation container	C = Concentration [g/m³]	D = Duration [h]	T = Temperature [°C]	Wood moisture [%]	Mortality [%]	Reference	Limitations/ Uncertainties
infested wood			L-P	debarked wood < 20 cm cross section	no data	93	24	15	75	99.9	ISPM 28 - FAO, 2017a	
						67		20				
						44		25				
						41		30				
infested wood	***Arhopalus tristis***	Cerambycidae	E-L-P-A	debarked wood < 20 cm cross section	no data	93	24	15	75	99.0	ISPM 28 - FAO, 2017a	
						67		20				
						44		25				
						41		30				
no wood			A	exposed insects	70 ml plastic container inserted in a 220 l chamber	15	24	15	not applicable	100	Zhang, 2006	tested outside wood/bark
						30						
						60						
						120						
			E			15				99.3		
						30				99.6		
						60				98.9		
						120				100		
no wood	***Semanotus japonicus***	Cerambycidae	E	eggs on glass container covered with filter paper	30 l fumigation container	40	24	25	not applicable	100	Soma et al., 1997	tested outside wood/bark
			E	eggs on glass container covered with filter paper	30 l fibre glass container	39.6	48	15	not applicable	95.0	Soma et al., 1996	LD_{50} on 5–8 days old eggs
			L	exposed insects		5.0–40.0	24	15		100		
Chamaecyparis obtusa / Cryptomeria japonica	***Callidiellum rufipenne***	Cerambycidae	E	eggs on glass container covered with filter paper	30 l fumigation container	30	24	25	not applicable	100	Soma et al., 1997	tested outside wood/bark
			L	logs 5–10 cm diameter		15	24	25	no data	100		
			A			10				100		
			L-P-A	logs 5–10 cm diameter	30 l fibre glass container	5.0–40.0	24	15	no data	100	Soma et al., 1996	

Plant/Material	Pest	Family	Life stage E = Eggs L = Larvae P = pupae A = adults	Type of samples	Type of fumigation container	C = Concentration [g/m^3]	D = Duration [h]	T = Temperature [°C]	Wood moisture [%]	Mortality [%]	Reference	Limitations/ Uncertainties
Pinus densiflora	***Monochamus alternatus***	Cerambycidae	E	eggs on glass container covered with filter paper	30 l fumigation container	100	24	25	not applicable	100	Soma et al., 1997	tested outside wood/bark
			L	logs 10 cm diameter		20			no data	100		
			P			20				100		
			L	exposed insects	30 l fibre glass container	5.0–40.0	24	15	no data	100	Soma et al., 1996	
Bambusa	***Chlorophorus annularis***	Cerambycidae	L	bamboo poles 116 cm lenght	403 l fumigation chambers	96	24	15.9	no data	100	Yu et al., 2010	
						80		21.5		100		
						64		26		100		
			L-P-A			64		23		100		
no wood	***Hylastes ater***	Curculionidae	L-A	exposed insects	70 ml plastic container inserted in a 220 l chamber	15	24	15	not applicable	100	Zhang, 2006	tested outside wood/bark
						30						
						60						
						120						
pine wood	***Xyleborus pfeilii***	Curculionidae	E	eggs on glass container covered with filter paper	bottle 15 cm 3 cm diameter	100	24	25	not applicable	39.3	Soma et al., 1997	tested outside wood/bark
no wood			E	exposed insects in artificial diet	30 l fibre glass chamber	40	48	15	not applicable	11.1	Mizobuti et al., 1996	very difficult for the eggs to estimate applied dose for attaining 100% mortality
						50				23.1		
						80	24			19.0		
			L			20	48			91.1		
						30				90.4		
						40				97.6		
						50				98.8		
			P			20	48			100		
						30						
						40						
						50						

Plant/Material	Pest	Family	Life stage E = Eggs L = Larvae P = pupae A = adults	Type of samples	Type of fumigation container	C = Concentration [g/m³]	D = Duration [h]	T = Temperature [°C]	Wood moisture [%]	Mortality [%]	Reference	Limitations/ Uncertainties
			A			20 10	48 24			100 100		
						30						
						40						
						50						
pine wood			L	exposed insects in artificial diet	30 l fumigation container	5	24	25	not applicable	77.1	Soma et al., 1997	tested outside wood/bark
						10				84.2		
						20				90.6		
						30				93.2		
						40				93.5		
						50				98.1		
						100				99.3		
				pine logs 10 cm diameter		30			no data	85.7		mortality 3 days after fumigation
						50				84.1		
			P	exposed insects in artificial diet		5			not applicable	64.7		tested outside wood/bark
						10				91.3		
						20				97.4		
						30				99.3		
						40				100		
						50				100		
						100				100		
				pine logs 10 cm diameter		30			no data	100		mortality 3 days after fumigation
						50				100		
			A	exposed insects in artificial diet		5			not applicable	100		tested outside wood/bark
						10				100		
						20				100		
						30				100		
						40				100		

