Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Dendroctonus valens

March 2021

Summary and conclusions of the rapid PRA

This rapid PRA shows:

Dendroctonus valens is a bark beetle from the subfamily Scolytinae, which is native to North America. Its recorded hosts include a wide variety of *Pinus* species (pine trees), with occasional reports on other conifers. Adults and larvae construct galleries in the lower bole (below about 2.5 m) and into the roots. In its native range it is a secondary pest on dead or already declining trees. However, it is an invasive pest in parts of China where it has been causing very high impacts, potentially linked to severe drought in the worst affected region. The beetle also vectors a number of plant pathogenic fungi, though it does not appear to have an obligate association with any of them. Definitive data on spread capacity are lacking, but some specimens of *D. valens* appear to be capable of flying at least 10-20 km.

Risk of entry

The riskiest pathways were all considered to be based around wood of its host trees, as *D. valens* is mostly associated with older, larger trees. Entry in wood with bark, isolated bark, wood packaging material and woodchips were all considered to be **moderately likely**. This was with **medium confidence** for **wood with bark** and **wood packaging material**, but **low confidence** for **isolated bark** and **woodchips**, as data on volumes, end use, etc. were not readily available for these commodities.

All other pathways considered (**wood without bark**, **plants for planting**, **cut branches**) were assessed as **very unlikely** with **high confidence** as there was considered to be little likelihood of association of *D. valens* with the commodity and/or the trade is prohibited.

Risk of establishment

Establishment outdoors was considered **very likely** with **high confidence**. *Dendroctonus valens* is present in much of North America, including in regions which are climatically very similar to the UK. *Pinus* trees are grown very widely, including species which are confirmed hosts of *D. valens*.

Establishment under protected conditions was considered **very unlikely** with **high confidence**. With the exception of some specialist bonsai growers, suitable hosts are not grown in such conditions, and available information suggests that *D. valens* prefers older, larger, trees.

Economic, environmental and social impact

In the native range of North America, *D. valens* is seldom regarded as a damaging pest, and any reports of serious damage on apparently healthy trees appear to be exceptional. Impacts in **North America** are considered to be **very small** with **high confidence**. In the invasive range in China, large areas of apparently healthy trees have been killed by *D. valens*. However, there may have been precipitating factors, notably a severe drought over several years, which allowed *D. valens* to attack the stressed trees. Impacts in **China** were assessed as **large**, but with **medium confidence** as the factors behind the different impacts in North America and China are not fully understood.

The assessment of **potential impacts in the UK** were all made with **low confidence** due to the uncertainty of whether *D. valens* would behave as a secondary pest, as it does in North America, or a primary pest capable of killing trees, as it does in China. The impact of future climate change in the UK is uncertain, too, but it is possible that trees will become more stressed from wetter winters and hotter summers which are predicted to become more common in future. Trees under greater stress will be more susceptible to attack by the beetles. **Potential economic** and **environmental impacts** were considered to be **medium**, as *D. valens* is known to attack species such as *P. sylvestris* and *P. contorta*, which commonly grown in the UK and which are of economic and environmental importance. **Potential social impacts** were assessed as small, as *Pinus* are less commonly grown in cities etc. and many recreational woodlands are mixed species. However, if a single species plantation were to be badly affected by *D. valens*, the local social impact could be a lot higher.

Endangered area

This is uncertain. If impacts in the UK were similar to those in North America, no part of the UK is likely to be endangered as *D. valens* is likely to be a secondary pest. However, if impacts were similar to those in China, most of the UK could be endangered as suitable hosts are grown across the country and the beetle has adapted to a wide range of climates in its native range.

Risk management options

Due to the uncertainties over potential impacts in the UK, continued exclusion is considered to be the best option. While most pathways have existing mitigations in place in the legislation, consideration could be given to increasing measures on the pathway of ornamental wood products with bark.

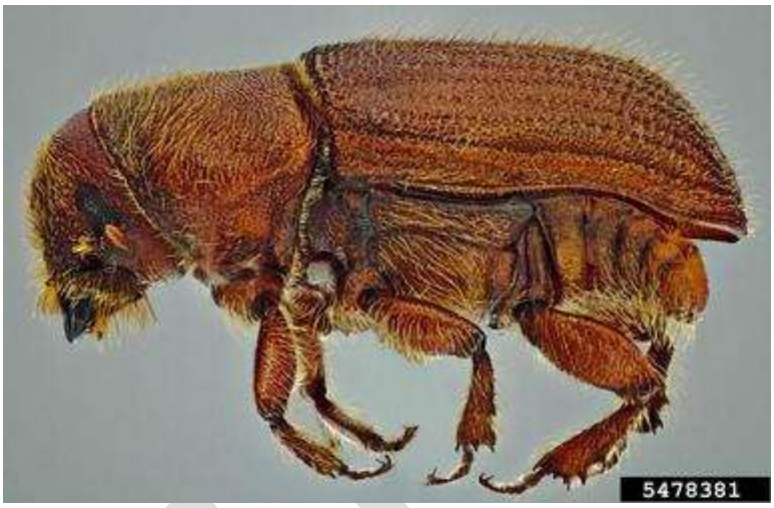
Due to its cryptic lifestyle and superficial similarity to bark beetles already present in the UK, it might be some time before an outbreak of *D. valens* were detected. This would mean that it could potentially have spread undetected, and eradication would be more difficult. Controlling the movement of host timber out of the affected area, felling of affected trees and, given the potential dispersal capacity, the use trap trees to attract adults to stay within the local area could all be considered.

As this is a quarantine pest not known to be present in the PRA area, non statutory controls are not appropriate for pest management. In the native range, improving general tree health is considered to be the best way of mitigating the impacts of *D. valens*.

Key uncertainties and topics that would benefit from further investigation

- An understanding of the factors responsible for the high impacts on living trees in China, and why these are much greater than the impacts seen in the native range of North America
- Whether populations from Central America are a distinct species incorrectly synonymised with *D. valens*
- More data about the trade in woodchips, the composition, and their storage

Images of the pest

	
Externally visible damage caused by *D. valens* infestation. © Bob Oakes, USDA Forest Service, Bugwood.org	Adult *D. valens*, which is between 6 and 10 mm long. © Steven Valley, Oregon Department of Agriculture, Bugwood.org

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

No					
Yes	✓	PRA area: UK or EPPO	EPPO	PRA scheme: UK or EPPO	EPPO

Given the many uncertainties remaining, a more detailed PRA is recommended to try and determine some of the factors behind the differing levels of impacts in North America and China. This seems most likely to be achieved through direct contact with researchers and/or foresters in China and possibly North America who have experience of *D. valens*. This pest is not present in the EPPO region, is found in a wide range of climatic types in its current range, and suitable and potentially suitable hosts are present throughout the region. Therefore, a PRA at the regional rather than national level would appear to be proportionate.

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

Yes Statutory action ☑ No Statutory action ☐

Due to the listing of “non-European Scolytidae spp.” in the plant health legislation, statutory action is already required against all findings of *D. valens* as it is a non-European species. Even if the legislation were to be altered in future, statutory action against *D. valens* is considered proportionate based on current information, due to the high level of impacts in China, albeit during a severe drought. If new information were to be received in future indicating potential impacts in the UK are likely to be more similar to those seen in North America, this PRA would require review. As part of that review, the decision on the appropriate level of action would be considered in light of the new information and updated PRA.

Stage 1: Initiation

1. What is the name of the pest?

Dendroctonus valens LeConte (Coleoptera: Curculionidae: Scolytinae).

Common name: red turpentine beetle. This name is due to the adults, which are reddish in colour and attracted to the odour of turpentine (Owen *et al.*, 2010).

Synonym: *Dendroctonus beckeri* Thatcher

The genus has undergone much revision but it is currently considered to contain 20 species, 18 in the Americas (predominantly North American) and two species native to Eurasia (Armendáriz-Toledano & Zúñiga, 2017a).

Notes on the inclusion of *Dendroctonus beckeri* in the coverage of this PRA

Dendroctonus beckeri is considered to be a synonym of *D. valens* (Wood, 1963). *Dendroctonus beckeri* was originally described from material collected in Guatemala (Thatcher, 1954; Perry, 1955) and was later synonymised with *D. valens* based on morphology. Recent molecular studies suggest that *D. beckeri* may be a distinct species occurring in Central America, whilst *D. valens* is native to North America (Cai *et al.*, 2008). There are small but consistent morphological differences (also noted by Wood, 1963), and molecular data indicates significant genetic differences between populations (Cai *et al.*, 2008; Armendáriz-Toledano & Zúñiga, 2017b).

Further work is required to confirm whether *D. beckeri* is a separate species from *D. valens* or if the synonymy is correct. As no formal taxonomic separation of *D. beckeri* and *D. valens* has been published at the time of writing this PRA, *D. beckeri* will be considered to be included under *D. valens* throughout this document. However, due to the taxonomic uncertainty, records will be separated by origin (where practical to do so).

Notes on the exclusion of *Dendroctonus rhizophagus* from this PRA

Many sources, such as CABI (2017), state that the endemic Mexican species *Dendroctonus rhizophagus* Thomas & Bright is a synonym of *D. valens*. However, though very similar morphologically, there are differences which allow the two species to be separated (Wood, 1982). There is also molecular evidence for the two species being separate (Cai *et al.*, 2011; Armendáriz-Toledano *et al.*, 2012). Therefore, this PRA on *D. valens* does not include records attributed to *D. rhizophagus* as the latter is considered to be a legitimate species.

2. What initiated this rapid PRA?

Dendroctonus valens was added to the UK Plant Health Risk Register[1] in April 2015 after it was identified by horizon scanning activities as a serious invasive pest in China causing damage to *Pinus* (pine) species. The rapid screening through the Risk Register suggested this beetle posed a high risk to the UK, and this PRA was commissioned to further assess the risk of the pest and decide if additional phytosanitary measures are justified.

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 plant health legislation, and in the lists of EPPO[2]?

This PRA was written during the transition period following the UK's departure from the EU. Therefore, the legislation which applied at the time of writing was the EU legislation 2019/2072[3], which will continue to apply to Northern Ireland. The post-transition legislation for Great Britain (The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020[4]) will not vary for *D. valens*.

Dendroctonus valens is not specifically included in the listing of pests in 2019/2072, but as it is a scolytine beetle it is included in Annex IIA (Union quarantine pests not known to occur in the Union territory) under the category of "Scolytidae spp. (non-European)". This beetle was added to the EPPO Alert list in 2019.

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

Native to North America, *D. valens* is also an invasive pest in China.

In North America, *D. valens* has been recorded from across Canada, from British Colombia in the west to Nova Scotia in the east, and as far north as Fort Smith (around 60°N) (Wood, 1982). In the USA, *D. valens* has been recorded from most of the country

[1] https://secure.fera.defra.gov.uk/phiw/riskRegister/
[2] https://www.eppo.int/ACTIVITIES/quarantine_activities
[3] http://data.europa.eu/eli/reg_impl/2019/2072/oj
[4] https://www.legislation.gov.uk/uksi/2020/1527/contents/made

other than some central states and parts of the south-east. There are also records of *D. valens* from Mexico (Cai *et al.*, 2008).

