



The Food & Environment Research Agency

Rapid Pest Risk Analysis (PRA) for

Polyphagous Shot Hole Borer (*Euwallacea* sp.) and Fusarium Dieback (*Fusarium euwallaceae*)

STAGE 1: INITIATION

1. What is the name of the pest?

Euwallacea sp. (Coleoptera, Curculionidae: Scolytinae) also referred to as *Euwallacea* aff. *forficata* and *Euwallacea* nr. *forficatus* Common name: polyphagous shot hole borer (PSHB) (USA), Avocado ambrosia beetle (Israel) and the associated mutualistic fungus *Fusarium euwallaceae* sp. nov.

Special notes on taxonomy

PSHB is morphologically indistinguishable from *Euwallacea fornicatus* (also referred to as *E. fornicata*), the tea shot hole borer, and was originally identified as this species in Israel and California (Mendel et al. 2012; Rabaglia et al. 2006). However significant differences in both mitochondrial and nuclear DNA between PSHB samples collected in Israel and California, and *E. fornicatus* samples from Sri Lankan tea plantations and elsewhere in South East Asia indicated that PSHB is a distinct species (Rabaglia et al. 2013, Leathers 2015). More work is required to establish if there may be more species in this complex before formal taxonomic names can be assigned. Other species of invasive *Euwallacea*, such as *E. validus*, can be distinguished morphologically.

PSHB is an ambrosia beetle, a member of the subfamily Scolytinae, which was historically treated as a separate family, the Scolytidae, but is now considered to be a specialised subfamily within the Curculionidae. The majority of the ambrosia beetles have a mutualistic relationship with fungi, which are introduced by the females into the larval gallery and act as the primary food source of both adults and larvae (Beaver et al. 1989). PSHB is associated with three fungi. The first to be isolated was a novel *Fusarium* species described as *Fusarium euwallaceae* sp. nov. (Freeman et al. 2013). This fungus appears to play a major role in the process of establishment in a new host, as well as acting as a food source for adults, and has often been found in trees attacked by PSHB but where breeding has failed to occur (Eskalen et al. 2013).

Two additional fungi associated with PSHB have been described more recently (Lynch et al. 2015 *in press*). One is a *Graphium* sp. provisionally named *G. euwallaceae*, and evidence suggests this fungus acts as the main food source of the larvae (Zvi Mendel *pers comm* 26.07.2014; Akif Eskalen *pers comm* 28.07.2014; Eskalen et al. 2014; Freeman et al. 2015). The other fungus isolated from galleries and beetles is *Acremonium pembeum*, but the role of this fungi is very unclear and it may not be a true symbiot (Freeman et al. 2015). Because these two species have only recently been described, and little is known about their role in the impacts of PSHB, they are not considered further in this PRA.

PSHB can be successfully reared in the laboratory on cultures of *F. euwallaceae*, though *E. fornicatus* cannot. The primary ambrosia fungus of *E. fornicatus* is *Fusarium ambrosium*, though other unidentified *Fusarium* species have also been isolated from beetle larval

galleries (Kumar et al. 1998). Significant mortality was seen when attempts were made to rear PSHB on *F. ambrosia*, providing further evidence that PSHB and *E. fornicatus* are distinct species (Freeman et al. 2012).

2. What initiated this rapid PRA?

In 2013 significant damage by this pest to English oak (*Quercus robur*) in California, USA triggered its addition to the UK Plant Health Risk Register (Fera 2013). Due to the potential threat to UK plant health, PSHB was given a priority for PRA.

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

STAGE 2: RISK ASSESSMENT

4. What is the pest's status in the EC Plant Health Directive (Council Directive 2000/29/EC¹) and in the lists of EPPO²?

PSHB is covered by the legislation in Annex IIAI of the EC Plant Health Directive under the listing for Scolytidae spp. (non-European) and its introduction is banned on plants of conifers (*Coniferales*), over 3m in height, other than fruit and seeds, wood of conifers with bark and isolated bark of conifers originating in non-European countries. The addition to the EPPO Alert list was approved in March 2015.

5. What is the pest's current geographical distribution?

Genetic analysis indicates the native distribution of PSHB to be Vietnam, and possibly elsewhere in South East Asia (Leathers, 2015).

PSHB has been introduced to southern California, USA and Israel. In the proposal to change the pest rating in California by the California Department of Food and Agriculture (CDFA), it was also listed as present in South Africa (Leathers, 2015). No other information could be found about the pest in South Africa. It was first identified in Israel as *E. fornicatus* in 2009 in association with a novel *Fusarium* species (Mendel et al. 2012). In California it was first collected in 2003 and identified as *E. fornicatus*. At that time it was only known from Florida and Hawaii in the rest of the USA (Rabaglia et al. 2006). Significant impacts were not observed in California until 2012 when damage from *Fusarium* dieback was first noted (Eskalen et al. 2012). Because of the fact that it is morphologically identical to *E. fornicatus*, the full distribution of PSHB in other regions of the world remains highly uncertain.

North America:	USA (California)
Central America:	Not recorded
South America:	Not recorded
Europe:	Not recorded
Africa:	South Africa
Asia:	Israel, Vietnam
Oceania:	Not recorded

¹ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0029:20100113:EN:PDF>

² <https://www.eppo.int/QUARANTINE/quarantine.htm>

6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA Area?

Neither PSHB, the associated ambrosia fungus *F. euwallaceae*, nor the morphologically identical *E. fornicatus* are present in the UK and neither has been intercepted to date.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

As its name suggests, the PSHB is a highly polyphagous species and has been recorded on a great number of woody trees and shrubs, though reports of attacks on conifers are very limited. Attack by PSHB may result in no colonisation by *F. euwallaceae*, colonisation by *F. euwallaceae* but no successful breeding of the beetles, or fungal colonisation and successful breeding of PSHB. All three results can still prove damaging to the tree, but, in general, reproductive hosts suffer the most severe decline symptoms due to significant colonisation by *F. euwallaceae* and repeated attacks by adult beetles.