Plant/Material	Pest	Family	Life stage E = Eggs L = Larvae P = pupae A = adults	Type of samples	Type of fumigation container	C = Concentration [g/m³]	D = Duration [h]	T = Temperature [°C]	Wood moisture [%]	Mortality [%]	Reference	Limitations/ Uncertainties
						50				100		
						100				100		
				pine logs 10 cm diameter		30			no data	100		mortality 3 days after fumigation
						50				100		
no wood	***Xyleborus validus***	Curculionidae	A	exposed insects in artificial diet	30 l fibre glass chamber	5	24	15	not applicable	100	Mizobuti et al., 1996	
			L			40				11.1		
pine wood			A	pine logs 10–20 cm diameter	30 l fumigation container	10	24	25	no data	100	Soma et al., 1997	
						30						
Lindera triloba	***Scolytoplatypus tycon/S. mikado***	Curculionidae	E-L-P-A	logs 2–5 cm	30 l fumigation container	10	24	25	no data	100	Soma et al., 1997	
						20						
						30						
Chamaecyparis obtusa/ Cryptomeria japonica	***Xylosandrus germanus***	Curculionidae	A	logs 10–20 cm diameter	test in 30 l fumigation container	10	24	25	no data	100	Soma et al., 1997	
						30						
no data			A	logs 10–20 cm diameter	30 l fibre glass chamber	5	24	15	no data	100	Mizobuti et al., 1996	
			L			40				11.1		
Pinus densiflora	***Cryphalus fulvus***	Curculionidae	E	eggs on glass container covered with filter paper	30 l fumigation container	10	24	25	not applicable	90.3	Soma et al., 1997	tested outside wood/bark
						20				100		
						30						
Pinus densiflora			E	in pieces of bark	30 l fibre glass container	86.4	48	15	no data	95.0	Soma et al., 1996	LD_{50} on 1–7 days old eggs
						130				100		estimated practical dose
Larch	***Ips cembrae***	Curculionidae	E	eggs on glass container covered with filter paper	30 l fumigation container	10	24	25	not applicable	98.1	Soma et al., 1997	tested outside wood/bark
						20				100		
						30				71.4–100		
						40				93.0		

Plant/Material	Pest	Family	Life stage E = Eggs L = Larvae P = pupae A = adults	Type of samples	Type of fumigation container	C = Concentration [g/m³]	D = Duration [h]	T = Temperature [°C]	Wood moisture [%]	Mortality [%]	Reference	Limitations/ Uncertainties
						50				98.1		
						60				100		
						70				97.6		
						80				97.1		
			L-P-A	exposed insects	30 l fibre glass container	5.0–40.0	24	15	not applicable	100	Soma et al., 1996	
Chamaecyparis obtusa	***Phloeosinus perlatus***	Curculionidae	E	eggs on glass container covered with filter paper	30 l fumigation container	10	24	15	not applicable	85	Soma et al., 1997	tested outside wood/bark
						20				100		
						30						
			E	in pieces of bark	30 l fibre glass container	61.3	48	15	no data	95	Soma et al., 1996	LD_{50} on 1–10 days old eggs
			L-P-A	logs 2–5 cm diameter		5.0–40.0	24	15	no data	100		
Pinus densiflora	***Pissodes nitidus***	Curculionidae	E	eggs on glass container covered with filter paper	30 l fumigation container	30	24	25	not applicable	98.1	Soma et al., 1997	tested outside wood/bark
						50				99.5		
			L	logs 8 cm diameter		30			no data	100		
						50						
Pinus sp.	**Sirahoshizo sp.**	Curculionidae	L	pine logs 10–15 cm diameter	30 l fibre glass container	5.0–40.0	24	15	no data	100	Soma et al., 1996	
Quercus crispula	***Platypus quercivorus/P. calamus***	Platypodidae	E-L-P-A	logs 15 cm diameter	30 l fumigation container	10	24	25	no data	100	Soma et al., 1997	99.7% mortality observed on P. quercivorus larvae. Survivors were considered to develop to further stages during 14 days storage
						20				(99.7) 100		
						30				100		

Plant/Material	Pest	Family	Life stage E = Eggs L = Larvae P = pupae A = adults	Type of samples	Type of fumigation container	C = Concentration [g/m^3]	D = Duration [h]	T = Temperature [°C]	Wood moisture [%]	Mortality [%]	Reference	Limitations/ Uncertainties
			L-A	logs 10–20 cm diameter	30 l fibre glass chamber	15	24	15	no data	100	Mizobuti et al., 1996	
infested wood	***Anobium punctatum***	Anobiidae	E-L-P-A	debarked wood < 20 cm cross section	no data	93	24	15	75	99.7	ISPM 28 - FAO, 2017a	
						67		20				
						44		25				
						41		30				
WPM pine and oak wood	***Lyctus africanus***	Lyctidae	E-L-P-A	pallets 114 × 102 × 12 cm	cargo container	40	24	28	25	100	Rajendran and Lalith Kumar, 2008	assessment for survivorship made on dust depositon due to insect activity (3 months observation time)
						50						
	***Sinoxylon* sp.**	Bostrichidae				40						
						50						
	Dinoderus ocellaris					40						
						50						

Appendix C – Elicited values for pest freedom

This appendix provides the rating based on expert judgement regarding the likelihood of pest freedom from *A. planipennis* for the ash log with bark and debarked ash logs fumigated with sulfuryl fluoride imported to EU from the US.

C.1. Overall likelihood of pest freedom of containers of ash logs with bark treated with sulfuryl fluoride.