Table 1: Distribution of *Dendroctonus valens*

Continent	Country
North America:	**Canada**: Alberta, British Colombia, New Brunswick, Newfoundland, Northwest Territories, Nova Scotia, Manitoba, Ontario, Quebec (Bousquet, 1991) and Saskatchewan (CABI & EPPO, 2017). **Mexico**: Molecular analysis: specimens grouping with US populations were sampled from: Chihuahua, Distrito Federal, Michoacán and Nuevo León (Cai *et al.*, 2008). Molecular analysis: specimens grouping with Guatemalan specimens were sampled from Chiapas and Durango (Cai *et al.*, 2008). Other Mexican records (where molecular analysis has not been carried out) are from: Aguascalientes, Baja California, Coahuila, Colima, Guerrero, Hidalgo, Jalisco, México, Morelos, Oaxaca, Puebla, Querétaro, San Luis Potosí, Sinaloa, Sonora, Tamaulipas, Tlaxcala, Veracruz and Zacatecas (Atkinson, 2018). **USA**: Arizona, California, Colorado, Connecticut, Delaware, Georgia, Idaho, Illinois, Indiana, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin and Wyoming (Atkinson, 2018).
Central America:	Molecular analysis suggests that at least the Guatemalan and Honduran records (along with some Mexican specimens) form a distinct group separated from more northern populations (Cai *et al.*, 2008; Armendáriz-Toledano & Zúñiga, 2017b). Molecular analysis of other Central American records has not apparently taken place. **Belize** (Armendáriz-Toledano & Zúñiga, 2017b). **Guatemala** (Thatcher, 1954; Perry, 1955; Wood, 1982; Cai *et al.*, 2008). **Honduras** (Wood, 1982). **Nicaragua** (Armendáriz-Toledano & Zúñiga, 2017b).
South America:	No records
Europe:	No records
Africa:	No records
Asia:	**China**: Beijing (Pan *et al.*, 2010), Hebei, Henan (Sun *et al.*, 2004), Inner Mongolia (Liu *et al.*, 2011), Shaanxi and Shanxi (Sun *et al.*, 2004).
Oceania:	No records

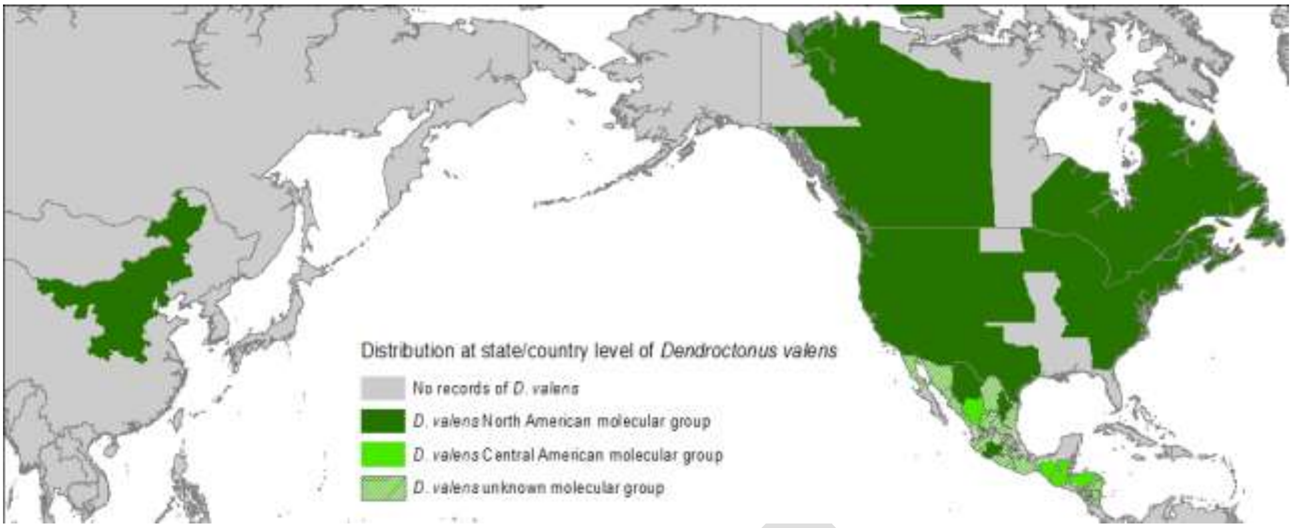


Figure 1. Pacific-centred distribution map of *D. valens* at a state or county level (data sources are the same as Table 1).

In China *D. valens* is thought to have been introduced into Shanxi in the early 1980s, with the first outbreaks reported in 1999 (Yan *et al.*, 2005). Since then, it has spread and now infests several provinces in northern China. Overviews of the Chinese situation are provided by many authors, such as Sun *et al.* (2004); Liu *et al.* (2014).

Some Mexican records and those from Guatemala (and perhaps elsewhere in Central America) have genetic differences compared to *D. valens* from the rest of North America. It is unclear if Central American specimens are the same species as those from further north (see Question 1, notes on the inclusion of *D. beckeri*).

Though records from south-east USA do exist, they are not necessarily reliable: for example the record for Florida is regarded as either an interception or requiring the identification to be checked (Atkinson, 2018). A record for Louisiana in CABI and EPPO (2017) requires further confirmation: the cited reference states specimens of *D. valens* were trapped in Wisconsin, but not in Louisiana (Erbilgin *et al.*, 2001). *Dendroctonus valens* has not been recorded from some states where it may be present, for example Oklahoma, though it has recently been found for the first time in Texas (Atkinson & Riley, 2013).

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

Dendroctonus valens is not established in any part of the UK and no transient populations have been recorded. A single interception was recorded in England and Wales in 2005, on *Pinus* wood originating in China. The specimen was found on 'pet wood': a structure made out of coniferous wood with bark attached, imported for use in pet rodent cages (Defra, unpublished data). It is assumed to have been an adult, but no further details are available (e.g. live, dead). There is no suggestion that this pest had reached the wider environment.

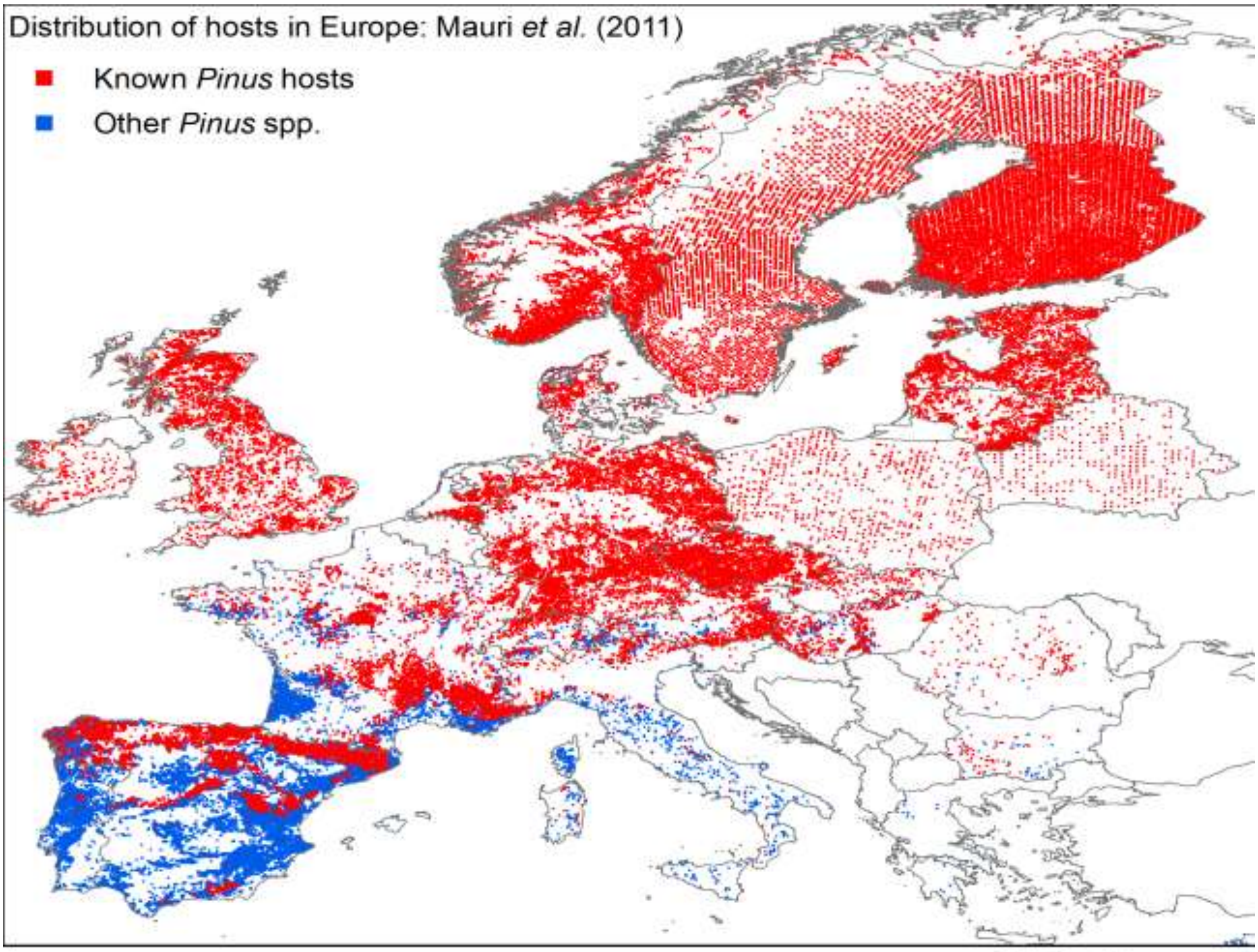
Elsewhere in Europe, no reports of outbreaks or interceptions identified as *D. valens* are recorded on EUROPHYT (database searched July 2020).

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?

Most recorded hosts are *Pinus* species, though occasional records on other conifer genera do exist. A list of all *Pinus* species listed as hosts of *D. valens* found in the literature is provided in Table 2. Several sources state that *D. valens* is likely to feed on any species of *Pinus*, and if this is indeed the case, then the list below may well increase, especially if *D. valens* expands its range in China and encounters new Asian *Pinus* species as it spreads. As can be seen from Table 2, *Pinus* from both subgenera and across the lower taxonomic divisions are recorded as hosts. No data could be found on *Pinus* species which were not suitable hosts for *D. valens*. It is unclear if all listed hosts allow development to take place, or if any are only suitable for adult feeding and are not reproductive hosts.

Of the hosts listed in Table 2, *Pinus sylvestris* (Scots pine) is a widely planted native species in the UK which is in the same phylogenetic clade as *P. tabuliformis* (Gernandt *et al.*, 2005), on which *D. valens* has had high impacts in China. *Pinus sylvestris* is very important both as an economic forestry species and as a key component of native pine woodland, including vulnerable habitats such as the ancient Caledonian pine forest in Highland Scotland. It is also planted quite commonly as an amenity tree in parks, etc. *Pinus sylvestris* is the only species which has been recorded as a host both in North America (e.g. (Wood, 1963; Atkinson, 2018)) and in China where there is a record of *D. valens* on *P. sylvestris* var. *mongholica* (Yan *et al.*, 2005). Other *Pinus* known to be hosts of *D. valens* which are commonly planted in the UK are *P. contorta* (lodgepole pine), *P. radiata* (Monterey pine), *P. ponderosa* (ponderosa pine) and *P. strobus* (Weymouth pine or white pine). Figures for Northern Ireland are not available, but Forestry Commission (2017) statistics show that Great Britain has a total area of 218,000 ha of *P. sylvestris* and 100,000 ha of *P. contorta*. *Pinus nigra* (Corsican pine) has not been recorded as a host of *D. valens* to date, though it seems likely that it would be suitable, and this host is grown on around 46,000 ha in Great Britain.

Figure 2 (next page). *Pinus* spp. distribution in Europe. Red are recorded hosts of *D. valens*, blue are other *Pinus* spp. which are potential hosts. The data provided by Mauri *et al.* (2017) (top map) are based on over half a million species-level records and are at a resolution of 1 x 1 km. The classification of source data differs across national boundaries, e.g. compare Norway and Sweden. Known hosts are: *Pinus contorta, P. ponderosa, P. radiata, P. strobus* and *P. sylvestris*. Others are based on: *P. banksia, P. brutia, P. canariensis, P. cembra, P. halpensis, P. heldreichii, P. mugo, P. nigra, P. pinaster, P. pinea* and *P. wallichiana*. The data provided by Köble and Seufert (2001) (bottom map) are based on the percentage of each tree species in the forest using a 1 x 1 km grid and interpolation. Known hosts are: *P. contorta, P. radiata, P. strobus* and *P. sylvestris*. Others are: *P. brutia, P. canariensis, P. cembra, P. halpensis, P. leucodermis, P. nigra, P. pinaster, P. pinea* and *P. uncinata*.


Distribution of hosts in Europe: Mauri et al. (2011)
Known Pinus hosts
Other Pinus spp.