A survey of two infested botanical gardens in California found 207 species of woody plant with signs of attack consistent with PSHB, and *F. euwallaceae* was isolated from 113 species in 40 families (Eskalen et al. 2013). The families with the most infected species were the Sapindaceae (maples), Fabaceae (legumes – only woody hosts) and Fagaceae (beeches).

The number of confirmed reproductive hosts is smaller, but may be underestimated. Table two shows the confirmed reproductive hosts. In Israel, PSHB has largely been associated with avocado (*Persea americana*), but box elder (*Acer negundo*), *Quercus pedunculifolia* (a species with complicated taxonomy considered by some to be a race of *Q. robur*), *Q. robur*, *Platanus* (plane) and castor bean (*Ricinus communis*) have also been recorded as suitable reproductive hosts (Zvi Mendel pers comm). In Vietnam, acacia (*Acacia* spp.), cinnamon (*Cinnamomum* spp.), castor bean, avocado and tea (*Camellia* spp.) were found to be infested (California Avocado Commission 2014).

Table 2: A list of reproductive hosts of PSHB (Eskalen 2015).

Family	Species	Common Name
Sapindaceae	<i>Acer negundo</i>	Box Elder
	<i>Acer macrophyllum</i>	Big leaf maple
	<i>Acer buergerianum</i>	Trident maple
	<i>Acer palmatum</i>	Japanese maple
	<i>Acer paxii</i>	Evergreen maple
	<i>Alectryon excelsus</i>	Titoki
Euphorbiaceae	<i>Ricinus communis</i>	Castor bean
Lauraceae	<i>Persea americana</i>	Avocado
Fagaceae	<i>Quercus robur</i>	English oak
	<i>Quercus agrifolia</i>	Coast live oak
	<i>Quercus suber</i>	Cork oak
	<i>Quercus engelmannii</i>	Engelmann oak
	<i>Quercus lobata</i>	Valley oak
Platanaceae	<i>Platanus racemosa</i>	Californian sycamore
	<i>Platanus x acerifolia</i>	London plane
Fabaceae	<i>Albizia julibrissin</i>	Mimosa
	<i>Erythrina corallodendron</i>	Coral tree
	<i>Cercidium floridum</i>	Blue palo verde
	<i>Parkinsonia aculeata</i>	Palo verde
	<i>Castanospermum australe</i>	Moreton bay chestnut
	<i>Cercidium sonora</i>	Brea
	<i>Prosopis articulata</i>	Mesquite
	<i>Wisteria floribunda</i>	Japanese wisteria

	<i>Acacia spp.</i>	Acacia
Salicaceae	<i>Salix babylonica</i>	Weeping willow
	<i>Salix laevigata</i>	Red willow
	<i>Salix gooddingii</i>	Goodding's black willow
	<i>Populus trichocarpa</i>	Black cottonwood
Aquifoliaceae	<i>Ilex cornuta</i>	Chinese holly
Theaceae	<i>Camellia semiserrata</i>	Camellia
Antingiaceae	<i>Liquidambar styraciflua</i>	Liquidambar
Myrtoideae	<i>Eucalyptus ficifolia</i>	Red flowering gum
Simaroubaceae	<i>Ailanthus altissima</i>	Tree of heaven
Betulaceae	<i>Alnus rhombifolia</i>	White alder

From the recorded hosts, English oak (*Q. robur*) is a very important and widespread native species in the UK. Several of the recorded *Acer* hosts are grown as ornamentals. London plane and other *Platanus* species are planted extensively as urban amenity trees and weeping willow (*Salix babylonica*) is an introduced species common along waterways in the UK. It seems very likely that the PSHB would also be able to infest UK species of genera used as reproductive hosts elsewhere, such as alders (*Alnus spp.*) and ornamental wisteria (*Wisteria spp.*)

Other native species that have been recorded as being attacked by PSHB and susceptible to *Fusarium* dieback, but have not been confirmed as breeding hosts, include English holly (*Ilex aquifolium*), silver birch (*Betula pendula*), strawberry tree (*Arbutus unedo*), and European beech (*Fagus sylvatica*) (Eskalen et al. 2013). In addition, *Vitis vinifera*, grown for wine production in the UK, is also susceptible to attack by PSHB and *Fusarium* dieback, but it has not yet been recorded in vineyards.

8. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area? (By pathway):

The pathways by which PSHB entered the USA and Israel are unknown, though experts on PSHB in California are of the opinion it arrived on infested dunnage (Akif Eskalen *pers comm.*). The population from the San Diego outbreak differs genetically from that of the Los Angeles/Israeli outbreak, and thus may represent two separate introduction events into California (Drill 2014; Leathers 2015). The origin of PSHB is likely to be Vietnam, though the full distribution of the pest is still uncertain and it may be present in other areas. There may also be additional pathways that have not been identified below.

Annex I contains tables of data extracted from Eurostat on the import of various commodities that PSHB could be associated with. These tables are referred to throughout this section. Because there is only a single reference to PSHB being present in South Africa (Leathers 2015), with no data on the distribution of the pest within this country or the hosts attacked, imports from this country were not included in the analysis.

Disease can occur on avocado plants that have been directly inoculated with *F. euwallaceae*, and the fungus has been found in isolation without PSHB, but there is no evidence to suggest that *F. euwallaceae* is spread by another other mechanism or vector except PSHB. Evidence suggests members of the genus *Euwallacea* spread their associated *Fusarium* in an obligate manner (Kasson et al. 2013). Thus introduction and spread of *F. euwallaceae* is not considered separately.

Plants for Planting

PSHB has been recorded attacking hosts with trunk diameters as small as 5 cm, and damage has also been recorded on branches as small as 2.5 cm (Coleman et al. 2013), thus young woody plants moving in the nursery trade could be infested by PSHB. In California, PSHB has largely been reported attacking trees in urban locations, though there are also reports in commercial avocado production. PSHB is a Q-rated pest in California, meaning that nursery stock suspected to be infested is placed on hold for destruction or treatment. In March 2015, a consultation began to change the status of PSHB to B rated, meaning that any measures taken would be at the discretion of the individual county agricultural commissioner (Leathers, 2015). *F. euwallaceae* has been found in isolation at a nursery in California, and plants were destroyed (NPAG, 2013). Where action is taken, it should reduce the spread of PSHB in the USA, which could otherwise move rapidly in trade increasing the range of the pest and likelihood of entry to the UK on planting material.