C.1.1. Reasoning for a scenario which would lead to a reasonably low number of infested containers of ash logs with bark (lower limit)

Although the pest is widespread in the US where the ash grows, the scenario assumes a low pest pressure. The scenario also assumes that (a) natural enemies are well established, and already active in reducing the pest population; (b) infested trees are promptly identified and discarded by licence foresters when selecting trees to be harvested; (c) inspection of logs allows identifying signs of the pest especially on the two heads of logs, and (d) fumigation conditions in terms of temperature requirements are fully standardised making the treatment highly effective.

C.1.2. Reasoning for a scenario which would lead to a reasonably high number of infested containers of ash logs with bark (upper limit)

The pest is widespread in the US where the ash grows and the scenario assumes a high pest pressure. The scenario also assumes that (a) natural enemies are still not well effective in reducing the pest populations; (b) a certain number of infested trees are not identified and discarded by licence foresters when selecting trees to be harvested; (c) inspection of logs does not allow identifying signs of the pest even on the two heads of logs, and (d) temperature requirements during fumigation are not kept during the whole process making the treatment less effective.

C.1.3. Reasoning for a central scenario equally likely to over- or underestimate the number of infested containers of ash logs with bark (median)

The scenario assumes that the pest is widespread with a moderate pest pressure. Although natural enemies have been released in the last years, their efficacy in reducing the pest population is still low. The scenario assumes that licence foresters are trained and efficient in detecting symptomatic trees even in the early stages of infestation, although some symptomatic trees can go undetected due to the intrinsic difficulties in observing canopy symptoms from the ground. The scenario also assumes that the fumigation with sulfuryl fluoride is highly although not completely effective in killing the pest.

C.1.4. Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile/interquartile range)

The first quartile describes the highest uncertainty that reflects uncertainty on most of the information available. The third quartile describes moderate uncertainty reflecting the high efficacy of fumigation with sulfuryl fluoride and the ability to promptly detect infested trees.

C.1.5. Elicitation outcomes of the assessment of the pest freedom for *Agrilus planipennis* on containers of ash logs with bark

The following tables show the elicited and fitted values for pest infestation (Table C.1) and pest freedom (Table C.2).

Table C.1: Elicited and fitted values of the uncertainty distribution of pest infestation by *A. planipennis* per 10,000 containers

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Elicited values	5					25		50		120					500
EKE	5.00	5.65	6.95	10.1	15.2	22.7	31.6	54.9	89.6	115	151	197	260	324	408

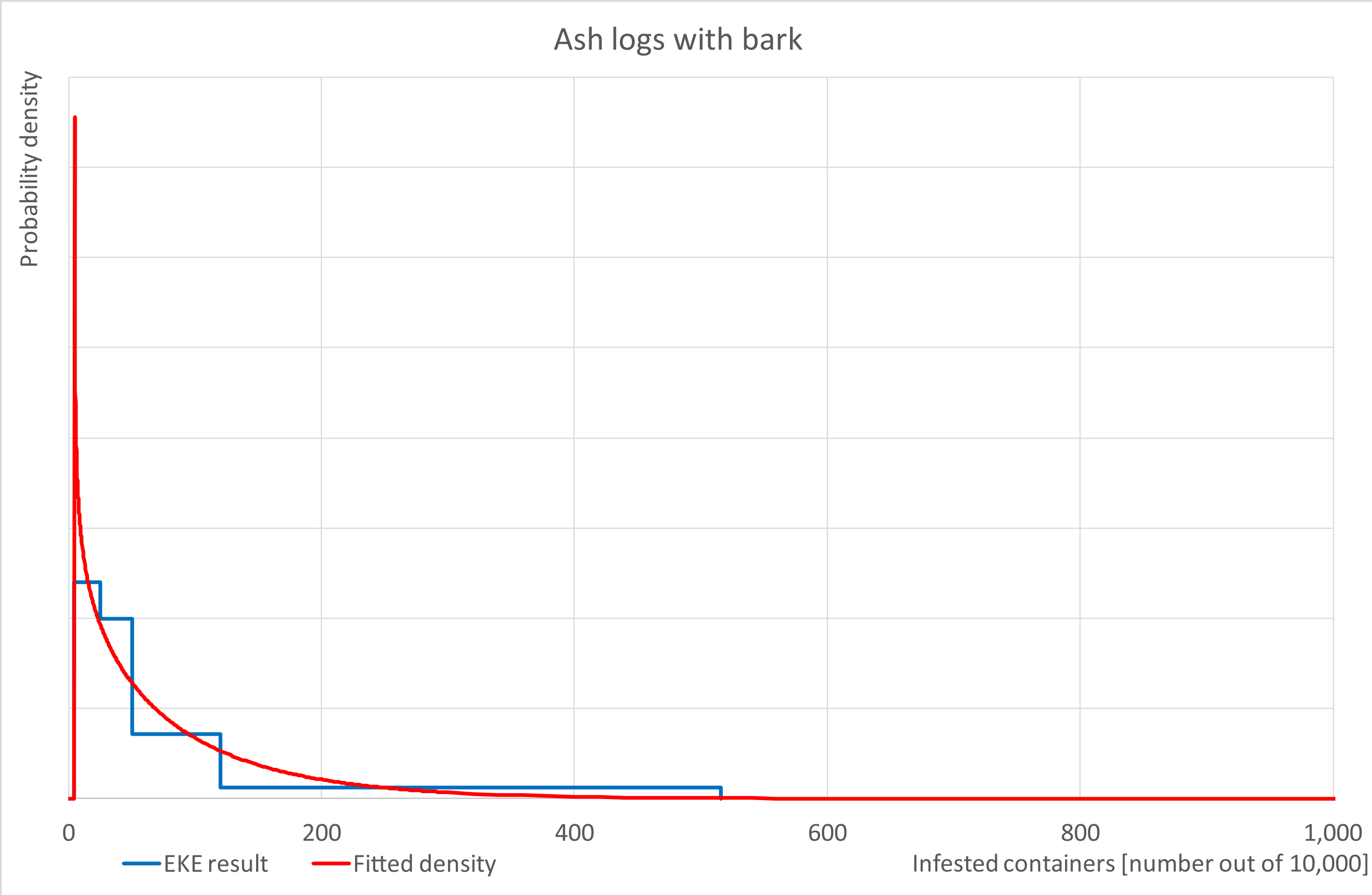
The EKE results is the BetaGeneral (0.80685, 100.87, 4.7, 10,000) distribution fitted with @Risk version 7.6.