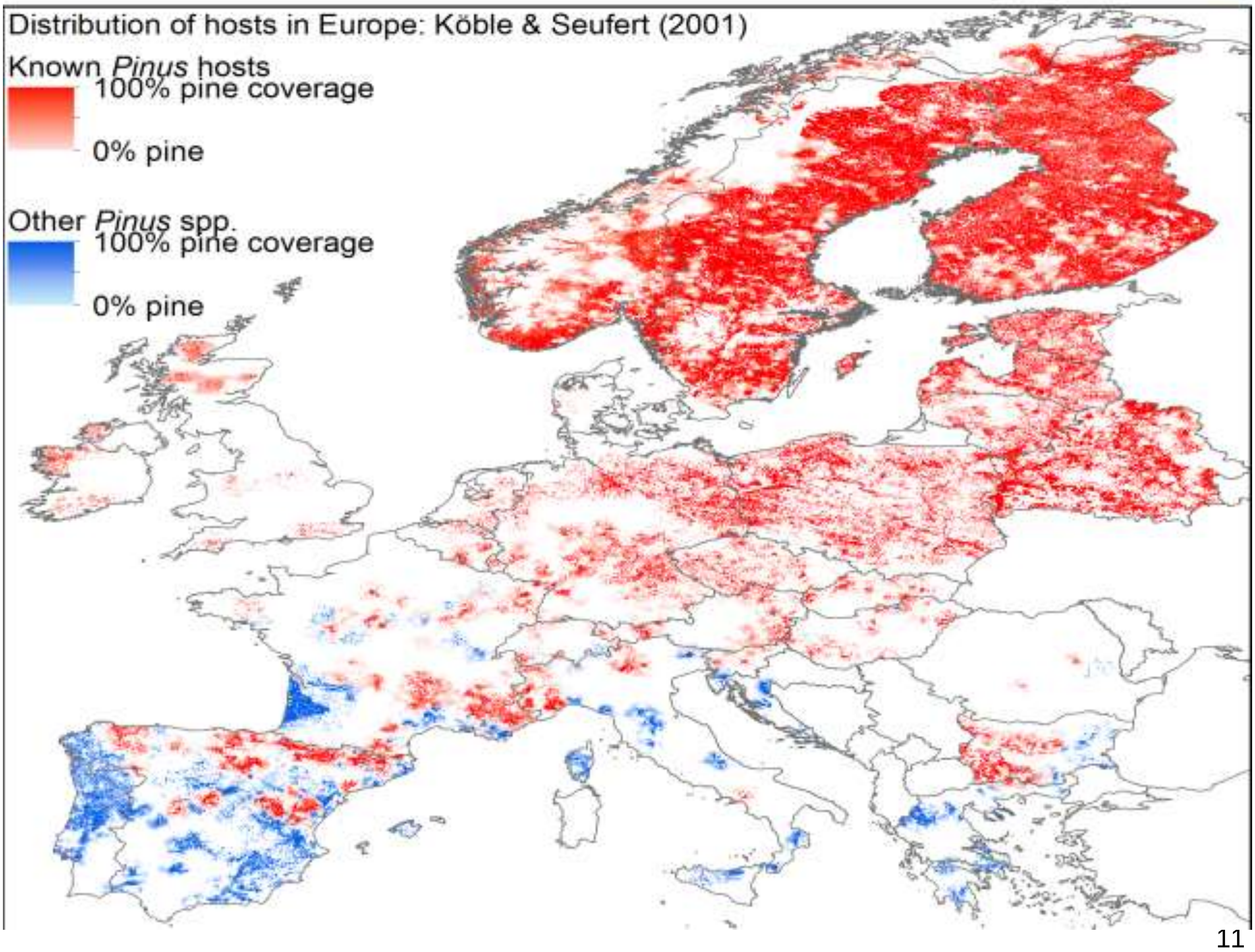

Distribution of hosts in Europe: Köble & Seufert (2001)
Known Pinus hosts
100% pine coverage
0% pine
Other Pinus spp.
100% pine coverage
0% pine

Table 2. *Pinus* host records of *D. valens*, including subgeneric classification. Also indications of geographic region each host has been recorded from, and an indication of how widely each is planted in the UK. Only species names recognised as valid in the Plant List (version 1.1)[5] are included; taxonomic rank below species (subspecies, varieties, etc.) are not included separately. Table sorted by subgenus, section, subsection then species.

Pinus species	Further classification (Gernandt *et al.*, 2005)			North America	China	UK distribution (Source: BSBI[6])	Key reference(s) for host association
	Sub-genus	Section	Sub-section				
P. resinosa	*Pinus*	*Pinus*	*Pinus*	✓		No data	Atkinson (2018)
P. sylvestris	*Pinus*	*Pinus*	*Pinus*	✓	✓	Extremely common over whole UK	Wood (1963); Yan *et al.* (2005)
P. tabuliformis	*Pinus*	*Pinus*	*Pinus*		✓	No data	Yan *et al.* (2005)
P. echinata	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Atkinson (2018)
P. greggii	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Salinas-Moreno *et al.* (2004)
P. herrerae	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Salinas-Moreno *et al.* (2004)
P. lawsonii	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Atkinson (2018)
P. leiophylla	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Salinas-Moreno *et al.* (2004)
P. lumholtzii	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Salinas-Moreno *et al.* (2004)
P. oocarpa	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Salinas-Moreno *et al.* (2004)
P. patula	*Pinus*	*Trifoliae*	*Australes*	✓		Several records in south England	Salinas-Moreno *et al.* (2004)
P. pringlei	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Salinas-Moreno *et al.* (2004)
P. radiata	*Pinus*	*Trifoliae*	*Australes*	✓		Scattered records across the UK, most common in south	Atkinson (2018)
P. rigida	*Pinus*	*Trifoliae*	*Australes*	✓		Very few records	Atkinson (2018)
P. teocote	*Pinus*	*Trifoliae*	*Australes*	✓		No data	Salinas-Moreno *et al.* (2004)
P. contorta	*Pinus*	*Trifoliae*	*Contortae*	✓		Very common over most of the UK	Atkinson (2018)
P. virginiana	*Pinus*	*Trifoliae*	*Contortae*	✓		No data	Atkinson (2018)
P. arizonica	*Pinus* (assumed)	*Trifoliae* (assumed)	*Ponderosae* (assumed)	✓		No data	Salinas-Moreno *et al.* (2004)

[5] http://www.theplantlist.org/ (accessed 16 July 2018)
[6] http://bsbi.org/maps (accessed 16 July 2018)

Pinus species	Further classification (Gernandt *et al.*, 2005)			North America	China	UK distribution (Source: BSBI[6])	Key reference(s) for host association
	Sub-genus	Section	Sub-section				
P. coulteri	*Pinus*	*Trifoliae*	*Ponderosae*	✓		Very few records	Atkinson (2018)
P. devoniana	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Salinas-Moreno *et al.* (2004)
P. douglasiana	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Armendáriz-Toledano and Zúñiga (2017b)
P. durangensis	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Salinas-Moreno *et al.* (2004)
P. engelmannii	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Salinas-Moreno *et al.* (2004)
P. hartwegii	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Salinas-Moreno *et al.* (2004)
P. jeffreyi	*Pinus*	*Trifoliae*	*Ponderosae*	✓		Very few records	Salinas-Moreno *et al.* (2004)
P. maximinoi	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Atkinson (2018)
P. montezumae	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Salinas-Moreno *et al.* (2004)
P. ponderosa	*Pinus*	*Trifoliae*	*Ponderosae*	✓		Scattered records across the UK	Salinas-Moreno *et al.* (2004)
P. pseudostrobus	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Salinas-Moreno *et al.* (2004); Atkinson (2018)
P. sabiniana	*Pinus*	*Trifoliae*	*Ponderosae*	✓		No data	Atkinson (2018)
P. cembroides	*Strobus*	*Parrya*	*Cembroides*	✓		No data	Salinas-Moreno *et al.* (2004)
P. edulis	*Strobus*	*Parrya*	*Cembroides*	✓		No data	Atkinson (2018)
P. monophylla	*Strobus*	*Parrya*	*Cembroides*	✓		Very few records	Atkinson (2018)
P. quadriflolia	*Strobus*	*Parrya*	*Cembroides*	✓		No data	Atkinson (2018)
P. bungeana	*Strobus*	*Quinquefoliae*	*Gerardianae*		✓	Very few records	Yan *et al.* (2005), Wang *et al.* (2007)
P. armandii	*Strobus*	*Quinquefoliae*	*Strobus*		✓	No data	Yan *et al.* (2005)
P. ayacahuite	*Strobus*	*Quinquefoliae*	*Strobus*	✓		No data	Salinas-Moreno *et al.* (2004)
P. flexilis	*Strobus*	*Quinquefoliae*	*Strobus*	✓		Very few records	Atkinson (2018)
P. lambertiana	*Strobus*	*Quinquefoliae*	*Strobus*	✓		No data	Atkinson (2018)
P. monticola	*Strobus*	*Quinquefoliae*	*Strobus*	✓		No data	Atkinson (2018)
P. strobiformis	*Strobus* (assumed)	*Quinquefoliae* (assumed)	*Strobus* (assumed)	✓		No data	Atkinson (2018)
P. strobus	*Strobus*	*Quinquefoliae*	*Strobus*	✓		Scattered records across the UK	Armendáriz-Toledano and Zúñiga (2017b)

Occasional host records from other coniferous genera can be found in the literature. In North America, *D. valens* has been recorded from *Abies concolor, Larix laricina, Picea glauca, P. excelsa* and *P. rubens* (Atkinson, 2018), and in China from *Picea meyeri* (Yan *et al.*, 2005; Wang *et al.*, 2007). While these records demonstrate *D. valens* is capable of feeding on other conifers, these all seem to be minor hosts and attacks on non-*Pinus* genera appear to be the exception rather than the rule.

8. Summary of pest biology and/or lifecycle

Owen *et al.* (2010) provide a good general overview of *D. valens* from which the following information on the biology from the native range of North America is summarised. *Dendroctonus valens* is a bark beetle, tunnelling into the phloem layer in the inner bark to feed and develop. Adults are 6–10 mm long and can fly long distances. Once a female has located a suitable host tree, it tunnels into the bark to create an egg gallery, usually near ground level and which follows the grain of the wood. When populations are high, trees as small as “a few inches” in diameter may be attacked (Owen *et al.*, 2010), though usually only larger trees are used. The female releases a sex pheromone, which attracts a male, and it then lays multiple eggs in the egg gallery, which range from around 1–3 cm in width, and can be anything from 15–60 cm in length. One female can create multiple egg galleries, and lay several broods of eggs, though as each female is joined by a single male in the tunnels, it seems likely that larvae from different broods are full siblings. Tunnels can be started both above and below ground, and are usually noticeable due to the formation of “pitch tubes”: detritus in the form of resin from the tree mixed with beetle frass (see left hand photograph at the start of this PRA). On the tree bole, most tunnels are found below a height of around 2.5 m. While below-ground galleries are typically started at the root collar, subsequent attacks can extend far into the root system. Eggs hatch within a few weeks and larvae feed on the phloem, creating multiple fan-like tunnels as they tunnel away from the egg gallery. Larvae reach a maximum size of about 10 mm in length, and the rate of development is temperature-dependent. Larvae can develop for anything between “a few months to over a year” (Owen *et al.*, 2010), and the whole lifecycle can take place in less than a year to 1–2 years. Overlapping generations can occur. Some larvae overwinter, and so do adults, especially in parts of the distribution which have cold winters when young adults remain under the bark through winter, before emerging the next spring.

While many galleries can be present in one tree, *D. valens* does not usually have mass attacks on single trees in North America, which some of the more aggressive bark beetles exhibit. In North America, *D. valens* is mostly considered to attack trees which are already significantly stressed and/or dying, though an increase in local populations can lead to more attacks on apparently healthy trees (Randall, 2010).

In China, the lifecycle is reported to be quite similar, though root colonisation in China may be more frequent than in North America (Yan *et al.*, 2005). When population levels are low, healthy trees do not appear to be susceptible, at least to damaging levels of attack. Rather, newly felled trees, stumps or weakened trees are chosen by the beetles instead

(Zhang *et al.*, 2002), similar to the situation in North America. However, when populations are high, apparently healthy *P. tabuliformis* trees over 20 years old can be attacked and killed (Zhang *et al.*, 2002) and mass attacks are known to occur (Liu *et al.*, 2017). Female *D. valens* produce a sex pheromone which is attractive to other females (Liu *et al.*, 2013), but also other pheromones which are unattractive to other females of *D. valens*, even in very small quantities (Liu *et al.*, 2017). The story is clearly complex, and from the information currently available it is difficult to determine what exactly prompts the switch from unattractive to attractive signals, or if pheromones released at different times cause different responses.

9. 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?

As a pest which is largely associated with galleries in the bark of the bole and roots of larger *Pinus* spp. trees, the main pathways for entry to the UK are those of various types of wood and wood products.

This PRA was written during the transition period following the UK's departure from the EU. Therefore, the legislation which applied at the time of writing was the EU legislation 2019/2072, which will continue to apply in Northern Ireland. The post-transition legislation for Great Britain (The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020[7]) does not vary in listing for *D. valens* (as "Scolytidae spp. (non-European)"), nor in the measures outlined below. Details of placement in the equivalent GB Annexes are included in brackets after the EU Annex details.

Wood: legislation overview

The risk associated with the import of wood with or without bark is very different, and the two pathways are assessed separately below. However, much of the legislation applies to conifer wood, without specifying whether it includes bark or not. To prevent too much duplication, a summary of current legislation on conifer wood is included below, before individual wood pathways are discussed and rated separately. Legislation which applies to more processed wood, e.g. wood chips, is discussed individually under those pathways.

Under Regulation (EU) 2016/2031, wood is defined; the Plant Health (Amendment etc.) (EU Exit) Regulations 2020[8] does not alter these provisions. The original regulation should be consulted for the specifics, but a summary of "wood" is either that which has kept all or part of its natural round surface, with or without bark; or is without a round surface which has been produced by sawing, cutting or cleaving; or is in the form of wood chips, wood

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[7] https://www.legislation.gov.uk/uksi/2020/1527/contents/made
[8] https://www.legislation.gov.uk/uksi/2020/1482/contents/made

waste, etc., but has not undergone certain forms of processing; or wood intended for use in packaging.