In Israel nearly all reports are in commercial avocado production but PSHB has been recorded on other hosts (Freeman et al. 2013), though there are no published reports of nursery infestations. Avocado is a preferred host of PSHB, however observations in the USA indicate that once PSHB has infested and killed preferred hosts they will move on to a wide variety of other species, and thus spread in Israel into nurseries growing other PSHB hosts could occur in the future. Planting material of a wide number of woody species from Israel is imported into the rest of the EU, as well as directly into the UK. A search of Eurostat for imports under commodity codes related to woody plants from Israel, USA and Vietnam into the UK and EU for the years 2012-2014 is shown in Table 3 in Annex I.

Import of potential host material was negligible from Vietnam, and relatively low from the USA – especially when taken in the context that only a fraction, if any, of the material imported will originate from the range of PSHB in California. There is a significant trade within the EU from Israel. Though the pest still has a limited distribution, it is likely to continue to spread. The inconspicuous nature of the pest, especially when infestations are recent, means that detecting it on planting material during inspections on import is unlikely. Entry on planting material is rated as moderately likely, with medium confidence.

Plants for planting	Very unlikely	<input type="checkbox"/>	Unlikely	<input type="checkbox"/>	Moderately likely	<input checked="" type="checkbox"/>	Likely	<input type="checkbox"/>	Very likely	<input type="checkbox"/>
Confidence	High Confidence	<input type="checkbox"/>	Medium Confidence	<input checked="" type="checkbox"/>	Low Confidence	<input type="checkbox"/>				

Non-Squared Wood and Woodchips

On some host species including oak, PSHB will penetrate large branches and the main stem to a depth of between 1 – 4 cm (Eskalen and Stouthammer, 2012) so unsquared timber, woodchips or isolated bark could provide a pathway of entry. Between 1984-2008 the USA made 6 interceptions of *Euwallacea* sp. in association with wood (including wood packaging material) that originated in Asia, indicating that this genus can move along the pathway (Haack and Rabaglia, 2013).

PSHB is not currently recorded as present in commercial timber production in Israel or California. However in Vietnam it was observed infesting wood in *Acacia* and cinnamon plantations, but it is likely that fungal staining would reduce the commercial value and making it unsuitable to be sold as logs. It is not known if *Acacia* or cinnamon timber is imported into the UK from Vietnam, no evidence of this trade could be found but it could still occur in low volumes. The main timber species that are regularly imported and that are attacked by PSHB are *Quercus*, *Salix*, *Eucalyptus* and *Platanus*. Of these only *Quercus* is imported from the US in significant amounts into the UK. Table 4 in Annex I shows the import of *Quercus* wood from the USA into the UK and EU from 2012-2014. The commodity codes do not distinguish between non-squared and squared wood. In that same period the only other countries from which *Quercus* timber was imported from were within the EU and

Canada (Eurostat, 2014), and the pest is absent from both of these areas, so entry of the pest on *Quercus* timber from other parts of its range is very unlikely. There has been a decrease in imports of *Quercus* timber directly into the UK in recent years, falling from the 2012 figure of around 1700 tonnes to 66 tonnes in 2014. Total EU imports of the same commodity are over 10,000 tonnes per year. However only a small amount of the *Quercus* timber will have originated from the range of PSHB. In addition there are EU requirements for wood of *Quercus* and *Platanus* originating from the USA requiring it to be bark free or having undergone suitable heat treatment. Isolated bark of *Quercus* is prohibited from the USA (except *Q. suber*), reducing the risk of entry on this pathway. There are no requirements on timber originating from elsewhere.

Further searches of Eurostat for imports of Eucalyptus timber (in the same time period and also not distinguishing between squared and non-squared wood) from the known range of PSHB are summarised in Table 5 in Annex I. There were no imports directly into the UK but a small amount of material was imported into the EU from the USA and Vietnam. *Acacia*, *Cinnamomum*, *Platanus*, and *Salix* do not have specific commodity codes that allow import data to be extracted from Europhyt.

A report from 2004 indicated that within the state owned Vietnamese Forestry Corporation, which managed approximately 7200 hectares of acacia hybrid plantations, approximately half of acacia hybrid wood produced was used for woodchips for export and the other half used in production of MDF (van Bueren, 2004). By 2013 there were 550,000 hectares of acacia and acacia hybrid plantations in Vietnam with the major use being wood chip export (Sadanandan Nambiar et al. 2015). Import of fuel wood and wood chips into the EU from China, India, Korea, Thailand and Vietnam was previously investigated by EPPO as part of a PRA on *Apriona* species, which found this only occurred in small volumes between 2006 – 2010, with no import from Vietnam (EPPO 2013). Further searches of Eurostat for deciduous wood chip imports from the range of PSHB are summarised in Table 6 in Annex I. Wood chips were imported from Vietnam in 2013 and 2014 in the EU – 103 tonnes in 2014. Though this commodity code will also cover woodchips of species not recorded as hosts of PSHB, it is worth noting that *Acacia* is a major contributor to the total wood chip production in Vietnam.

Table 6 also shows import of fuel wood (which will include non-hosts) from the range of PSHB. There has been considerable variation in the amount of fuel wood imported from Vietnam into the EU – around 1200 tonnes in 2012 compared to only around 20 tonnes in 2013 and 2014. This variation, as well as a lack of data on the proportion of imports that are PSHB hosts, increases the uncertainty around this rating.

Given that PSHB is only recorded as a pest of timber production in Vietnam, and there is little trade in non-squared wood and wood chips from its known distribution, entry on this pathway is considered unlikely. There is low confidence associated with the rating. As well as considerable variation in the trade, the commodity codes do not distinguish between host and non-host species of PSHB and it is also not known what proportion of the trade originates from regions where PSHB is present, which is particularly related to the assessment of risk for material of US origin. If the pest continues to spread, or if there is an increased trade in wood chips or other non-squared wood from the current PSHB distribution, risk of entry on this pathway may increase, and would also be higher in instances of non-compliance with EU regulations.