Based on the numbers of estimated infested containers the pest freedom was calculated (i.e. = 10,000 – number of infested containers per 10,000). The fitted values of the uncertainty distribution of the pest freedom are shown in Table C.2.

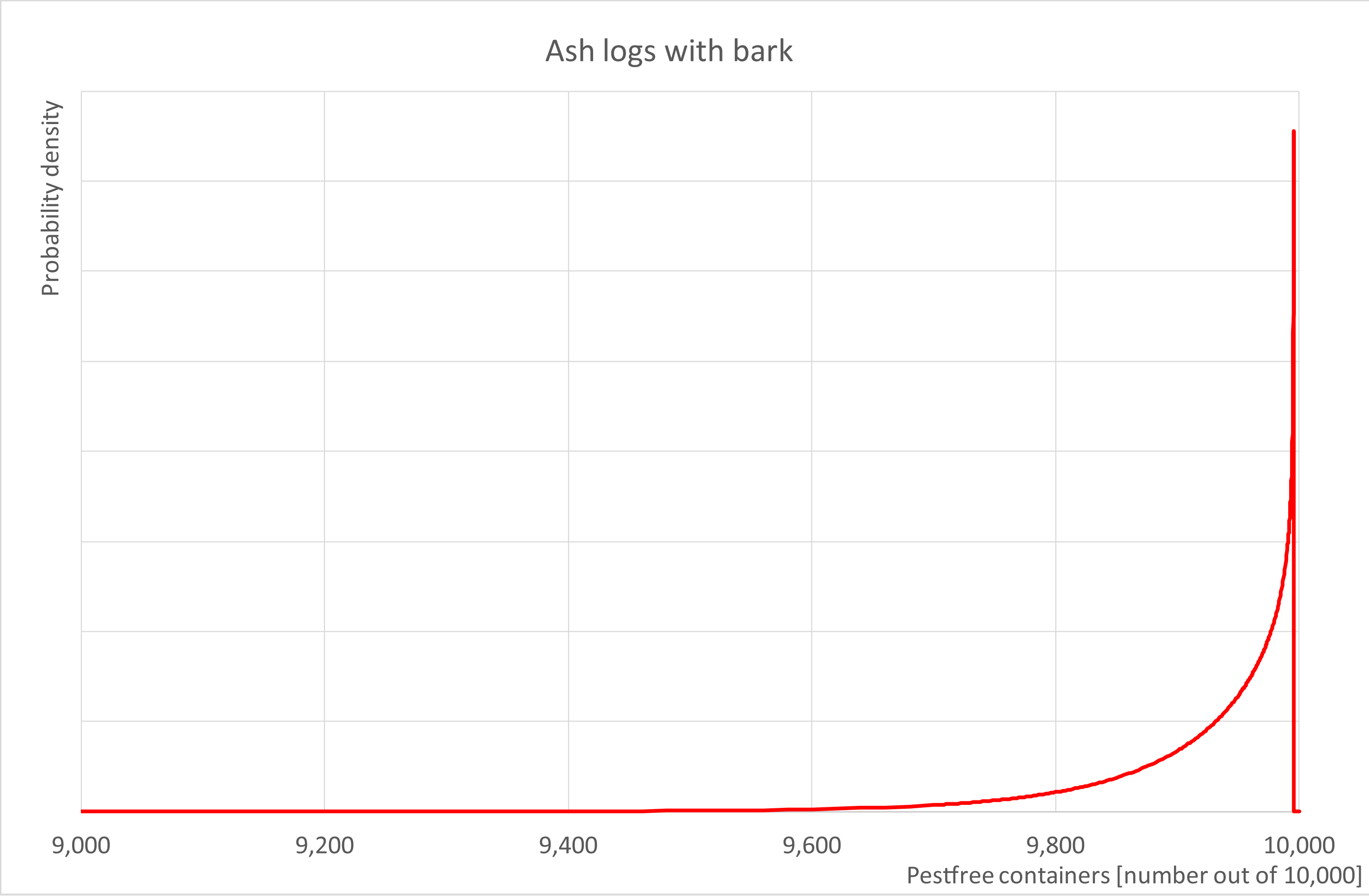
Table C.2: The uncertainty distribution of logs free of *A. planipennis* per 10,000 containers calculated by Table C.1