In Commission Implementing Regulation (EU) 2019/2072, Annex VII [GB: Annex 7] contains details of measures which apply to coniferous wood from Canada, China, Mexico and the USA (and other countries outside the range of *D. valens*) where *Bursaphelenchus xylophilus* (pinewood nematode) is known to occur. The wood must have been treated by one of four methods, which are (i) heat and requirements regarding transport outside the flight season of the vector longhorn beetles, (ii) fumigation, (iii) chemical impregnation or (iv) heat treatment plus kiln drying. Coniferous wood from other countries in the range of *D. valens* must meet one of six options: (i) originate in an area free from various pests including “non-European Scolytidae spp.” (which includes *D. valens*), (ii) bark-free and free from grub-holes more than 3 mm across, (iii) kiln dried, (iv) fumigated, (v) chemically impregnated or (vi) heat treated.

Regarding option (ii), no data could be found on the size of exit holes of *D. valens*, but given the adult beetle is 6–10 mm long, it is possible that exit holes could be smaller than 3 mm. However, the beetles and larvae feed in the lower bark and do not burrow more deeply into the wood, and so the other part of this requirement (bark-free) would serve to mitigate the risk of *D. valens* being associated with such wood.

Under Annex III, the UK or parts of the UK, have Protected Zone (PZ) status for six bark beetle species [GB: Annex 2 contains the three species where the whole UK has a PZ (*Ips amitinus, I. duplicatus* and *I. typographus*); Annex 3 contains three species where part of the UK has a PZ (*Dendroctonus micans, Ips cembrae* and *I. sexdentatus*)]. The associated measures in Annex X [GB: Annex 7 for the three species absent from the whole UK] may help to reduce the likelihood of entry of *D. valens* to the UK (or parts of the UK), as it has a similar lifecycle to the targeted species. To be imported into the relevant PZ, conifer wood must meet one of three requirements: (i) stripped of bark, (ii) come from an area free from the specified bark beetle species or (iii) kiln dried. Of the six species, two have distributions in China which overlap with *D. valens*: 1. the whole of the UK has a PZ for *Ips duplicatus* (distribution overlaps with *D. valens* in the Chinese province of Inner Mongolia only (EPPO, 2018)) and 2. Northern Ireland and the Isle of Man have a PZ for *Ips sexdentatus* (distribution overlaps with *D. valens* in Shanxi and Shaanxi only (EPPO, 2018)).

The four remaining species do not have distributions which overlap with the current range of *D. valens*. 3. *Dendroctonus micans* (PZ for Northern Ireland, Isle of Man and Jersey) and 4. *Ips typographus* (PZ for the UK) are both present in limited parts of China, but they are not recorded from any of the same provinces as *D. valens* (EPPO, 2018). 5. *Ips amitinus* (PZ for the UK) and 6. *Ips cembrae* (PZ for Northern Ireland and the Isle of Man), have not been recorded from any country where *D. valens* is known to be present (EPPO, 2018).

EPPO (2020) examined the risk from bark and ambrosia beetles associated with non-coniferous wood. This study focussed on non-coniferous wood due to the fact that coniferous wood is already highly regulated while non-coniferous wood has fewer regulations. That said, the measures on non-coniferous wood recommended by EPPO (2020) would also appear to be proportionate for coniferous wood (at least until such time as a detailed assessment on coniferous wood might be made). EPPO recommended measures for mitigating the risks of introduction of bark and ambrosia beetles for round wood (with or without bark) or sawn wood. One of three treatments ((i) heat treatment, (ii) ionising radiation or (iii) fumigation) to be used in combination with storage and transport of the commodity in conditions to prevent infestation. Debarking of wood is recommended for a higher level of protection. The EPPO work also considered pest-free areas and concluded that this was not a suitable measure for taxonomic groupings higher than species (such as non-European Scolytinae). The recommendation was to assess pest free areas at a species level, and to make each assessment with regard to the individual species and its characteristics (EPPO, 2020).

Wood without bark

All life stages of *D. valens* are associated with bark, and not with deeper layers of wood. Therefore, the likelihood of association of this pest with wood which does not contain bark is considered to be low. There are mitigations which apply against the movement of bark beetles and other wood pests on conifer wood from all countries where *D. valens* is known to occur (see the earlier section on Wood: legislation overview). *Pinus* wood which has been sawn (and thus is unlikely to contain any bark) is imported from many countries where *D. valens* occurs in reasonable quantities, both to the UK and to the EU (Table 3).

Table 3. Import (tonnes) of *Pinus sylvestris* (2010–2016) or *Pinus* spp. wood (2017-2019) to the UK and rest of the EU from countries where *D. valens* is known to occur. The commodity codes used are for categories which are less likely to include bark and include “sawn or cut lengthwise, sliced or peeled, with a thickness of > 6 mm” in the commodity description (i.e. 44071033, 44071093, 44071110, 44071120 or 44071190). Origins from where no imports were recorded during this period are not included in the table. Source: Eurostat (data extracted 3 April 2020).

Destination	Origin	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
UK	Canada	614.5	441.3	211.8	135.6	139.8	85.1	121.7	3,844.9	3,106.3	2,029.3
	China	1,201.7	268.1	–	–	60.4	36.5	9.5	–	–	–
	Honduras	–	20.1	–	39.2	15.4	21.5	–	65.3	26.9	39.4
	USA	1,638.3	1,142.0	1,218.2	912.1	656.1	471.2	366.1	5,399.4	4,955.4	5,804.0
EU (not including UK)	Canada	99.7	56.1	22.3	47.7	10.4	153.9	238.2	5,803.4	2,408.7	2,266.5
	China	55.0	0.2	–	–	56.4	1.1	25.2	1,329.6	137.8	294.9
	Honduras	122.3	–	17.0	–	–	37.7	44.8	701.3	760.5	586.2
	USA	2,407.2	1,756.1	613.1	781.3	1,238.7	3,254.8	687.0	19,688.9	20,544.8	19,237.7

The Eurostat data is reliant on the correct declaration of customs codes and may not always be accurate. It is unclear if the large variations in some years, e.g. USA to UK 2012–2016, reflect true variation in import volume or problems with the source data.

Validated data from the Forestry Commission on the import of all spruce, pine and fir wood from Canada and the USA suggests there is likely to be an average import of around 23,000 m^3 in recent years, but historically most of this is spruce (*Picea* spp.), not pine. Data on pine imports is available from Liverpool docks for eastern white pine (*P. strobus*), though it is unclear if bark is associated with the consignments or not. The data on *P. strobus* show that 350 containers (a standard shipping container is 25 m^3) of *P. strobus* arrived in a 45 month period from 16 June 2017 to 26 February 2021, or an average of just under 200 m^3 per month for this period. (All data in this paragraph is via I. Brownlee, Forestry Commission, pers. comm. February-March 2021).

As there is considered to be a low likelihood of association of the pest, and there are requirements for treatment of coniferous wood from outside Europe which are designed to reduce the chances of entry of pests including bark beetles, overall entry on **wood without bark** is assessed as **very unlikely** with **high confidence**, though this confidence level is dependent on thorough removal of all bark.

Wood with bark

All life stages of *D. valens* are associated with tunnels in the inner bark (phloem layer) (Owen *et al.*, 2010): adults spend much of their lives in tunnels they chew in the bark, and eggs, larvae and pupae all develop inside the bark. Therefore, any *Pinus* wood product which contains bark may also contain *D. valens* at any life stage. The introduction to China is considered to have occurred with unprocessed logs from the western USA, used for mining construction (Yan *et al.*, 2005; Cai *et al.*, 2008). Adults are mobile and can fly long distances, and locating suitable new hosts in the wider environment is not considered to be limiting.

Data on imports of various categories of *Pinus* or coniferous wood which <u>may</u> contain bark are available from Eurostat (2018) and are summarised in Table 4. Some of the commodity codes changed in 2017, so data are not comparable across all years. For 2016 and earlier, there were two categories: 1) *P. sylvestris* wood in the rough and 2) *P. sylvestris* sawlogs. From 2017, there are three categories: 1) *Pinus* spp. sawlogs with a cross-section of ≥15 cm, 2) *Pinus* spp. wood in the rough with a cross-section of ≥15 cm which are not sawlogs and 3) *Pinus* spp. wood in the rough <15 cm in cross-section. Also in 2017, the category of fuel wood in logs, billets, faggots or similar forms was split into coniferous and non-coniferous. However, the data for coniferous fuel wood may not be accurate. Great Britain has a pre-notification scheme for firewood (with a similar scheme in Northern Ireland). All commercial importers of firewood must be registered and notify consignments to the Forestry Commission before they arrive in the country. Though Eurostat records some import of coniferous fuel wood to the UK in 2017 from countries with *D. valens* (data included in figures presented in Table 4), the Great Britain firewood pre-notification scheme does not have records of this commodity being imported from these countries. The consignments may have been wrongly categorised, and could possibly be other forms of fuel wood such as wood pellets (N. Mainprize, Forestry Commission England, personal communication August 2018). Data on pine imports are available from Liverpool docks for eastern white pine (*P. strobus*), though it is unclear if bark is associated with the consignments or not. These data show that in a 45 month period (16 June 2017 to 26 February 2021) an average of just under 200 m^3 per month was imported. Imports of southern yellow pine (this name is used for several species including *P. palustris*) are also recorded by the Forestry Commission. Trial imports of heat treated logs are being received via Southampton, and it is assumed these contain bark. It is intended that these imports will increase in volume to 375 m^3 per month, with a potential for doubling in the future if the trade remains free of problems (I. Brownlee, Forestry Commission, pers. comm. February-March 2021).

Table 4. Import (tonnes) of *Pinus* or coniferous wood which may include bark to the UK and rest of the EU from countries where *D. valens* is known to occur. Commodity codes (changed in 2017) are: 44032031, 44032039, 44032190, 44032200. Origins from where no imports were recorded during this period are not included in the table. Source: Eurostat (data extracted 3 April 2020).

Destination	Origin	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
UK	Canada	13.0	–	–	–	–	–	–	–	–	–
	China	–	–	–	–	–	–	–	6.8	–	0.9
	Honduras	–	–	–	–	–	–	–	2.9	19.2	–
	USA	–	–	–	–	–	–	–	12.7	15.2	953.3
EU (not including UK)	Canada	125.8	2.7	–	–	–	–	–	0.1	79.9	5.2
	China	–	–	–	–	–	12.3	–	381.1	2.1	3.3
	Honduras	–	–	–	–	–	–	–	9.2	6.9	–
	Mexico	–	–	–	–	–	–	–	–	15.1	–
	USA	–	–	131.4	–	–	20.4	18.4	91.5	78.2	87.9

While import of significant quantities of *Pinus* wood which may contain bark does take place from countries where *D. valens* is known to occur, there are required treatment measures which apply to conifer wood including kiln drying, fumigation, chemical impregnation or heat treatment, against both Scolytidae spp. (non-European) and pine wood nematode. Details are provided under the earlier section “Wood: legislation overview”. These measures are considered to decrease the risk of entry on **wood with bark**, which is assessed as **moderately likely** with **medium confidence**. This confidence level reflects the fact that if the required treatments are not carried out correctly, this commodity will have a high risk as any viable life stages of the insect are likely to be able to complete their development.

Bark

There may not always be a clear distinction between bark and the previous pathway of wood with bark, as some bark may contain small amounts of wood, for example the ornamental wood products discussed later. In this PRA, “bark” is defined as a product which is largely composed of bark, and includes some products which contain a small amount of wood attached to the bark. Only bark which contains the phloem layer is likely to pose a risk, as this is where the larvae feed.

Dendroctonus valens eggs and larvae are found in tunnels in the inner bark (feeding on the phloem), pupation occurs in the galleries, and adults also spend a large part of their life in the tunnels. Therefore, all life stages may be associated with bark. Eggs and young larvae are not likely to be able to complete development on isolated bark before the bark dries out and becomes unsuitable for further feeding. Older larvae, pupae and adults may all be able to complete development and emerge from isolated bark, and as adults are mobile, it is likely that they would be able to locate suitable new host trees, though the beetles would need to be able to find their way outside if the infested product was destined for indoor use and kept in a house. Adults are capable of laying multiple broods (Owen *et al.*, 2010), meaning that the species is demonstrably capable of leaving an existing egg gallery and creating new ones.

There are no data on how much isolated *Pinus* bark is imported into the UK or Europe from countries where *D. valens* is present. However, as the UK interception of *D. valens* in a rodent cage toy shows (see answer to question 6), conifer bark is imported from at least China in a form which may contain the pest, though the interception records are unclear if the intercepted specimen was live or dead. Results from searching online for pet cage furniture made from natural wood show that there is a very wide range of such products available, many with bark attached. At least some of these could be made from *Pinus* wood and bark. Other ornamental wood products with bark imported from China (including bird feeders and Christmas wreaths), showing evidence of insect damage, have been seen by members of the Plant Health and Seeds Inspectorate and forestry inspectors in UK shops and on stalls at various shows (Defra and Forestry Commission, unpublished data). An internal report investigating unprocessed wood products, often containing bark, did not identify any insects, live or dead, though some exit holes were found (Forestry Commission, 2020). The wood products examined also had a low moisture content, which would not favour survival or development of most insects.