Non squared wood & woodchips	Very unlikely	<input type="checkbox"/>	Unlikely	<input checked="" type="checkbox"/>	Moderately likely	<input type="checkbox"/>	Likely	<input type="checkbox"/>	Very likely	<input type="checkbox"/>
	High Confidence	<input type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input checked="" type="checkbox"/>				

Squared Wood

The process of squaring wood will largely remove the outer parts where PSHB would be present, but will not remove all of the outer wood and thus still presents a pathway of entry. For squared timber of *Quercus* and *Platanus* that originate in the USA the EU requirements as described above still apply, and *Quercus* timber should be bark free and have undergone suitable treatments. Tables 4 and 5 in Annex I contain data that relate to the import of both squared and non-squared timber of *Quercus* and *Eucalyptus* from the known range of PSHB. However, there are no requirements on timber that originates elsewhere. As for non-squared wood, the staining of timber caused by the fungal symbionts will also reduce its commercial value, and import volumes are generally low. Given this information, entry on this pathway is considered unlikely with medium confidence.

Squared wood	Very unlikely	<input type="checkbox"/>	Unlikely	<input checked="" type="checkbox"/>	Moderately likely	<input type="checkbox"/>	Likely	<input type="checkbox"/>	Very likely	<input type="checkbox"/>
	High Confidence	<input type="checkbox"/>	Medium Confidence	<input checked="" type="checkbox"/>	Low Confidence	<input type="checkbox"/>				

Wood Packaging Material

Wood packaging material (WPM) that is not compliant with ISPM15 could provide a pathway of entry for PSHB. Members of the Scolytinae are commonly intercepted on non-compliant WPM. Thus, 73% of Scolytinae interceptions in the USA were on WPM and new introductions of Scolytinae are strongly associated with WPM (Marini et al. 2011). It is thought that dunnage may have been the pathway of entry of PSHB into the USA (Eskalen pers. comm 30.9.2014). Dunnage tends to be made of low quality timber (such as that which may occur due to PSHB infestation and fungal staining) and is often associated with infestation of insects (Stanaway et al. 2001). It is not known if PSHB is a pest in any plantations where timber may be used for WPM production.

Currently all WPM originating from outside of the EU should be ISPM15 compliant. This means the wood should be debarked, though areas of bark less than 3cm in width, or greater than 3 cm in width but with the total surface area of an individual piece of bark less than 50 cm², is permitted. WPM must then undergo heat treatment that achieves a minimum temperature of 56°C for 30 minutes throughout the entire profile of the wood, or undergo treatment with methyl bromide. Bark beetles have been shown to re-colonise treated WPM with pieces of bark of approximately 25-35 cm² (Evans 2007). PSHB infests living, and often apparently healthy, trees, making attack of treated WPM unlikely. Though ISPM15 treatment is likely to reduce the risk of entry on this pathway it does not eliminate risk of entry on WPM. Within the European Union, a survey of WPM post-implementation of ISPM15 showed 0.3% of WPM marked as compliant with ISPM15 were found to be infested with insects of quarantine concern. When such material is stored or discarded outside, transfer to a suitable host can occur. In addition there are recorded instances of non-compliance with ISPM15, with the UK reporting 20 and the rest of the EU reporting 62 such interceptions in the period between Jan – November 2014 (Europhyt data retrieved 03.02.2015).

Entry on WPM is rated as moderately likely. There is low confidence associated with the rating, as it is not known how much WPM is produced in the areas where PSHB is known to be present, or what volume of potentially risky wood is imported into the UK.

WPM	Very unlikely	<input type="checkbox"/>	Unlikely	<input type="checkbox"/>	Moderately likely	<input checked="" type="checkbox"/>	Likely	<input type="checkbox"/>	Very likely	<input type="checkbox"/>
	High Confidence	<input type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input checked="" type="checkbox"/>				

Hitchhiking

PSHB may hitchhike on commodities such as produce and cut flowers, or be associated with packing cases (NPAG, 2013). California has intercepted other *Euwallacea* species on cut flowers, ginger and macadamia (Leathers 2015). A survey of 3001 sea cargo containers in Australia found 20 *Euwallacea* spp., though none were live (Stanaway et al. 2001). This survey concentrated on, but did not exclusively look at, containers that had been carrying timber. It has also been theorised that movement between avocado production sites in Israel may have been aided by beetles hitchhiking on packing crates (Eskalen 2012). Avocados are imported into the UK from both Israel and the USA (Fresh Produce Consortium 2011), providing a potential pathway of entry, and PSHB could hitchhike on other commodities. Adult females, that leave the larval galleries after being mated by their male siblings, are capable of flight and thus have potential to transfer to a suitable host, but suitable hosts may not be present within the immediate vicinity of the entry ports. Entry on this pathway is considered unlikely, although ambrosia beetles have been intercepted in association with other commodities in the past, the end use of these commodities will strongly influence its ability to transfer to a suitable host. Confidence in the rating is low as it is not clear if PSHB has been moving via hitchhiking or natural spread in Israel.

Hitchhiking	Very unlikely	<input type="checkbox"/>	Unlikely	<input checked="" type="checkbox"/>	Moderately likely	<input type="checkbox"/>	Likely	<input type="checkbox"/>	Very likely	<input type="checkbox"/>
Confidence	High Confidence	<input type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input checked="" type="checkbox"/>				

9. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

To date there have been no studies on the temperature requirements for the development of PSHB. However given the current distribution of the pest, climate is likely to be the limiting factor in establishment outdoors. Regions where PSHB are located in southern California and Israel have Mediterranean climates with much hotter summers and milder winters than the UK. The climate in Vietnam is largely tropical with high temperatures all year round (Embassy of Vietnam 2007).