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Values	9,500					9,880		9,950		9,975					9,995
EKE results	9,592	9,676	9,740	9,803	9,849	9,885	9,910	9,945	9,968	9,977	9,985	9,990	9,993	9,994	9,995

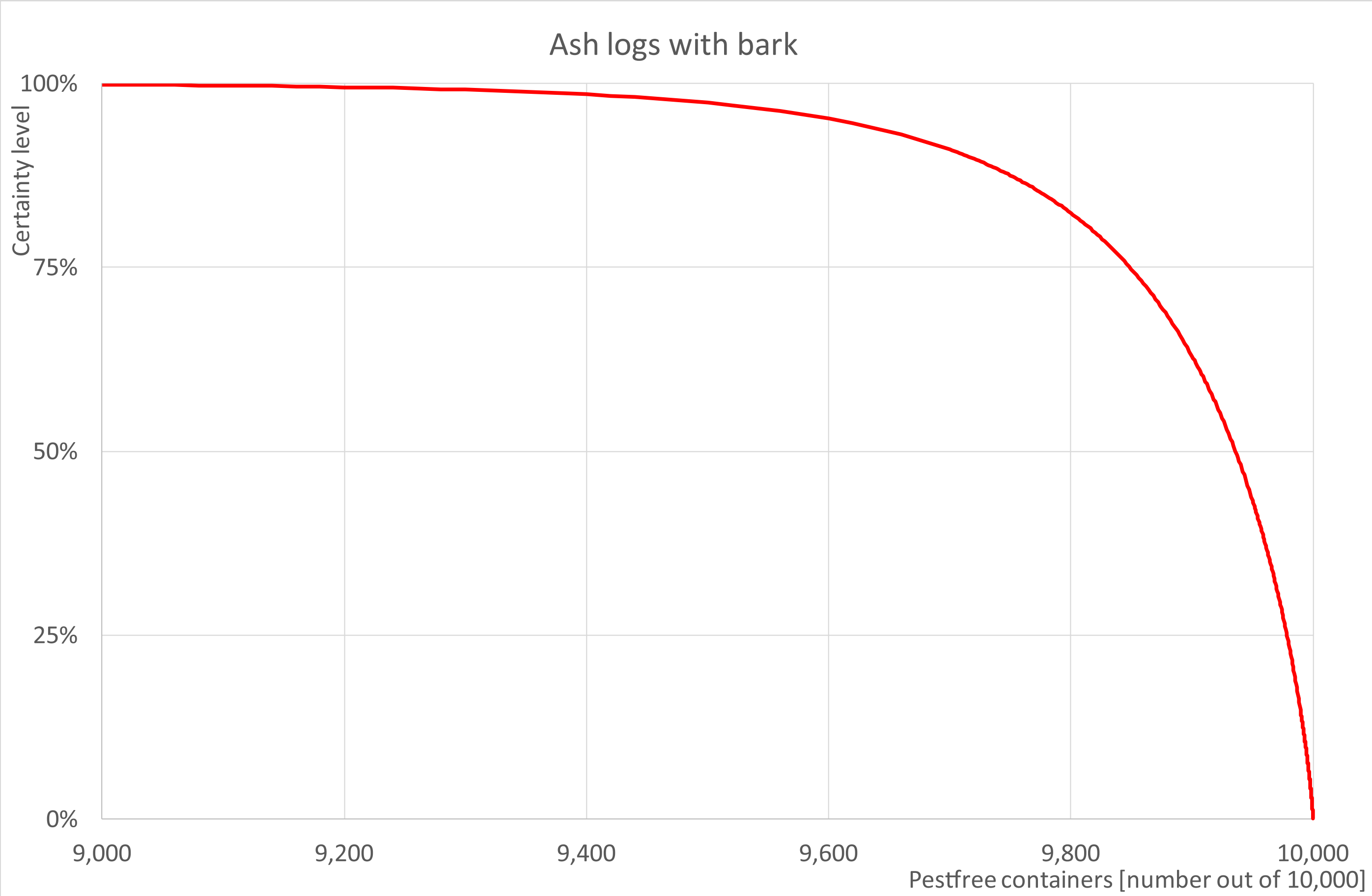
The EKE results are the fitted values.


Ash logs with bark
Probability density
0
200
400
600
800
1,000
Infested containers [number out of 10,000]
EKE result
Fitted density

(a)


Ash logs with bark
Probability density
9,000
9,200
9,400
9,600
9,800
10,000
Pestfree containers [number out of 10,000]

(b)



(c)

Figure C.1: (a) Elicited uncertainty of *A. planipennis* infestation per 10,000 containers (histogram in blue– vertical blue line indicates the elicited percentile in the following order: 1%, 25%, 50%, 75%, 99%) and distributional fit (red line); (b) uncertainty of the proportion of pest free containers per 10,000 (i.e. =1 – pest infestation proportion expressed as percentage); (c) descending uncertainty distribution function of pest infestation per 10,000 containers

C.2. Overall likelihood of pest freedom of containers of debarked ash logs treated with sulfuryl fluoride

C.2.1. Reasoning for a scenario which would lead to a reasonably low number of infested containers of debarked ash logs (lower limit)

Although the pest is widespread in the US where the ash grows, the scenario assumes a low pest pressure. The scenario also assumes that (a) natural enemies are well established, and already active in reducing the pest population; (b) infested trees are promptly identified and discarded by licence foresters when selecting trees to be harvested; (c) debarking reduces the population density by killing the life stages under the bark; (d) inspection of debarked logs allows identifying signs of the pest consisting of galleries; (e) fumigation conditions in terms of temperature requirements are fully standardised making the treatment highly effective.