Bark chips can also be used as mulch for gardens, but this commodity is discussed under the pathway of “wood chips” which follows.

There are legislative controls on movement of isolated conifer bark. In Annex VII of 2019/2072 [GB: Annex 7], isolated conifer bark from non-European countries must meet one of two requirements: (i) fumigation or (ii) heat treatment, together with requirements regarding transport outside the flight season of the longhorn beetle vectors of *B. xylophilus* (pine wood nematode). Additionally, in Annex III the whole of the UK has Protected Zone (PZ) status for three named bark beetle species (*I. amitinus, I. duplicatus* and *I. typographus*) [GB: Annex 2]. Northern Ireland together with some of the Crown Dependencies have PZs for another three species (*D. micans, I. cembrae* and *I. sexdentatus*) [GB Annex 3]. The measures supporting these PZs which are included in Annex X [GB: Annex 7] may help to reduce the chances of *D. valens* entering the UK, or parts of the UK. Isolated conifer bark must meet one of two requirements: (i) fumigation or other appropriate treatments against bark beetles or (ii) come from an area free from the specified bark beetle species. Two of the PZ species have distribution ranges which partially overlap with *D. valens*: 1. *Ips duplicatus* has a distribution which overlaps with *D. valens* in the Chinese province of Inner Mongolia only (EPPO, 2018), and 2. *Ips sexdentatus* where the distribution overlaps with *D. valens* in Shanxi and Shaanxi only (EPPO, 2018). A further limitation of the PZ measures are that bark beetles are highly cryptic and are very mobile. Thus, surveys to establish pest free areas are unlikely to be wholly effective.

The EPPO (2020) study into bark and ambrosia beetles associated with non-coniferous wood recommended phytosanitary measures for isolated bark. These are one of three treatments ((i) heat treatment, (ii) ionising radiation or (iii) fumigation), to be used in combination with storage and transport of the commodity in conditions to prevent infestation (EPPO, 2020). While the study specifically excluded coniferous wood, these measures are also likely to be appropriate for scolytine beetle pests of coniferous wood such as *D. valens*.

Overall, entry on **isolated bark** is considered **moderately likely** but with **low confidence** as there are a lack of data on how much might be traded and how much bark contains the inner phloem layer where *D. valens* is found. While there are mitigations in place, the total volume imported is not known, and the importation of ornamental bark products is of concern.

Wood packaging material (WPM)

Dendroctonus valens is only present in countries outside the UK and EU. All WPM (including dunnage) must meet the requirements listed in ISPM 15[9] before it can enter the UK from any country outside the EU. In summary, the ISPM 15 requirements are that all WPM must be made from debarked wood, though there are tolerances which allow “any number of visually separate and clearly distinct small pieces of bark” to remain if they are less than 3 cm wide or, if wider than 3 cm, individual pieces have a surface area of less than 50 cm^2. Additionally, the WPM must have undergone one of four treatments: there are two different heat treatment options or two options for fumigation. All WPM must bear a mark identifying which treatment was used and where the wood has been treated. However, there have been cases of poor compliance with ISPM 15, including fraudulent markings, identified during EU audits of Chinese WPM procedures (Eyre *et al.*, 2018). Between April 2013 and March 2015, there were 12 interceptions in the EU of Scolytinae (not identified further) on WPM from China used for transporting heavy stone products, which is considered to be high risk as it is frequently made of poorer quality wood (Eyre *et al.*, 2018). Between 1999 and 2014, Scolytinae were detected in the EU on general WPM from China, but not the USA (Eyre *et al.*, 2018). New Zealand identified a number of Scolytinae from North America 1950-2000 (the whole time period analysed), but the proportion declined over time, while Scolytinae interceptions on wood from China were

[9] https://www.ippc.int/en/core-activities/standards-setting/ispms/ (accessed 1 August 2018)

only recorded from 1980 onwards (Brockerhoff *et al.*, 2006). During this time, New Zealand recorded interceptions of other *Dendroctonus* species (on *Pinus* and *Picea*), but not *D. valens*.

If treated wood is stored outside, it may be reinfested; Haack and Petrice (2009) demonstrated that several Scolytinae species infested heat-treated logs, including *P. resionosa*, which were placed in a clear-cut corridor through a mature tree stand. They also found live scolytines associated with assorted WPM imported into the USA with patches of bark. Scolytine larvae could be associated with surprisingly small patches of bark, around 16 cm^2 in area. However, it isn't clear if larvae under bark patches this small would have been able to complete development. Experimentally, development was not possible in patches of 25 cm^2, and narrow strips were less favourable than squarer patches of the same area (Haack & Petrice, 2009).

Only a proportion of WPM will be made out of *Pinus* wood, and the removal of most of the bark will reduce the population of *D. valens*. However, WPM is associated with the trade of many commodities, and even if *Pinus* is only a small proportion of WPM, it will still be a significant quantity. Data on the amount of *Pinus* used in WPM are not available and therefore the amount of material moving in trade is an uncertainty.

While ISPM 15 will reduce the risk of viable *D. valens* being associated with WPM made of *Pinus* spp., past interceptions show that this pathway remains a risk for the bark beetle subfamily, and *D. valens* seems as likely to be associated with WPM as other Scolytinae. *Dendroctonus valens* is widespread in North America, but is only present in a part of China, but China has had a poorer record of ISPM 15 compliance in the past compared to North America. The pathway of **wood packaging material** is assessed as **moderately likely** with **medium confidence**.

Wood chips (including hogwood)

Wood chips may be imported for a variety of end uses. A major and growing sector is using wood chips as a biomass fuel source, but other uses include the manufacture of paper, garden mulches, playground substrates or bedding for a diverse range of animals including pet rodents, poultry and horses. A major uncertainty is what volume of *Pinus* wood chips is imported from countries where *D. valens* is present, and how much is sourced from UK (or European) timber. Individual companies may state the origin of their product(s), especially if wholly UK-sourced, but general data across the whole sector are hard to find and mostly quite dated. There are data available on the import of coniferous wood chips more generally, and this is presented in Table 5. Only a proportion of this wood is likely to originate from *Pinus*, and some wood chips may originate from areas within a country where *D. valens* is not present. Additionally, *D. valens* is only present in the phloem layer under the bark, which is likely to only form a small portion of the total volume of wood chips. An additional caveat with these data is that the volume is very variable across years, even from the same country (e.g. very high volumes from Canada to the UK in 2010, or USA to the EU in 2014 compared to the amounts imported in other years). It is unclear if this is true variation, mis-classification of some imports, or other errors.

Table 5. Import (tonnes) of “coniferous wood in chips or particles (excl. those of a kind used principally for dying or tanning purposes)” (commodity code 44012100) to the UK and the rest of the EU from countries where *D. valens* is known to occur 2010–2019. Origins where no imports were recorded from during this period are not included in the table. Source: Eurostat (data extracted 3 April 2020).

Destination	Origin	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
UK	Canada	39,248.0	–	–	–	82.6	69.9	14.6	–	–	–
	China	1.4	–	–	1.4	–	0.1	0.1	8.9	–	–
	Honduras	–	–	–	–	1.1	–	–	–	–	–
	USA	11.6	3.7	29.1	5.5	5.1	–	–	1.2	–	0.6
EU (not including UK)	Canada	–	–	0.1	1.2	0.5	–	36.1	0.6	1.4	3.2
	China	2.5	0.1	5.9	1.0	–	47.7	0.3	2.5	–	33.8
	Honduras	19.4	–	–	–	–	7.8	–	–	–	–
	Nicaragua	–	–	–	–	–	30.0	–	–	–	–
	USA	48.3	77.1	63.1	935.6	34.7	13.1	79.2	4.6	3.7	9.5

The number of individual beetles, pupae or larvae which survive the chipping process is likely to be relatively low (EPPO, 2019). However, given the small size of *D. valens* (adults are about 10 mm in length), wood chips will be bigger in size than the beetles or their larvae. The EPPO (2020) study on bark and ambrosia beetles in non-coniferous wood concluded that chipping to sizes commonly used for commercial chips did not completely remove the risk of association of these beetles with wood chips, and consequently EPPO did not recommend chipping as a mitigation measure for imported wood. Aside from the physical risks to the pest from the chipping process, if it is a larva, there may not be enough wood in the chip to sustain the remainder of its development to adult. Due to the higher surface area, chips will also dry out faster, again reducing the chances of larval or pupal development to adult. Any adult which emerges in transit may not be able to move around and locate other emerging adults to mate, depending on how compacted the woodchips are. Individual insects of any life stage may also be killed by the heat generated by the start of decomposition in the central portions of the consignment, though wood chips at the edges are unlikely to heat up to a lethal temperature and will permit more freedom of movement for emerging adults. Records from a UK site storing wood pellets (not wood chips) indoors showed that the temperature had risen to a high of 51°C: the site contained large volumes of material, stored in sections 55 m by 18 m by 10.5 m high and each capable of holding at least 4,000 tonnes (Simpson *et al.*, 2016). Wood fuel may also be moved from container to transport etc. by screw augers, which are likely to damage or kill some insects. Unless either a fertilised female survives chipping and transport, or there are enough immature individuals for a male and female to emerge geographically and temporally close together in the wood chippings, a population could not establish. Finally, the end use of the woodchips affects the chances of transfer to a growing host in the wider environment, and so they are considered separately here.

The use of wood as a biomass fuel source is increasing, especially for electricity generation. However, many if not all plants appear to use more highly processed wood pellets rather than wood chips (Hogan, 2013) and no life stage of insects (including *D. valens*) are likely to survive the pelleting process (EPPO, 2019). Other than the Eurostat data, there appears to be little recent data on import volumes and sources of woodchips for use in power generation. Hogan (2013) provides an overview of the UK trade in wood fuel, but it is likely that the figures presented there will be rather out of date over seven years on. The data presented suggest that the import of wood chips from outside the EU was not common, though there is some possibility for confusion if wood chips arrived at another EU port initially, and were then transferred to a smaller ship to be transported within the EU (Hogan, 2013). The chances of transfer from wood chips destined to be burnt as fuel to growing *Pinus* trees is relatively small. In transport or storage, the chips will be piled up and only beetles in chips at the edge of the pile/load are likely to be able to move into the wider environment successfully. If the wood chips are burnt quickly, then there is limited opportunity for any individual to complete development and adults to successfully emerge. The greatest risk would be if piles of wood chips were stored outside for a period of time. A report by the Health and Safety Executive on storage of woodfuel (both chips and pellets) for smaller-scale boilers (e.g. schools) found that fuel was contained in specialised indoor storage facilities or sealed outdoor silos; however, the need for adequate ventilation for indoor storage was noted in the report (Simpson *et al.*, 2016). Most ventilation was passive, via slatted openings, and so it would be possible for insects to orient towards the light from the vents and crawl outside. However, there is a lack of information on storage in larger facilities.

Large volumes would mean there are likely to be more insects in the consignment. This in turn means there is more chance of a greater number of adults emerging at the same time, and hence meeting and successfully mating. However, it is considered unlikely that any adult attempting to emerge from a wood chip in the centre of a large pile would be able to move into the wider environment and this may reduce the number of adults actually able to transfer into hosts in the wider environment.

Much the same constraints as detailed for biomass fuel will apply to woodchips used for the manufacture of paper or cardboard products. Namely: the manufacturing process will kill all life stages, but outdoor storage (or storage indoors with good ventilation to the outside) for future use will have some risk.

Wood chips used as garden mulches or similar surface coverings, e.g. in playgrounds, are likely to be the riskiest of the end-uses (EPPO, 2019). The wood chips will mostly be spread outside, where any emerging adult beetles will be able to fly off to locate growing *Pinus* trees. In addition, the chips will be in contact with the ground and thus will be slower to dry out as they will absorb some moisture. Therefore, if the insects can survive the chipping process, it is possible that the wood chips will retain enough moisture to allow continued development of some life stages to reproductive adults, e.g. late instar larvae, pupae or teneral (newly emerged) adults. The amount of mulch spread in domestic gardens is likely to be relatively low and is mostly sold via DIY stores in sealed and compressed plastic sacks. The numbers of individuals is also likely to be small, reducing the chances of founding a breeding population. However, larger volumes of woodchips may be used in landscaping (e.g. retail parks, supermarkets, etc.), and the risk here will be greater.