An initial risk assessment performed by the USDA’s New Pest Advisory Group (NPAG) concluded that PSHB was only likely to pose a threat to tropical and subtropical regions of the USA, however this assessment was made when PSHB was still thought to be *E. fornicatus* in association with a novel *Fusarium*, but it acknowledged there was uncertainty over the true identity of the pest (NPAG, 2013). A later assessment by the CDFA stated that within the tree the pest was protected from the outside environment, and was expected to be able to establish across the whole of California where its hosts are present (Leathers 2015), though currently distribution is limited to Southern California. The closely related *E. fornicatus* has a distribution limited to tropical and subtropical regions. Studies investigating development at various temperatures showed that no eggs hatched at 15°C and nor did pupae develop, the optimum temperatures for development were 28°C and 30°C (Walgama and Zalucki 2007). Development time of pupae was also significantly slower at 18°C at 15 days compared to 6 days at 28°C. Data on total development time from egg to adult at various temperatures are not available, though, in the field in Sri Lanka, the total life cycle for *E. fornicatus* is around 45 days and there are multiple generations per year, the number depending on the altitude. It is not known if the same temperature requirements apply to PSHB.

E. validus is another, morphologically distinct, *Euwallacea* species native to South Asia that was introduced to the USA in 1976. It has since spread across the Eastern United States and was reported in Ontario, Canada for the first time in 2013 (Douglas et al. 2013). Although the distribution of other ambrosia beetles is not generally a good indicator of the full potential range, it is likely that PSHB has not yet reached the northernmost limit to its potential distribution in the USA.

English oak (*Q. robur*) and plane trees are a preferred reproductive host of PSHB in its current range and infestation leads to the production of large numbers of beetles (Zvi Mendel *pers comm*, Akif Eskalen *pers comm*). In Southern California, it was initially estimated there were approximately 2 to 4 generations per year in urban areas (Coleman et al. 2013), and it has since been described as having a high reproduction rate (Leathers 2015). In Israel, the generation time is around 8-10 weeks (during the summer) and there are multiple generations per year. However, estimating the number of generations is complicated by the fact that females may remain within larval galleries for several generations (Zvi Mendel, *pers comm*. 17.09.2014). The overwintering strategy of PSHB is unclear, but it appears to be within the larval galleries and this behaviour may help protect PSHB from the colder winter conditions in the UK. The current distribution in Israel and southern California implies that climate may limit establishment in the UK even though large numbers of the preferred reproductive host species are present. Establishment outdoors in the UK is therefore considered to be unlikely, though with low confidence due to the lack of specific data on the temperature requirements of PSHB and its ability to adapt to cooler conditions in the UK. For example, if PSHB were able to overwinter sheltered within trees, establishment could occur with significantly fewer generations per year. Establishment is much more likely in other regions of the EU with Mediterranean climates similar to those seen in Israel and California.

The preferred hosts of PSHB are generally not grown under protection in the UK, however, given its polyphagous nature, there may be some woody ornamentals grown under protection in the UK that could be suitable hosts. There are no reports of this PSHB attacking protected crops in its current distribution – in general ambrosia beetles are not considered pests of protected cultivation, and thus establishment under protection is considered very unlikely.

Outdoors	Very unlikely	<input type="checkbox"/>	Unlikely	<input checked="" type="checkbox"/>	Moderately likely	<input type="checkbox"/>	Likely	<input type="checkbox"/>	Very likely	<input type="checkbox"/>
Confidence	High Confidence	<input type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input checked="" type="checkbox"/>				
Under Protection	Very unlikely	<input checked="" type="checkbox"/>	Unlikely	<input type="checkbox"/>	Moderately likely	<input type="checkbox"/>	Likely	<input type="checkbox"/>	Very likely	<input type="checkbox"/>
Confidence	High Confidence	<input checked="" type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input type="checkbox"/>				

10. If the pest needs a vector, is it present in the UK/PRA area?

PSHB is a free living organisms and no vector is required.

11. How quickly could the pest spread in the UK/PRA area?

There are little data available on the spread capacity of the pest. Up until 2014, most spread in California had been local, but in 2014 a beetle was found in a trap in Santa Cruz, some 300 miles from the main infestation in the Los Angeles area. However the sample was not suitable for molecular analysis and thus cannot be confirmed as PSHB – it may be *E. fornicatus* which is occasionally intercepted in California (Leathers 2015). The related *E. fornicatus* has been shown to be able to fly up to 2 km without the help of wind (Akif Eskalen *pers. comm.*). Spread in Israel has been reported to be around 10 - 20 km a year (Woodward 2012, Leathers 2015). Emergence and flight by females occurs from late spring into late autumn (Zvi Mendel, *pers comm*. 16.09.2014). Females are described as strong fliers (Leathers 2015). It is theorised that spread between avocado plantations in Israel was by female adults hitchhiking on packing crates (Eskalen 2012).

Natural spread in the UK is expected to be slow, due to a lower reproduction rate of the pest should it establish, but if PSHB was to enter nursery stock or infest trees used for timber/fuel wood it could spread quickly.

Natural Spread	Very slowly	<input type="checkbox"/>	Slowly	<input checked="" type="checkbox"/>	Moderate pace	<input type="checkbox"/>	Quickly	<input type="checkbox"/>	Very quickly	<input type="checkbox"/>
	High Confidence	<input type="checkbox"/>	Medium Confidence	<input checked="" type="checkbox"/>	Low Confidence	<input type="checkbox"/>				
With trade	Very slowly	<input type="checkbox"/>	Slowly	<input type="checkbox"/>	Moderate pace	<input type="checkbox"/>	Quickly	<input checked="" type="checkbox"/>	Very quickly	<input type="checkbox"/>
	High Confidence	<input checked="" type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input type="checkbox"/>				

12. What is the pest’s economic, environmental and social impact within its existing distribution?

PSHB is a relatively recent introduction to both Israel (2005) and the USA (2003, but not noted to be in association with *F. euwallaceae* until 2012) and little quantitative data are available on impacts. There is no published information on the impacts in South Africa, and very little on impacts in Vietnam. The majority of ambrosia beetles attack sick or otherwise physiologically stressed trees (Hulcr et al. 2007), but PSHB appears to be able to attack apparently healthy trees. PSHB burrows into trees to create larval galleries, inoculating the tunnel with *F. euwallaceae* and other fungi whose growth causes dieback due to clogging of the xylem vessels (Coleman et al. 2013). The fungus has been observed to be able to move at least 150cm along the xylem tissue, and disease will occur if directly inoculated into avocado trees (Mendel et al. 2012). Not all attacks by PSHB result in the establishment of *F. euwallaceae* but can still prove damaging by providing an entry point for secondary fungal pathogens (Eskalen et al. 2013).