C.2.2. Reasoning for a scenario which would lead to a reasonably high number of infested containers of debarked ash logs (upper limit)

The pest is widespread in the US where the ash grows and the scenario assumes a high pest pressure. The scenario also assumes that (a) natural enemies are still not well effective in reducing the pest populations; (b) a certain number of infested trees are not identified and discarded by licence foresters when selecting trees to be harvested; (c) debarking only slightly reduces the population density of the pest; (d) signs of the pests on debarked logs can be overlooked because a certain amount of bark may remain on the logs; and (e) temperature requirements during fumigation are not kept during the whole process making the treatment less effective.

C.2.3. Reasoning for a central scenario equally likely to over- or underestimate the number of infested containers of debarked ash logs (median)

The scenario assumes that the pest is widespread with a moderate pest pressure. Although natural enemies have been released in the last years, their efficacy in reducing the pest population is still low. The scenario assumes that licence foresters are trained and efficient in detecting symptomatic trees even in the early stages of infestation, although some symptomatic trees can go undetected due to the intrinsic difficulties in observing canopy symptoms from the ground. The scenario also assumes that the debarking is effective in reducing the population density by killing those individuals present under the bark and in making detection of signs of the pest on the logs possible. The fumigation with sulfuryl fluoride is highly although not completely effective in killing the pest.

C.2.4. Reasoning for the precision of the judgement describing the remaining uncertainties (1st and 3rd quartile/interquartile range)

The first quartile describes the highest uncertainty that reflects uncertainty on most of the information available. The third quartile describes moderate uncertainty reflecting the high efficacy of fumigation with sulfuryl fluoride, the ability to promptly detect infested trees and logs after the debarking.

C.2.5. Elicitation outcomes of the assessment of the pest freedom for *Agrilus planipennis* on containers of debarked ash logs

The following tables show the elicited and fitted values for pest infestation (Table C.3) and pest freedom (Table C.4).

Table C.3: Elicited and fitted values of the uncertainty distribution of pest infestation by *A. planipennis* per 10,000 containers

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Elicited values	1					2		3		7					15
EKE	0.21	0.38	0.60	0.97	1.42	1.95	2.49	3.68	5.17	6.14	7.43	9.0	10.9	12.8	15.0

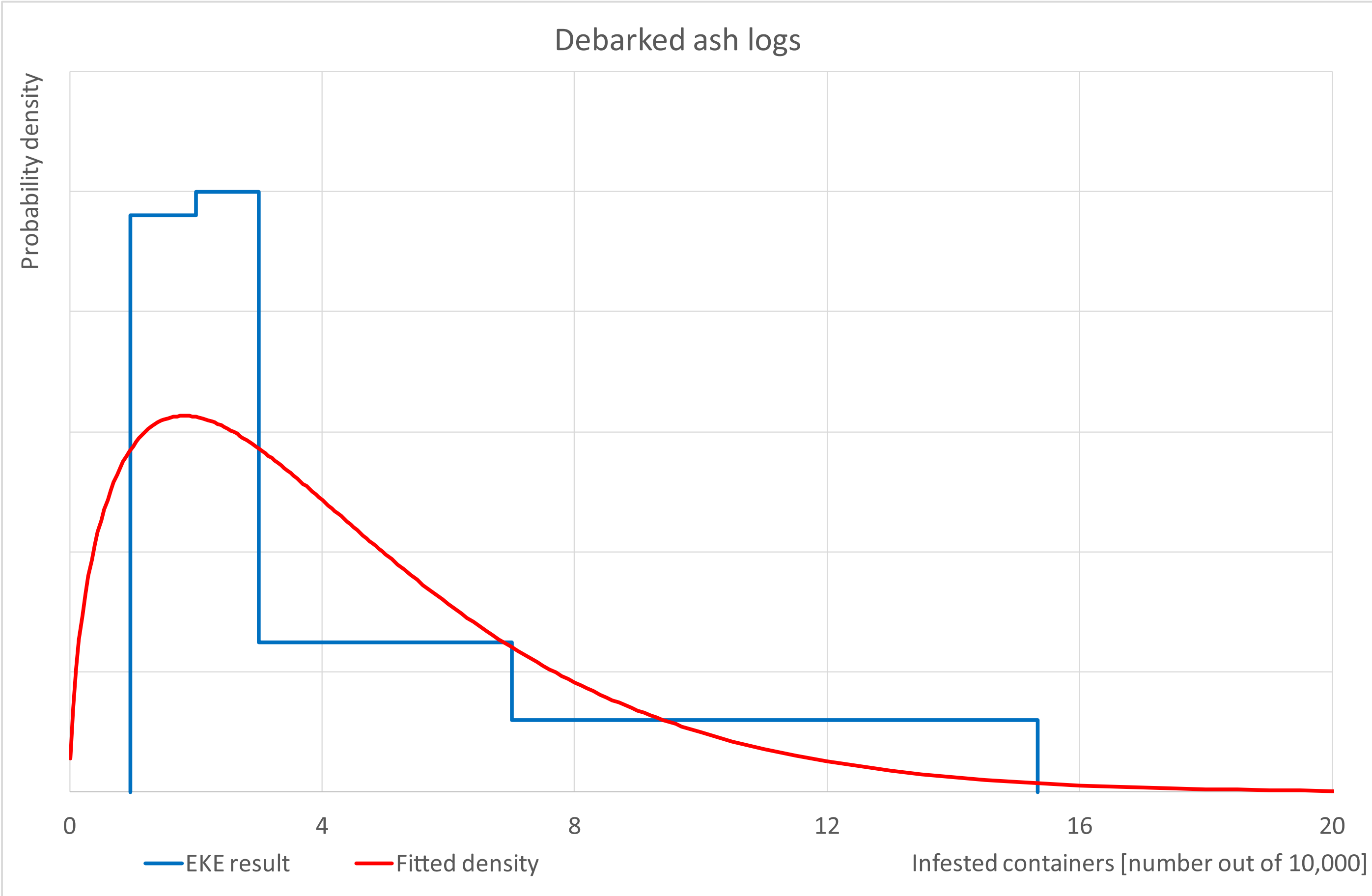
The EKE results is the BetaGeneral (1.5691, 16.783, 0,52) distribution fitted with @Risk version 7.6.