Woodchip bedding for small animals is not a likely pathway, as the wood particles are likely to be dried and chopped finely for small animals meaning that no individual is likely to survive the chipping process. In addition, softwoods such as pine are less favoured as small animal bedding as there is some evidence that aromatic chemicals in softwood bedding can cause health problems in rodents. Woodchips are increasingly popular for horse bedding, e.g. Bedmax[10], Equichip[11] or Cushionbed[12], and are also used by some (mainly domestic) poultry keepers. These wood chips are likely to be bigger in size than rodent bedding, and thus individual beetles may survive the chipping process. Conditions may not be ideal for continued beetle development, as the bedding will mostly be stored in sealed plastic bales, and after use is likely to be put on a manure heap for composting. Stables, manure heaps and some poultry runs are likely to be open to the outside, allowing any emerging beetles to locate hosts in the wider environment. Again, volumes will be relatively small at any one location and so the number of individual beetles is likely to be low, reducing the chances of sufficient numbers of adults emerging together. Woodchip used in larger volumes, e.g. commercial poultry farms, would have a greater volume. However, due to the high volumes there will be waste management procedures in place, and these are likely to be managed to reduce transmission of poultry diseases which should also reduce the risk of *D. valens* surviving. However, no data could be found on the use of chips as animal bedding overall or for any particular species, only individual anecdotes, and this makes assessment of this end-use of woodchips uncertain.

In Annex VII of 2019/2072 [GB: Annex 7], coniferous wood chips from Canada, China, Mexico and the USA (plus other countries outside the range of *D. valens*) where *Bursaphelenchus xylophilus* (pinewood nematode) is known to occur must have been treated: the three options are (i) heat treatment and requirements regarding transport outside the flight season of the vector beetles, (ii) fumigation, or (iii) heat treatment plus kiln drying. Coniferous wood chips from other non-European countries must meet one of five options: (i) originate in an area known to be free from non-European Scolytidae (and other specified wood boring beetles), (ii) produced from debarked round wood, (iii) kiln-dried, (iv) fumigated or (v) heat treatment.

While the end use of the woodchips does affect the likelihood of successful transfer to the wider environment, either the volumes are likely to be small and hence the number of adults low (mulch, animal bedding), or if the volume is higher, the end use or storage

[10] https://www.bedmaxshavings.com/ (accessed 27 May 2020)
[11] https://www.diversefarming.co.uk/equi-chip (accessed 27 May 2020)
[12] https://giffords.biz/products/cushionbed/ (accessed 27 May 2020)

conditions seem likely to reduce the number of adults successfully emerging into the wider environment (wood chips for fuel, paper or cardboard manufacture). Given the process of chipping will reduce survival to start with, the chances of entry on all forms of **wood chips** is considered **moderately likely** but with **low confidence** as data on many elements of this pathway including trade volumes are lacking, or are not provided in great detail. It seems likely that with the switch to woodchips as biofuel and renewable energy, the trade patterns, both in terms of volume and origin, could be quite dynamic in the next few years, and this contributes to the low confidence rating.

Plants for planting

Dendroctonus valens usually attacks larger, older trees (Owen *et al.*, 2010), which are less likely to be moved in trade than younger specimens. Under Annex VI of 2019/2072 [GB: Annex 6], plants of *Pinus* other than fruit and seeds (as well as all the other recorded host genera: *Abies, Larix* and *Picea*) are prohibited from all countries in the current known distribution of *D. valens.* Though there are two derogations allowing for the import of *Pinus parviflora* bonsai trees (including *P. parviflora* grafted onto other *Pinus* spp. rootstock), these only apply to Japan (2002/887/EC) and the Republic of Korea (20002/499/EC), and *D. valens* has not been reported from either country. Entry on **plants for planting** is considered **very unlikely, with high confidence.**

Cut branches

"Cut branches" are defined here rather broadly as parts of trees with foliage (needles), but no roots. Thus, they range in size from twigs (e.g. for wreaths or floristry) all the way to Christmas trees, where the whole tree minus the roots is included.

Dendroctonus valens will not be associated with the very thin twigs, other than adults on the surface, and even this is not likely as adults spend most of their time inside the galleries.

Larvae are not likely to be found associated with cut branches, as most galleries are constructed in larger trees, in the lower part of the bole and in the roots (Owen *et al.*, 2010). Also, transfer from cut branches to living hosts by larvae which are not particularly mobile is not realistically possible. Though the likelihood of association with smaller branches is relatively low, mature larvae may be able to develop to adults, or pupae or adults may be present. In these cases, it would be possible for adults to emerge and fly long distances and they would be likely to find suitable *Pinus* hosts. Adults spend most of their time in egg galleries and not outside the tree, so the chances of adults being present on the outside of cut branches are again considered to be low.

Christmas trees would pose the greatest risk, as they include the lower trunk where *D. valens* constructs its galleries, but most Christmas trees are relatively young, small trees and hence the likelihood of *D. valens* colonising these trees is quite low. Additionally, Christmas trees are often *Abies* (fir) or *Picea* (spruce), with *Pinus* less commonly used. As the cut trees must last for at least two weeks after sale, most are likely to be sourced relatively locally rather than spend a large proportion of their shelf life in transit from more distant forests. While technically Christmas trees have a short lifespan and at the end of it many will be disposed of e.g. by council chipping, plenty are left outside in gardens etc. for months. This could allow *D. valens* time to develop and emerge, though the shift from outdoor winter conditions to heated house to outdoor conditions again is likely to adversely affect the survival of all lifestages.

Cut branches of *Pinus* and the other known hosts of *D. valens* are covered in the prohibition under Annex VI of 2019/2072 [GB: Annex 6] for *Pinus* plants (as well as plants of the other known host genera of *Abies, Larix* and *Picea*). This is because the wording used is “plants other than fruit and seeds” and this includes cut branches with or without foliage, Christmas trees, and other similar plant parts (definition included in Regulation (EU) 2016/2031). Entry on **cut branches** is considered **very unlikely with high confidence.**

Wood of conifers without bark	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		
Wood of conifers with bark	Very unlikely ☐	Unlikely ☐	Moderately likely ☑	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		
Bark	Very unlikely ☐	Unlikely ☐	Moderately likely ☑	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		
Wood packaging material	Very unlikely ☐	Unlikely ☐	Moderately likely ☑	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		
Wood chips	Very unlikely ☐	Unlikely ☐	Moderately likely ☑	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		

Plants for Planting	Very unlikely	✓	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐		☐		☐

Cut branches	Very unlikely	✓	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐				

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

This beetle is a free living organism and does not require a vector.

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

Outdoors

Dendroctonus valens is found throughout much of North America, from a number of Canadian provinces in the north, throughout much of the USA (excluding some central regions and some states in the south-east) and south into parts of Mexico. There are also records from Central America, but at least some of the Central American populations form a distinct phylogenetic cluster (see the answers to questions 1 and 5 of this PRA for more details). Even if only the records from Mexico northwards are considered, *D. valens* is found in a wide climatic range and it is likely that the UK, and indeed much of Europe, would prove to be climatically suitable for the establishment of this pest. *Pinus* are widely distributed throughout the UK, and two very common species, *P. contorta* and *P. sylvestris*, are known hosts of *D. valens.* As the pest is able to survive in a wide range of climatic conditions in its native range, including locations very similar to the UK (e.g. Washington State and British Colombia), and hosts are widely distributed and common throughout the UK, establishment outdoors is considered **very likely** with **high confidence**.

Under protection

Pinus are not commonly grown in protected environments, other than some nurseries while the plants are very young. Seedlings are not suitable hosts for *D. valens*. *Pinus* bonsai may be grown under protection for a greater length of time and are probably most at risk from *D. valens*. As bonsai are deliberately stressed as part of their cultivation, to keep the trees small, they could potentially be more susceptible to attack. Conversely, given the preference of *D. valens* for older trees, even more mature bonsai are unlikely to be large enough to be highly attractive to adults seeking suitable hosts. Overall, establishment under protected cultivation is considered **very unlikely** with **high confidence**.

Outdoors	Very unlikely ☐	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☑
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Under Protection	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

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

Natural spread

A small amount of data on natural spread are available. In North America, there is a statement that beetles can fly “more than 10 miles” (around 16 km) in the original 1971 edition of a factsheet by Smith (which does not contain citations). However, when this factsheet was updated by Owen *et al.* (2010), the previous spread text was replaced by “Beetles fly, potentially for many miles” with no data on actual distances covered. Mark-release-recapture experiments were conducted in Wisconsin, USA. Though only small numbers of *D. valens* were recaptured (5 individuals from over 300 released, less than 2% overall), the mean recapture distance was 0.55 km. Some individuals were captured over 1 km from the release point, and traps were located a maximum of 2 km from the release point (Costa *et al.*, 2013).

Spread in China was reported to be 20 km or more (Zhang *et al.*, 2002), though the paper is in Chinse and of limited accessibility without professional translation. Later sources citing Zhang state that spread can be up to 35 km (e.g. Yan *et al.*, 2005).

For bark beetles more generally, there is often a pattern of variable flight distances within a population: many individuals only fly short distances but some will disperse much further (Jones *et al.*, 2019). If this is the case for *D. valens*, it makes it more difficult to come to conclusions about how far beetles may be capable of dispersing overall. In New Zealand, dispersal of two species of invasive *Pinus*-feeding Scolytinae from the genus *Hylastes* was studied. Traps were set up in *Pinus* plantations and also at measured distances in the wider environment. The furthest capture distance from a plantation was over 40 km for both species. The greatest distance from the nearest *Pinus* windbreaks (i.e. smaller groups of host trees in the wider landscape) was over 25 km for both species (Chase *et al.*, 2017), though there may have been occasional isolated host trees closer than this.

Though the data on spread are less authoritative than some reviews might suggest, *D. valens* does appear to be capable of significant flight dispersal, and therefore the rate of **natural spread** was considered to be **quickly**, but with only **low confidence** as detailed data are lacking and it is possible that many beetles may not disperse very far at all from the tree they emerged from, if suitable hosts are available locally. Only three sources of data could be found on the rate of spread for *D. valens* specifically.

Spread with trade

All life stages of *D. valens* are cryptic, and there is evidence that this species has successfully moved in international trade from North America to China. Therefore, if *D. valens* was to be introduced to the UK, it seems very likely to be capable of being transported with traded material around the UK. To prevent spread in trade, the cause of any visible damage would need to be identified as a non-native beetle before the consignment was moved. Currently the UK has 65 species of Scolytinae, both native and introduced (Duff, 2016). Of these, 16 species have a preferred host of *Pinus* spp.

At the present time only one species of *Dendroctonus* occurs in Great Britain (but not Northern Ireland), namely *D. micans* which was introduced from continental Europe. This species has established populations in west central and southern England and Wales, and has spread into southern Scotland. Parts of the west of Scotland have a pest free area for *D. micans*. Northern Ireland has a Protected Zone against *D. micans* which includes measures to mitigate against the risk of its introduction there. Host preference differs between *D. valens* and *D. micans*: in Great Britain *Picea* spp are the preferred hosts of *D. micans*, not *Pinus* spp. However, *D. micans* will feed on *Pinus* (EPPO, 2018) and *D. valens* will feed on *Picea* spp. (Atkinson, 2018), so this is not a distinguishing character.

Accurate identification of bark beetles based on morphology is difficult and often requires specialist examination. In some circumstances, molecular techniques may aid in identification of a species. Both morphological and molecular techniques require time and resource to confirm a species identification, so there is the potential for *D. valens* to be moved in trade before an incursion or outbreak is positively identified. **Spread with trade** is assessed as **very quickly** with **high confidence**.

Natural Spread	Very slowly ☐	Slowly ☐	Moderate pace ☐	Quickly ✓	Very quickly ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ✓		
With trade	Very slowly ☐	Slowly ☐	Moderate pace ☐	Quickly ☐	Very quickly ✓

Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐

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

Impacts of *D. valens* in different parts of its range are not the same, and so impacts have been separated into two geographical categories: those seen in the native range in the Americas and impacts in the invasive range in China.

North and Central America

In North America, *D. valens* is mostly considered to attack trees which are already significantly stressed and/or dying, though an increase in local populations can lead to more attacks on trees which appear to be healthy (e.g. Wood, 1982; Randall, 2010). There are few data on impacts in Central America but there have been some reports that *D. valens* has killed "apparently healthy pine trees" in some locations (Armendáriz-Toledano & Zúñiga, 2017b). In general, *D. valens* is mostly considered a secondary pest. Even when trees have been damaged by fire, *D. valens* is generally not considered to contribute significantly to tree mortality (Westlind & Kelsey, 2019 and references therein).

There are some data on impacts in the native range which are more specific, though they do not alter the conclusion that *D. valens* is seldom a primary pest in its native range. *Dendroctonus valens* has been found infesting declining *P. resinosa* stands in the Great Lakes regions and analysis showed populations were higher in declining stands compared to healthy ones (Erbilgin & Raffa, 2001). Many other pests and pathogens were present in the declining stands and there is no indication that *D. valens* was acting as a primary pest. Declining stands were thought to occur due to a complex interaction among many biotic and abiotic stresses (Klepzig *et al.*, 1991; Erbilgin & Raffa, 2001), of which *D. valens* appears to be one of the contributing factors. In a plantation in California, *P. ponderosa* showed mortality due to attacks by *D. valens*, though the trees were stressed by compacted soil and damage due to thinning, which appeared to be contributing factors to the trees' susceptibility to beetle damage (Rappaport *et al.*, 2001).