Box elder, English oak, plane and castor bean are described as readily succumbing to infestation and mortality on these species as well as white alder (*Alnus rhombifolia*) and red willow (*Salix laevigata*) is frequently seen in California. PSHB attacks both the main trunk and large branches of plane and English oak, which die rapidly, usually within one to one and a half years after infestation (Zvi Mendel *pers comm.*, Eskalen *pers comm.*).

In general the largest economic impacts have been seen in avocado production in Israel, where PSHB is now described as a serious threat to the industry. Typical symptoms of infestation in avocados include wilting of branches, breakages in stems and branches where beetle galleries are present and death of trees – seen in both young and mature trees (Mendel et al. 2012). Beetles are only able to establish successful brood galleries in stems less than 4 cm; those in the main trunk or wider branches fail (Mendel 2014). Infestation often results in the production of “sugar volcanoes”, the production of a ring of sugar exudate, at the site of entry (Coleman et al. 2013). Avocado growers in Israel are reluctant to use pesticides to control PSHB for fear of loss of exports to the European Union, where there are strict pesticide residue requirements, and this lack of effective treatment is thought to contribute to the continued spread of the pest. Those that leave low residue levels have not been effective. Some groves have infestation rates of 100% (Eskalen 2012).

In California, PSHB has been found primarily in urban landscapes, but in February 2013 it was reported as present in the Angeles National Forest (Coleman et al. 2013). Given the very recent introduction of this pest into the wider environment, no environmental impacts have been reported, but since it is known to breed and kill native Californian species these impacts may increase in the future. A Californian risk assessment concluded that significant environmental impacts are expected including changes to ecosystem processes (Leathers 2015). There are no reported environmental impacts in Israel.

In California, there have been significant impacts on trees in the urban environment leading to social impacts. Numerous amenity and garden trees have been infested and have either died or been destroyed. The LA Times reported that a tree weakened by disease toppled into a neighbour's garden, and that there was concern that infested street trees could pose a hazard to members of the public if they dropped branches (Kahn 2014a) since many recorded hosts are commonly planted as street trees (Eskalen et al. 2013). The cost of the control of PSHB in street trees is not known, but it has been reported in newspapers that hundreds of trees in the Los Angeles area have been removed and such removals cost at least \$1000 each (Brennan 2013). It is thought that PSHB will have a significant impact on cultural practices and ornamental plantings (Leathers 2015). There have been several publicity campaigns (published in both English and Spanish) to raise awareness of the beetle and give advice on how to deal with infested trees, and public meetings have also been held to inform residents about the pest (Eskalen 2014a; City of Pasadena 2014; Kahn 2014b). Social impacts have potential to increase if the pest continues to spread.

Infestations have been reported from two botanical gardens in California (Eskalen et al. 2013). One of these gardens, the LA Arboretum, estimates that 10-20 trees have died as a direct result of the activity of PSHB, including a *Quercus engelmannii* (a vulnerable species according to the IUCN red list of threatened species) and five species of *Acer* originating from Europe and Asia. It has been noted that damage increased after a hurricane force storm (though the infestation was likely to have been present for at least two to three years before the storm) (Frank McDonough, *pers comm.* 21.08.2014). This provides some evidence that, like other ambrosia beetles, PSHB may be more damaging to already stressed trees, however many attacks on apparently healthy trees have also been noted.

Impacts overall are rated as large with high confidence, and, considering this is a relatively recent infestation, are expected to rise if PSHB continues to spread.

Impacts	Very small	<input type="checkbox"/>	Small	<input type="checkbox"/>	Medium	<input type="checkbox"/>	Large	<input checked="" type="checkbox"/>	Very large	<input type="checkbox"/>
Confidence	High Confidence	<input checked="" type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input type="checkbox"/>				

13. What is the pest's potential to cause economic, environmental and social impacts in the UK/PRA area?

It is not possible to determine what the full host range of PSHB would be in the UK, though studies in host range in California indicate it has a strong preference for broad-leaved trees – no conifers have been recorded as reproductive hosts and are thus unlikely to be at risk (Eskalen et al. 2013). Climate is likely to limit the pest's impacts in the UK, as, even if establishment occurs, the developmental time is likely to be longer and PSHB would be expected to produce fewer generations per year than in its current distribution. However the successful infestation of the *Fusarium* dieback may still lead to tree death even with relatively low numbers of beetle larval galleries. Potential impact ratings are highly uncertain due to a lack of data on the pest's full host range and temperature development requirements of both PSHB and *F. euwallaceae*.

If PSHB was successfully introduced, economic and environmental impacts on known reproductive hardwood tree hosts such as English oak are unlikely to occur since the climate is unlikely to be suitable. Many stands of oaks in the south of England have been identified as being affected by Acute Oak Decline and it is possible that infestation with PSHB could worsen the impacts of Acute Oak Decline.

Plane trees are extensively planted in urban locations in the UK and large, mature city trees are highly valued. Cities can also form urban heat islands, where temperatures may be higher than surrounding rural areas and more suitable for the establishment of PSHB. If

PSHB were to establish on planes or other street trees in urban environments it is likely to spread quickly between the closely planted trees. Heavily infested or dead trees would have to be removed, which could have locally significant social impacts. Botanical collections and arboretum, where large numbers of exotic woody hosts that may prove suitable for PSHB infestation are kept, may also be impacted by the pest.

Based on current evidence indicating that the climate in the UK is unlikely to be suitable for the pest, expected impacts in the UK are rated as small, but without data on the temperature development requirements for PSHB or the fungus there is low confidence in this rating. Trees could still be killed by the pest but over a significantly longer time period than seen in California and Israel.