Based on the numbers of estimated infested containers the pest freedom was calculated (i.e. = 10,000 – number of infested containers per 10,000). The fitted values of the uncertainty distribution of the pest freedom are shown in Table C.4.

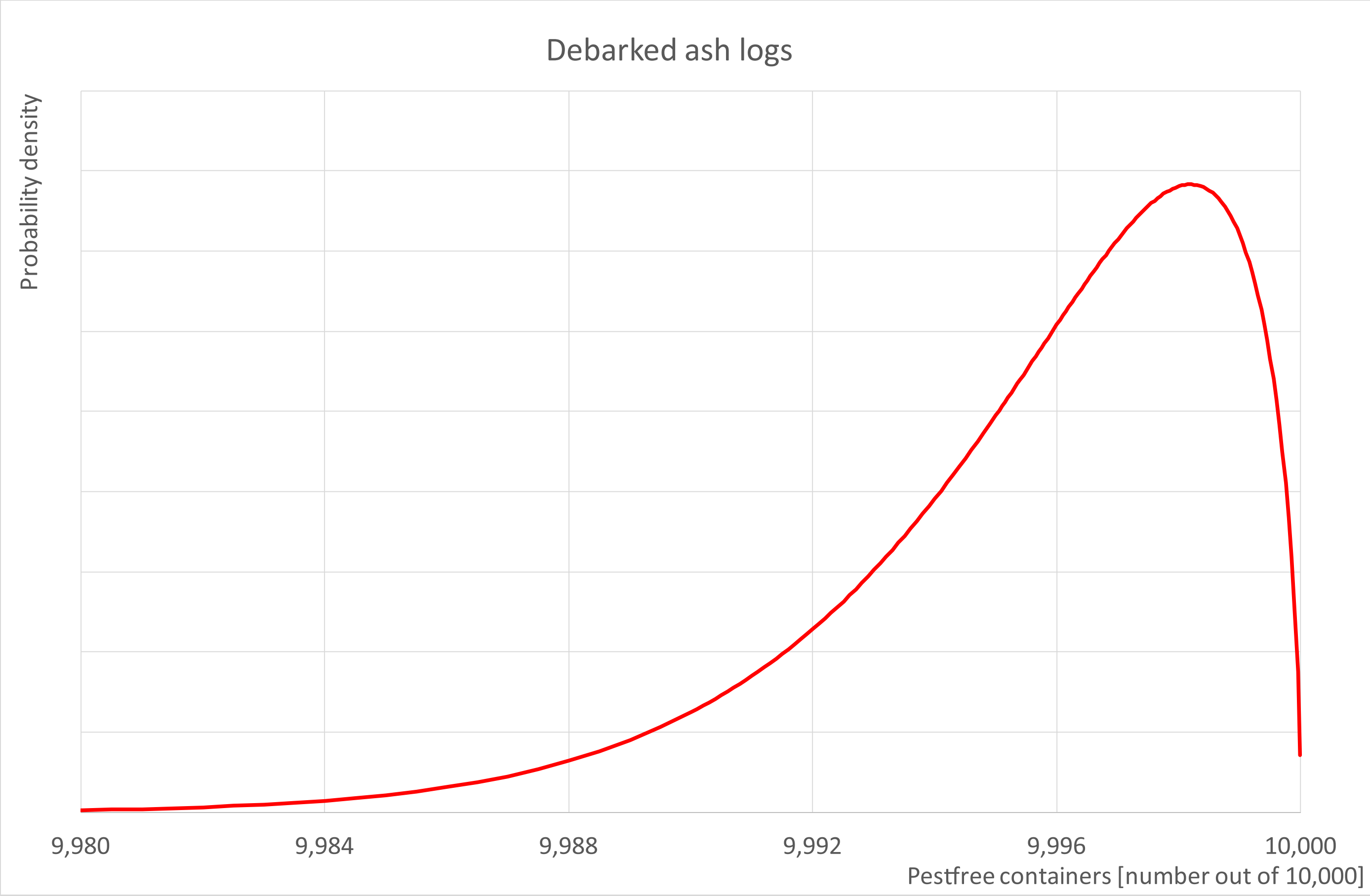
Table C.4: The uncertainty distribution of logs free of *A. planipennis* per 10,000 containers calculated by Table C.3

Percentile	1%	2.5%	5%	10%	17%	25%	33%	50%	67%	75%	83%	90%	95%	97.5%	99%
Values	9,985					9,993		9,997		9,998					9,999
EKE results	9,985	9,987	9,989	9,991	9,993	9,994	9,995	9,996	9,998	9,998.0	9,998.6	9,999.0	9,999.4	9,999.6	9,999.8

The EKE results are the fitted values.