Overall, impacts in North America are considered to be **very small** with **high confidence**. While there are a small number of reports of damage to healthy trees, these appear to be the exception rather than the rule and most impacts are recorded on already declining trees.

China

Dendroctonus valens was first identified in China in 1983 and the first report of a major outbreak was in 1999, following severe drought in previous years (Sun *et al.*, 2004). In the next five years, over 500,000 ha were infested, and over 4 million trees were killed, mostly those over 30 years old (Sun *et al.*, 2004). Another calculation a year later estimated the number of *P. tabuliformis* killed in China at over 10 million and mortality of other *Pinus* species due to *D. valens* attack was also recorded (Yan *et al.*, 2005; Sun *et al.*, 2013). In eastern Shanxi Province, about 30% of *P. tabuliformis* is estimated to have been infested and about 7% of the trees died in 2001 alone (Sun *et al.*, 2013). When the drought ended in 2004 and normal levels of rainfall were recorded, "it was nearly impossible to find one single successful attack in areas previously highly infested" (Jean-Claude Grégoire, personal communication, September 2020).

The lifecycle of *D. valens* in China is reported to be quite similar to that in North America, though root colonisation in China may be more frequent (Yan *et al.*, 2005) and this has been suggested to be an adaptation to cold winters (Sun *et al.*, 2013). It should be noted that in the northern part of its North American range, winter temperatures are also very low, but there are no data to indicate if these populations also colonise roots more frequently or if the higher rate of root colonisation in China may be due to some other factor. When population levels are low, newly felled trees, stumps or weakened trees are susceptible to attack in China (Zhang *et al.*, 2002), similar to the situation in North America. When populations are high in China, apparently healthy *P. tabuliformis* trees over 20 years old can be attacked and killed (Zhang *et al.*, 2002; Yan *et al.*, 2005). In contrast to North America, mass attacks of *D. valens* (when large numbers of beetles arrive on a single host in a short period of time, usually mediated by chemical signals, and the tree's defences are overcome) have been noted in China (Liu *et al.*, 2013; Liu *et al.*, 2017). One hypothesis for this difference is that North American beetles are able to reproduce in trees despite the host's resin defences, and so, to reduce competition, beetles produce pheromones which repel other *D. valens*. In contrast, *P. tabuliformis* produces a great deal of resin and isolated beetles are often killed by the tree, which may help to explain the higher numbers of individuals attacking a single tree in China (Liu *et al.*, 2017) as attacks by one or two pairs of beetles are often successfully overcome by the tree's defences.

The main outbreaks of *D. valens* in China have occurred in regions with a dry climate, and, as previously noted, the initial outbreaks followed severe drought; when the drought ended, damage due to *D. valens* declined (Sun *et al.*, 2013) or was nearly impossible to detect (Jean-Claude Grégoire, personal communication, September 2020). Milder winters may have helped population levels to build up by reducing winter mortality of the larvae. Silvicultural practices may also have contributed to the outbreaks, especially the practice of felling affected trees but leaving the stumps *in situ* without treatment. These stumps would have attracted *D. valens* adults and again favoured local population increases (Sun *et al.*, 2013).

There are suggestions that one of the fungi vectored by *D. valens* is less genetically diverse (Taerum *et al.*, 2017) and more pathogenic (Lu *et al.*, 2010) in China compared to North America, which may contribute to the differing impacts of *D. valens* in the two regions. For more details on this aspect, see part 15 of this PRA.

Overall, impacts in China are considered to be **large** with **medium confidence**. A cause of uncertainty is the role of drought in causing high impacts in the worst-affected areas of

China. It seems the *P. tabuliformis* trees were highly stressed by the lack of rainfall over several years, and this contributed to the impacts seen.

Impacts: North America	Very small ☑	Small ☐	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Impacts: China	Very small ☐	Small ☐	Medium ☐	Large ☑	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

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

The potential impacts of *D. valens* in the UK are subject to high uncertainty. The reasons for the higher impacts in China compared to the native range of North America are not fully understood, though severe drought may have played a key role in the Chinese impacts in the late 1990s to early 2000s. This means it is very difficult to predict whether *D. valens* might behave as a secondary pest in the UK (as it is in North America), or a primary pest (as it is in China).

If *P. tabuliformis* is particularly susceptible to attack by *D. valens*, then the UK would not appear to be at great risk as *P. tabuliformis* is not widely grown in this country. Liu *et al.* (2017) suggest that *P. tabuliformis* produces a lot of resin, and to overcome this, *D. valens* will attack a single tree in higher numbers, helping to explain why the attacks in China are more severe. Earlier work by Cheng *et al.* (2015) suggests that tree resin production differs according to the species of fungal associate vectored by *D. valens* (see section 15), and that *P. tabuliformis* was induced to produce high levels of defence chemicals by one of the main fungal associates, *Leptographium procerum.* The story of tree resin production, the role the different constituent chemicals play, and the response to beetle and fungal attack by each individual chemical appears to be highly complex and the overall picture is by no means certain.

In a phylogeny of the host genus, Gernandt *et al.* (2005) places *P. tabuliformis* close to seven *Pinus* species, all predominantly Asian in distribution: *P. densata, P. hwangshanensis, P. kesiya, P. luchuensis, P. taiwanensis, P. thunbergii* and *P. yunnanensis.* None of these pine species very closely related to *P. tabuliformis* are widely grown in the UK. It should however be noted that the phylogeny does include *P. sylvestris* in the same phylogenetic clade as *P. tabuliformis* (Gernandt *et al.*, 2005); *P. sylvestris* merely seems to be more distantly related to *P. tabuliformis* than other species in the same clade. Many species of *Pinus* which are widely grown in the UK are known to be hosts of *D. valens*, but high impacts have not been recorded to date on any of them.

It is possible that the very high impacts in China were actually driven by environmental stress factors, as there had been a multi-year severe drought in areas where serious damage was first recorded. This is supported by evidence that after the drought ended, high levels of damage by *D. valens* was difficult to find (Jean-Claude Grégoire, personal communication, September 2020). However, it is possible that more UK *Pinus* will become increasingly stressed compared to years past. There appears to be an increasing trend in the UK for milder, wetter winters followed by hotter, drier summers (Lowe *et al.*, 2018). The wet winters may cause stress to trees grown on soil which easily becomes waterlogged, e.g. clay or peat and drier summers will increase the potential for drought stress. In general, UK *Pinus* may not be in especially good health, and is vulnerable to the combined effects of existing diseases and pests (for example, *Dothistroma septosporum*) in addition to climate change (Patrick Robertson, pers. comm., November 2020). This may make the trees more attractive to *D. valens*, and increase the impacts of any attack. On the other hand, general good silvicultural practices to promote tree health may mean UK *Pinus* are less susceptible to attack by *D. valens*, and targeted measures to clear stumps, reduce the amount of cut or fallen wood left in the vicinity of growing trees and to carry out pruning or thinning outside the main adult flight period might further help to make trees less vulnerable to attack.

It is likely that *D. valens* would be introduced with some of the fungi and bacteria it vectors in its current range, but it is also very likely that it would begin to vector other pathogens already present in the UK given it is vectoring new fungal species in China (Lu *et al.*, 2008a; Lu *et al.*, 2008b; Taerum *et al.*, 2013). One fungus, *L. procerum,* (implicated in the higher impacts seen in China) is already present in the UK. However, the strains present in China do appear to be different from strains present in either North America or Europe (Lu *et al.*, 2010). There is therefore a risk that *D. valens* from China may be introduced with the more pathogenic strain of the fungus, and it is possible this may lead to impacts on UK *Pinus*.

Table 6 summarises some potential causes of the differing impacts and the consequences for potential UK impacts if *D. valens* was to establish here.

Table 6. Summary of factors which <u>may</u> influence the different impacts of *Dendroctonus valens* in its native and invasive ranges, and the status of each factor in the UK.

Potential source of different impacts	**North American situation**	**Chinese situation**	**UK factors of potential relevance**
Host species	Generalist on *Pinus* spp., both native to North America and introduced (Owen *et al.*, 2010), but none appear to be susceptible to high impacts if healthy.	Most impacts seen on *P. tabuliformis*, though mortality on other hosts has been recorded (Yan *et al.*, 2005). A hypothesis is that *P. tabuliformis* is especially susceptible due to high levels of resin production (Liu *et al.*, 2017).	*Pinus tabuliformis* is not widely grown in the UK. Few impacts recorded on healthy trees of the *Pinus* species widely grown here.
Environmental factors	One instance of *D. valens* having an impact on trees may have been due to compacted soil (Rappaport *et al.*, 2001).	Several years of severe drought preceded the highest impacts (Sun *et al.*, 2013). Attacks were difficult to find after the drought ended (Jean-Claude Grégoire, personal communication, September 2020).	The pattern in recent years of very wet winters and very dry springs in the UK may mean more *Pinus* could be stressed and be susceptible.
Silvicultural factors	Even if stumps are not cleared and populations build up, this rarely leads to attacks on healthy trees sufficient to kill them (Owen *et al.*, 2010).	Lack of stump clearance may have contributed to outbreaks in the early years (Sun *et al.*, 2013).	Promoting general tree health may help to reduce any impacts, along with more targeted measures if required. Cumulative impacts with diseases and pests already present in the UK are a concern.
Associated fungal community (Lu *et al.*, 2008a; Lu *et al.*, 2008b; Taerum *et al.*, 2013)	Species composition differs from region to region within North America.	Some fungi vectored are the same species as North America but other associations with Chinese fungi appear to be new.	It is likely that *D. valens* would start to vector fungi already present in the UK, in addition to any which arrived with the beetle.

Potential source of different impacts	North American situation	Chinese situation	UK factors of potential relevance
Fungal associate *Leptographium procerum* (Taerum *et al.*, 2017)	Genetically diverse.	Evidence of a genetic bottleneck. Chinese isolates appear to be more pathogenic to *P. tabuliformis* than North American isolates (Lu *et al.*, 2010).	European samples of this fungus are genetically diverse and similar to those found in North America. This fungus has been recorded from the UK.

Potential **economic impacts** in the UK are assessed as **medium**. It is likely that an increasing number of UK trees will be more stressed in the future as the climate changes. Current predictions are that there will be more frequent extreme climatic events in future (Lowe *et al.*, 2018) which are likely to stress trees planted here. There are existing diseases and pests affecting *Pinus* in the UK (e.g. *D. septosporum*), again stressing trees. These stressed trees will be more susceptible to attack by *D. valens* along with other secondary pests already present in the UK. As the beetle mainly attacks the lower part of the tree, it is possible that a reasonable amount of useable timber could be salvaged from affected trees, depending on the age and maturity at which they were attacked. If large areas of forest were affected, then there could be an economic impact due to loss of tourism, especially for iconic forests such as the Cairngorm national park (which contains parts of the Caledonian pine forest).

Potential **environmental impacts** are assessed as **medium** as trees which succumb to *D. valens* may be growing in marginal areas where alternative tree species might not grow easily. The loss of canopy cover and root systems may lead to soil erosion and other ecosystem impacts, particularly in a plantation monoculture if multiple trees are affected over a large area. Areas of environmentally important *Pinus* include the Caledonian pine forest in the Highlands of Scotland and the Thetford Forest in East Anglia. The Caledonian pine forest in particular is made up of veteran (and over-mature) trees in in remnant pockets, and some of these are found in close proximity to stands of *P. contorta* infected with *D. septosproum* (Patrick Robertson, pers. comm., November 2020). Further environmental impacts would be expected from the loss of native species associated with *Pinus* trees, especially if most of the local *Pinus* trees were killed. The loss of mature trees is particularly damaging in such environments, and replacement times are likely to be upwards of 50 years.

Potential **social impacts** are assessed as **small**. Many amenity *Pinus* are part of a mixed forest where their loss will be less noticeable. While *Pinus* spp. are grown in urban areas, other species, mainly broadleaved, are more widely planted, especially as street trees. Commercial forests do have social value for recreation, but loss or partial loss of a particular wood is likely to affect a day out rather than routine activities for most people, though impacts on a *Pinus* monoculture plantation could be very noticeable. If “destination” forests, such as the remnants of the Caledonian pine forest, were to be affected there is a potential for social impacts as tourists choose alternative holiday sites.