Economic Impacts	Very small	<input type="checkbox"/>	Small	<input checked="" type="checkbox"/>	Medium	<input type="checkbox"/>	Large	<input type="checkbox"/>	Very large	<input type="checkbox"/>
Confidence	High Confidence	<input type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input checked="" type="checkbox"/>				
Environ - mental Impacts	Very small	<input type="checkbox"/>	Small	<input checked="" type="checkbox"/>	Medium	<input type="checkbox"/>	Large	<input type="checkbox"/>	Very large	<input type="checkbox"/>
Confidence	High Confidence	<input type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input checked="" type="checkbox"/>				
Social Impacts	Very small	<input type="checkbox"/>	Small	<input checked="" type="checkbox"/>	Medium	<input type="checkbox"/>	Large	<input type="checkbox"/>	Very large	<input type="checkbox"/>
Confidence	High Confidence	<input type="checkbox"/>	Medium Confidence	<input type="checkbox"/>	Low Confidence	<input checked="" type="checkbox"/>				

14. What is the pest’s potential as a vector of plant pathogens?

As above, the ambrosia beetle PSHB introduces *F. euwallaceae* and *G. euwallaceae* deliberately into its larval galleries as a food source, and these fungi are also plant pathogenic. PSHB may be associated with other, yet unidentified, mutualistic fungi. Failed attacks can also lead to infestation by secondary fungal pathogens.

15. What is the area endangered by the pest?

The south of England is likely to be more suitable for the pest to establish and cause economic damage. In particular, oaks and amenity trees in urban areas such as plane are at greater risk.

Within the EU, those countries with more Mediterranean climates similar to those found in California and Israel and significantly more at risk should the pest be introduced than the UK, as the more suitable climate could lead to high pest numbers and significant impacts.

STAGE 3: PEST RISK MANAGEMENT

16. What are the risk management options for the UK/PRA area?

Exclusion

PSHB is a very small (<2 mm) cryptic species and as such exclusion could prove difficult, but would be the best risk management option for the UK. Southern Member States, where climates are similar to where the pest is currently damaging and crop hosts such as avocado

are grown, are at greater risk than the UK, and, as a consequence, listing in Annex IAI of the EC Plant Health Directive should be considered. Because of the taxonomic uncertainty surrounding this pest the listing could be extended to non-European species of *Euwallacea* spp. or alternatively, the current IAI listing for Scolytidae (non-European) on wood and plants of conifers could be extended to broadleaved trees, which would increase protection from other invasive ambrosia beetles. However, listing of the pest in EU legislation would not by itself reduce the risk of its entry into the EU unless it is accompanied by measures to reduce the risks associated with relevant pathways. Such measures could include the need for plants for planting and timber of species that could host PSHB to originate from Pest Free Areas. This could be challenging given the significant number of plants or timber varieties that PSHB could be associated with. Further scrutiny of the implementation of ISPM 15, especially in Vietnam where the pest is thought to have been introduced to California and Israel from, and other parts of South East Asia where it may be present, would help to reduce the risks of this and other wood-boring pests being moved on wood packaging material.

Targeted surveys against produce (in particular avocados) from the pest's current distribution could be considered to help establish the threat posed by hitchhiking, but the pest is likely to be very difficult to detect at entry.

Eradication, control and containment

The cryptic nature of the pest and its extensive host range means that eradication in the event of an outbreak would be difficult to achieve. Trials are still being carried out in California and Israel to establish effective chemical control, as well as possible biological control options (Drill 2014), but use of pesticides in the wider environment is unlikely to be feasible.

Destruction of heavily infested trees would help reduce local populations of PSHB and the spread of the pest. In California it is currently recommended that wood from infested trees is chipped (pieces should be no larger than one inch) and covered with a tarpaulin for several months to help kill the pest and prevent its spread (Eskalen 2014). Similar precautions would need to be taken in the UK, as movement of infested timber or wood waste for disposal creates a pathway of spread for the pest.

17. Summary and conclusions of the rapid PRA.

This rapid PRA shows that PSHB is a serious pest of deciduous trees where it has been introduced, and impacts are likely to increase as the pest continues to spread. The situation is rapidly changing, with further information about this pest being regularly published, meaning continued monitoring of the situation is required.

Risk of entry

Entry is unlikely on wood and bark (this category including woodchips, squared and unsquared wood), and hitchhiking and moderately likely on wood packaging material and plants for planting.

Risk of establishment

Establishment is unlikely, with low confidence. Several widely planted species in the UK including English oak and plane are preferred and highly successful reproductive hosts of PSHB. Climate may limit establishment, but no specific data on the temperature requirements for development of PSHB are available.

Economic, environmental and social impact

PSHB causes large impacts in its current range. Potential impacts in the UK are rated as small with low confidence, as it is not sure how damaging PSHB would be in the cooler climatic conditions of the UK. Even if PSHB has a slower development time in the UK, with

perhaps only one or two generations per year, successful growth of *F. euwallaceae* within woody hosts could still lead to decline or mortality of trees. .

Endangered area

Oak trees in the south of England and urban amenity trees are likely to be most at risk. The southern EU member states are significantly more at risk.

Risk management options

Exclusion, through legislation, is the best risk management option. The polyphagous nature of the pest and the lack of available control products would mean eradication is unlikely to be successful if establishment occurred.

Key uncertainties and topics that would benefit from further investigation

The key uncertainties around the pest are concerned with its taxonomy, full distribution and the temperature development requirements for both the beetle and its fungus. Though the current distribution indicates that the climate in the UK will be unsuitable for the pest, other Asian ambrosia beetles have shown massive expansions in range as invasive species and, without data on the temperature requirements for this pest, potential establishment and impacts are highly uncertain. Monitoring the spread of the pest northwards in California into regions with cooler summers should provide more information on the possible impacts of the pest in Europe.

18. Is there a need for a detailed PRA or for more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EU) and the PRA scheme (UK or EPPO) to be used.