Debarked ash logs
Probability density
0
4
8
12
16
20
EKE result
Fitted density
Infested containers [number out of 10,000]

(a)


Debarked ash logs
Probability density
9,980
9,984
9,988
9,992
9,996
10,000
Pestfree containers [number out of 10,000]

(b)

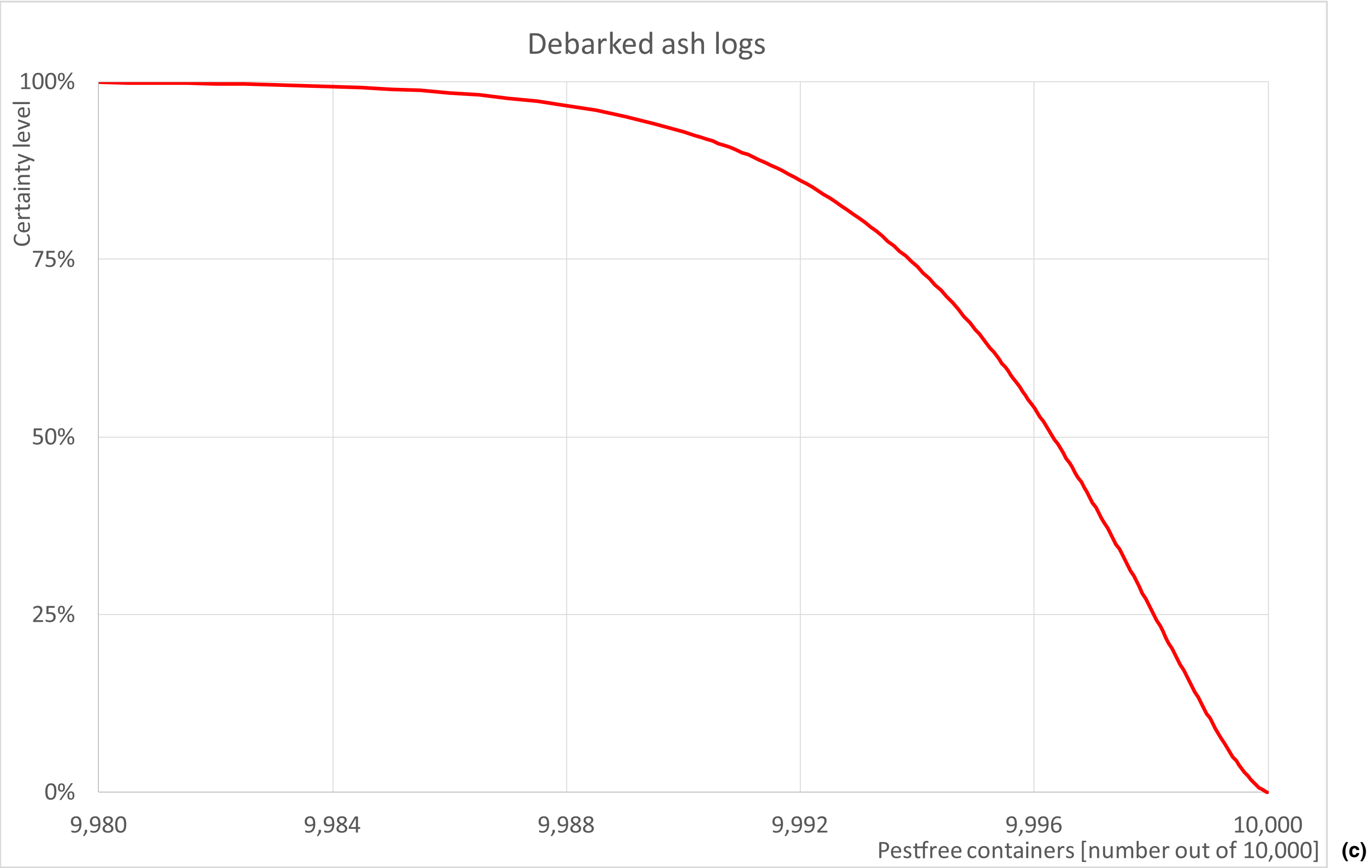


Figure C.2: (a) Elicited uncertainty of *A. planipennis* infestation per 10,000 containers (histogram in blue– vertical blue line indicates the elicited percentile in the following order: 1%, 25%, 50%, 75%, 99%) and distributional fit (red line); (b) uncertainty of the proportion of pest free containers per 10,000 (i.e. = 1 – pest infestation proportion expressed as percentage); (c) descending uncertainty distribution function of pest infestation per 10,000 containers.