Economic Impacts	Very small ☐	Small ☐	Medium ✓	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ✓		

Environ-mental Impacts	Very small ☐	Small ☐	Medium ✓	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ✓		

Social Impacts	Very small ☐	Small ✓	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ✓		

15. What is the pest's potential as a vector of plant pathogens?

Fungi (other than yeasts)

Dendroctonus valens is known to have a casual association with a number of plant pathogenic fungi. Vectoring beetles pick up the fungal spores from the environment (such as their galleries inside the tree) and carry them on their exoskeletons to new hosts. Many of the fungi associated with *D. valens* have been reported in association with other beetle species, and *D. valens* from different origins carry different fungal species (Taerum *et al.*, 2013). Unlike some Scolytinae, *D. valens* does not have specialised cuticular formations called mycangia to aid the transport of fungal spores (as reported in Sun *et al.*, 2013). There is no obligate beetle-fungus association between *D. valens* and any of the fungi it has been associated with, such as are seen in the ambrosia beetles. Of the list of fungi which have been associated with either the beetle or its galleries in Table 7, *L. procerum* is commonly associated with *D. valens* in eastern North America and China (Taerum *et al.*, 2017).

One explanation for the differing impacts of *D. valens* between North America and China is that the accompanying fungi may be more pathogenic in China. Lu *et al.* (2010) artificially inoculated *P. tabuliformis* seedlings with a range of fungal species and strains, including those native to North America, native to China, and originating in North America but isolated from their invasive range in China. The results showed that the invasive strains of *L. procerum* caused higher mortality rates and longer lesions in the seedlings than the *L. procerum* strains from North America. Other fungi tested did not show such a distinct difference. Cluster analysis based on molecular work on *L. procerum* originating in North America, China and Europe (including the UK) suggests that *L. procerum* from Europe (the putative origin of the fungus according to this study) and North America do not markedly differ from each other, but *L. procerum* from Chinese isolates are less genetically diverse and cluster together in a distinct group (Taerum *et al.*, 2017). Preliminary data suggest that infection by Chinese strains of *L. procerum* stimulates the affected tree to produce a volatile compound which is an attractant for *D. valens* (Lu *et al.*, 2010).

Table 7. Fungi recorded in association with *D. valens* or its galleries in its native range of North America and in its invasive range of China. Fungal species are as reported in the source papers and have not been checked against names in fungal taxonomic databases.

Fungal species	North America	China	Key reference(s)	Already present in UK?[13]
Ceratocystis collifera	✓	–	As reported in Lu *et al.* (2009a)	–
Graphium sp.	✓	–	(Owen *et al.*, 1987); as reported in Lu *et al.* (2009a)	? Genus present
Graphibium sp.	–	✓	Taerum *et al.* (2013)	–
Grosmannia aurea	✓	–	Taerum *et al.* (2013)	–
Grosmannia clavigera	✓	–	As reported in Lu *et al.* (2009a); as reported in Lu *et al.* (2009b)	–
Grosmannia europhioides	✓	–	As reported in Lu *et al.* (2009a)	–
Grosmannia hunti	✓	–	Taerum *et al.* (2013)	–
Grosmannia koreana	✓	✓	Lu *et al.* (2009b); Taerum *et al.* (2013)	–
Grosmannia piceaperda	✓	–	As reported in Lu *et al.* (2009a)	–
Grosmannia radiaticola		✓	Taerum *et al.* (2013)	–
Grosmannia spp.	✓	–	Taerum *et al.* (2013)	? Genus present
Hyalorhinocladiella pinicola	–	✓	Lu *et al.* (2009a); Lu *et al.* (2010)	? UK record identified to genus only
Leptographium alethinum	–	✓	Lu *et al.* (2009b); Taerum *et al.* (2013)	✓
Leptographium pini-densiflorae	–	✓	Lu *et al.* (2009a); Lu *et al.* (2010); Taerum *et al.* (2013)	–
Leptographium procerum	✓	✓	Klepzig *et al.* (1991); Klepzig *et al.* (1995); Lu *et al.* (2009a); Lu *et al.* (2009b); Taerum *et al.* (2013)	✓
Leptographium sinoprocerum	–	✓	Lu *et al.* (2009a); Lu *et al.* (2009b); Taerum *et al.* (2013)	–
Leptographium spp.	✓	–	Taerum *et al.* (2013)	? Genus present
Leptographium terebrantis	✓	–	Klepzig *et al.* (1991); Klepzig *et al.* (1995); as reported in Lu *et al.* (2009a); as reported in Lu *et al.* (2009b)	–

[13] Using data from http://basidiochecklist.science.kew.org/BritishFungi/GBCHKLST/gbchklst.htm (accessed 3 September 2020)

Fungal species	North America	China	Key reference(s)	Already present in UK?[13]
Leptographium truncatum	–	✓	Lu *et al.* (2009a); Lu *et al.* (2009b); Taerum *et al.* (2013)	✓
Leptographium wagneri	✓	–	(Owen *et al.*, 2005); as reported in Lu *et al.* (2009a); as reported in Lu *et al.* (2009b)	–
Leptographium wingfieldii	✓	–	As reported in Lu *et al.* (2009a); as reported in Lu *et al.* (2009b)	✓
Ophiostoma abietinum	✓	✓	Lu *et al.* (2009a); Taerum *et al.* (2013)	
Ophiostoma flocossum	✓	✓	Lu *et al.* (2009a); Taerum *et al.* (2013)	–
Ophiostoma ips	✓	✓	Klepzig *et al.* (1991); Klepzig *et al.* (1995); Lu *et al.* (2009a); Taerum *et al.* (2013)	✓
Ophiostoma minus	✓	✓	Lu *et al.* (2009a); Lu *et al.* (2010); Taerum *et al.* (2013)	–
Ophiostoma piceae	–	✓	Lu *et al.* (2009a); Taerum *et al.* (2013)	✓
Ophiostoma piliferum	✓	–	As reported in Lu *et al.* (2009a); Taerum *et al.* (2013)	✓
Ophiostoma sp.	–	✓	Lu *et al.* (2009a); Taerum *et al.* (2013)	? Genus present
Ophiostoma spp.	✓		Taerum *et al.* (2013)	? Genus present
Pesotum aureum	–	✓	Lu *et al.* (2009b)	✓
Pesotum pini	–	✓	Lu *et al.* (2009b)	–

If the differing pathogenicity of *L. procerum* in China and North America contributed to the higher impacts of *D. valens* in China, then it is possible that impacts of the beetle in the UK will be more similar to those in North America, as *L. procerum* is already present in this country (Wingfield & Gibbs, 1991) without records of high levels of damage, and European isolates of *L. procerum* are more similar to North American isolates than to Chinese isolates. The risk to the UK would be the introduction of the strains of *L. procerum* from China with higher pathogenicity, but a number of beetle species are likely to be able to vector the fungi, meaning that more vectors than just *D. valens* pose a risk.

Yeasts and bacteria

Other potential plant pathogens are also associated with *D. valens*, and at least some of the bacteria appear to mediate elements of the tree/beetle interactions. However, all insects carry bacteria and yeasts, and none of the evidence assessed during this PRA suggested that *D. valens* is an important vector of these organisms. Some references with brief notes are provided below concerning the relationship between *D. valens* and yeasts or bacteria.

Lou *et al.* (2014) discuss differing yeast species associated with *D. valens* in China and North America.

In North America, there is evidence to support a core bacteriome shared by all *D. valens* (Hernandez-Garcia *et al.*, 2018), but also a diversity of other bacterial species which appear to differ by geographic origin of the insects. Adams *et al.* (2010) demonstrated some evidence of geographic variation in bacteriome from different sites in the USA. Analysis of galleries from Wisconsin, USA identified more bacteria associated with galleries than the undamaged phloem (Mason *et al.*, 2016). Mexican *D. valens* were collected from four locations, and a total of 17 bacterial species were identified (Morales-Jiménez *et al.*, 2009). Subsequent molecular work by Hernandez-Garcia *et al.* (2018) from six sites across Mexico found that eleven genera were present at abundances of >1%, and at least 28 different bacterial genera were detected overall. In China, Xu *et al.* (2019) detected a total of 253 bacterial species, from 102 genera.

16. What is the area endangered by the pest?

If impacts of *D. valens* in the UK were more similar to those in North America, it is possible that no area of the UK would be endangered, as under this scenario *D. valens* would primarily be a secondary pest, not causing major economic impacts. Trees adversely affected by this beetle would probably have been weakened or dying anyway and *D. valens* would just be another secondary pest in addition to native species, though there is the possibility of cumulative impacts with other pests on declining trees such as *D. septosprorum*. Given the high impacts in China were likely to be linked to severe drought, this scenario is considered more likely.

If impacts were similar to those seen in China, the whole of the UK could be endangered by *D. valens*. *Pinus* spp. are widely planted throughout the UK and climate is not considered to be limiting given the current species distribution. The UK's *Pinus* trees are already affected by pests and diseases and it is possible that the existing cumulative impacts from these species would make trees and forests vulnerable to attack by *D. valens*. As *D. valens* prefers stressed trees, *Pinus* growing in drier areas such as East Anglia (including Thetford forest) may be more susceptible to attack.

Stage 3: Pest Risk Management

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

Exclusion

Due to the uncertainties over potential UK impacts, continued exclusion of *D. valens* would appear to be the best option for the UK. There are already legislative measures in place to control the entry of *Pinus* and other conifer wood and plants into the UK, and many of these measures are designed to mitigate against the entry of bark beetles such as *D. valens*. However, from interceptions in the UK (including the one finding of *D. valens* in a construction for pet rodents), it appears that the trade in potentially risky ornamental wood products is not always adequately controlled. Ongoing or enhanced inspection of any *Pinus* wood with bark, wood chips or *Pinus* wood packaging material from North America and China and awareness raising with relevant importers would help to monitor the risk of these pathways. Review of the appropriate legislation may also help to manage the risk. Given the potential distances adult *D. valens* are capable of flying and their highly cryptic lifestyles, future inclusion of pest free areas as a further mitigation would be problematic due to difficulties of surveying for the presence of this pest. Monoterpenes from pine resin (including turpentine) are attractants for *D. valens* (Owen *et al.*, 2010), and baited traps may aid surveys for this pest.

Eradication and containment

Early detection of any outbreak would be crucial in eradication or containment measures. *Dendroctonus valens* is very cryptic, spending most of its lifecycle under the bark. Adults, which are the life stage most likely to be encountered as they may be found outside the tree, are difficult to distinguish from many other bark beetles unless examined by a specialist in the laboratory. The species *D. micans* is already established in parts of Great Britain (Northern Ireland, the Isle of Man and Jersey have protected zones for *D. micans*) and, although *D. micans* mainly attacks *Picea* species in the UK, *Pinus* is a recorded host and it is possible that it could be confused with *D. valens* without specialist identification. There are other species of bark beetle in the UK which preferentially attack *Pinus* and, again, without specialist identification *D. valens* might be confused with these species. This could lead to a delay in identification meaning that any incursion might have a chance to spread significantly before detection.

If *D. valens* was detected in the wider environment in the UK, a number of measures could be implemented to eradicate or contain the outbreak. Measures should include controlling the movement of trees and timber (with bark) of all host species out of the infested area to prevent spread, and clearing infested trees (including the stumps and top parts of the roots), trees which could be attractive to the beetles (e.g. windblown trees), and disposing of the felled timber in a safe manner which does not spread the beetle. Given *D. valens* is capable of flying some distance, the use of ring barked trap trees and/or exploiting some of the research on attractant semiochemicals may be of benefit in reducing the spread by providing attractive hosts for the beetles to colonise within the outbreak area. Trap trees can be felled and disposed of later. Depending on the size of the outbreak, local publicity and/or education for foresters on identifying the signs of infestation with *D. valens* and distinguishing it from bark beetles already in the UK may be beneficial.

The Forestry Commission have published a contingency plan in preparation for findings of a different bark beetle, *Ips typographus* (Poulsom, 2015). Elements of that contingency plan may be of use in managing any outbreak of *D. valens*, though consideration would need to be given to the fact the two species do have different biologies and not all elements of the contingency plan would be appropriate for *D. valens*. Early indications are that the Forestry Commission have been able to locally eradicate an incursion of *I. typographus* that was detected in Kent in 2018, which indicates that if *D. valens* was detected early enough, eradication may be feasible.

Non-statutory controls

Given *D. valens* is not known to be present in the UK, or anywhere in Europe, non-statutory controls are not likely to be appropriate in managing any outbreaks of *D. valens* in the UK unless this pest is deregulated.

Dendroctonus valens is seldom subject to control measures in North America, because it is not generally a primary pest there. In China, control measures include good silvicultural practices such as minimising pruning or carefully timing it to reduce the attractiveness of wounded trees during adult flight periods; removing felled or fallen trees promptly and reducing tree density to improve tree resilience (Sun *et al.*, 2013). Semiochemicals which attract *D. valens* are known, and have been used in traps in China (Sun *et al.*, 2013). Similar measures could be employed in the UK if this beetle became established and caused damage. These may be of use in keeping local populations down to a manageable level, though are only likely to be effective in population control when other measures such as enhancing tree health and reducing stressors are also employed. Chemical control measures which are mentioned in some of the Chinese literature (e.g. Yan *et al.*, 2005) are highly unlikely to be approved for use in either forestry or amenity trees in the UK as pesticide approvals differ markedly between the two countries.

18. References

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