No	<input checked="" type="checkbox"/>
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Yes	<input type="checkbox"/>	PRA area: UK or EU	<input type="text"/>	PRA scheme: UK or EPPO	<input type="text"/>
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19. IMAGES OF THE PEST

 <p>Photo by G. Arakelian</p>	
<p>Adult female PSHB. Photo credit: G. Arakelian</p>	<p>'Sugaring' response on avocado in response to PSHB infestation. Photo credit: T. W. Coleman.</p>

20. Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

Yes
Statutory action

No
Statutory action

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ANNEX 1: EUROSTAT IMPORT DATA

Table 3. Import data of plants for planting of potential PSHB hosts (data will include non-host species) into the UK and EU (values include the UK data) from Israel, USA and Vietnam (i.e. countries where PSHB is known to occur at least in parts). Commodity codes were chosen for their likelihood of containing largely woody hosts which PSHB attacks. "Live forest trees" may include conifers, which are not hosts of PSHB, however many genera of conifer are prohibited from outside of Europe. Data extracted from Eurostat 12.05.2015

Commodity	Exporter	Importer	Year	Volume (100kg)
TREES, SHRUBS AND BUSHES, GRAFTED OR NOT, OF KINDS WHICH BEAR EDIBLE FRUIT OR NUTS (EXCL. VINE SLIPS)	Israel	UK	2012	-
			2013	
			2014	
		EU	2012	6
			2013	151
			2014	44
	USA	UK	2012	-
			2013	43
			2014	-
		EU	2012	668
			2013	632
			2014	1055
	Vietnam	UK	2012	-
			2013	
			2014	
EU		2012	-	
		2013		
		2014		
LIVE FOREST TREES	Israel	UK	2012	-
			2013	
			2014	
		EU	2012	
			2013	
			2014	
	USA	UK	2012	-
			2013	-
			2014	5

Commodity	Exporter	Importer	Year	Volume (100kg)
		EU	2012	1
			2013	-
			2014	5
	Vietnam	UK	2012	-
			2013	
			2014	
		EU	2012	
			2013	
			2014	

Commodity	Exporter	Importer	Year	Volume (100kg)
OUTDOOR TREES, SHRUBS AND BUSHES, INCL. THEIR ROOTS (EXCL. CUTTINGS, SLIPS AND YOUNG PLANTS, AND FRUIT, NUT AND FOREST TREES)	Israel	UK	2012	-
			2013	
			2014	
		EU	2012	7853
			2013	4666
			2014	3688
	USA	UK	2012	160
			2013	-
			2014	
		EU	2012	
			2013	593
			2014	620
	Vietnam	UK	2012	-
			2013	
			2014	
EU		2012		
		2013		
		2014		
OUTDOOR ROOTED CUTTINGS AND YOUNG PLANTS OF TREES, SHRUBS AND BUSHES (EXCL. FRUIT, NUT AND FOREST TREES)	Israel	UK	2012	80
			2013	8
			2014	12
		EU	2012	181
			2013	427
			2014	738
	USA	UK	2012	262
			2013	385
			2014	125
		EU	2012	304
			2013	535
			2014	326
	Vietnam	UK	2012	-
			2013	
			2014	
		EU	2012	81
			2013	-
			2014	3

Table 4. Import data for *Quercus* (oak) timber originating from the **USA** into the UK and EU (including UK data) from 2012-2014. There was no import of *Quercus* from Israel or Vietnam in this time period. Only a very small amount of the *Quercus* imported, if any, would originate from the range of PSHB in California – the exact proportion is unknown. Data extracted 12.05.2015.

Commodity	Importer	Year	Quantity (100kg)
SAWLOGS OF OAK "QUERCUS SPP.", WHETHER OR NOT STRIPPED OF BARK OR SAPWOOD, OR ROUGHLY SQUARED	UK	2012	-
		2013	
		2014	
	EU	2012	18568
		2013	16735
		2014	21127
OAK "QUERCUS SPP." IN THE ROUGH, WHETHER OR NOT STRIPPED OF BARK OR SAPWOOD, OR ROUGHLY SQUARED (EXCL. SAWLOGS; ROUGH-CUT WOOD FOR WALKING STICKS, UMBRELLAS, TOOL SHAFTS AND THE LIKE; WOOD IN THE FORM OF RAILWAY SLEEPERS; WOOD CUT INTO BOARDS OR BEAMS, ETC.; WOOD TREATED WITH PAINT, STAINS, CREOSOTE OR OTHER PRESERVATIVES)	UK	2012	17354
		2013	8988
		2014	663
	EU	2012	121331
		2013	114057
		2014	103701

Table 5. Import data for *Eucalyptus* timber into the **EU** for the period 2012-2014. There was no import directly into the UK, nor import from Israel into any part of the EU, in this time period. The *Eucalyptus* imported from the USA may not crossover with the range of PSHB in California. Data extracted 12.05.2015.

Commodity	Exporter	Year	Quantity (100kg)
EUCALYPTUS WOOD IN THE ROUGH, WHETHER OR NOT STRIPPED OF BARK OR SAPWOOD, OR ROUGHLY SQUARED (EXCL. ROUGH-CUT WOOD FOR WALKING STICKS, UMBRELLAS, TOOL SHAFTS AND THE LIKE; WOOD CUT INTO BOARDS OR BEAMS, ETC.; WOOD TREATED WITH PAINT, STAINS, CREOSOTE OR OTHER PRESERVATIVES)	USA	2012	119
		2013	186
		2014	-
	Vietnam	2012	74
		2013	-
		2014	-

Table 6. Import of fuel wood and wood chips from the range of PSHB – including non-host species. Only a small fraction of imports from the USA will originate from the range of the pest. Data extracted 12.05.2015.

Commodity	Exporter	Importer	Year	Volume (100kg)	
FUEL WOOD, IN LOGS, BILLETS, TWIGS, FAGGOTS OR SIMILAR FORMS	Israel	UK	2012	-	
			2013		
			2014		
		EU	2012		240
			2013		-
			2014		
	USA	UK	2012	268	
			2013	716	
			2014	36	
		EU	2012	702	
			2013	1624	
			2014	630	
	Vietnam	UK	2012	216	
			2013	-	
			2014		
EU		2012	12712		
		2013	200		
		2014	223		
WOOD IN CHIPS OR PARTICLES (EXCL. THOSE OF A KIND USED PRINCIPALLY FOR DYING OR TANNING PURPOSES, AND CONIFEROUS WOOD)	Israel	UK	2012	-	
			2013		
			2014		
		EU	2012		-
			2013		
			2014		
	USA	UK	2012	757	
			2013	1687	
			2014	1278	
		EU	2012	7441	
			2013	11514	
			2014	207900	
	Vietnam	UK	2012	-	
			2013		
			2014		
EU		2012	-		
		2013	15		
		2014	1033		