This text is an integral part of the *EPPO Study on bark and ambrosia beetles associated with imported non-coniferous wood* and should be read in conjunction with the study

Pest information sheet
Ambrosia beetle

XYLEBORUS GLABRATUS (COLEOPTERA: SCOLYTINAE)

redbay ambrosia beetle

EPPO Lists: Xyleborus glabratus was added to the EPPO Alert List in 2014 (updated version: EPPO, 2018a). The assessment of potential risks in this information sheet is not based on a full PRA for the EPPO region, but on an assessment of the limited information for that species used to prepare the information sheet.

PEST OVERVIEW

Taxonomy

Xyleborus glabratus Eichhoff 1877. No synonyms.

Associated fungi

The ambrosia symbiont is *Raffaelea lauricola* (Fraedrich *et al.*, 2008), which proved to be pathogenic on *Persea borbonia* and *P. palustris*, and causes vascular wilt on *P. americana* (EPPO, 2018a). In addition, Harrington *et al.* (2010) found five other *Raffaelea* species associated with *X. glabratus*: *R. arxii*, and 4 new species *R. subalba, R. ellipticospora, R. fusca* and R. *subfusca.* No information was found on the pathogenicity of these species.

Morphology and biology

Adults are 2-3 mm long, slender and brown-black in colour. Adult females tunnel in the xylem, infecting the host with *R. lauricola*. A comprehensive summary, including detailed pictures, is provided by Mann *et al.* (2015), and additional general information can be found in Haack and Rabaglia (2013) and EPPO (2018a). Although little is known on the biology of the species, it is noted that, as in the other *Xyleborus* species (Kirkendall, 1983), the sex ratio is very strongly female-biased, reproduction is haplodiploid, the males are haploid, flightless and dwarfed, and mate with their sisters in the gallery where there were born. Single, fertilised females leave the galleries and colonise hosts.

Under controlled conditions, the optimal temperature was ca. 28 °C, no development was observed at 16 °C, and it is estimated that the lower threshold temperatures for egg and pupal development is ca. 14°C and 11°C (Brar *et al.*, 2015). At 25°C in logs (*Persea americana*, *P. borbonia* and *P. palustris*), teneral adults started appearing ca. 30 days after gallery initiation and mature females emerged after ca. 60 days (i.e. teneral adults spent ca. 30 days in the host) (Brar *et al.*, 2013). Formby *et al.* (2013, 2018) showed that *X. glabratus* is freeze-intolerant and chill-susceptible. The lower lethal temperature (−10.0°C) was warmer than the supercooling point (− 22.0°C), and chill injury was observed at −5°C. They concluded that temperatures will be limiting via chill injury where minimum winter temperatures are −6.2°C or colder for 12 h.

Xyleborus glabratus attacks healthy and stressed hosts (Hughes *et al.*, 2016). *Persea borbonia* of a diameter >2.5 cm were rapidly killed, but smaller diameter trees (< 2.5cm) survived for years. Trees < 2.5 cm were poor quality hosts for *X. glabratus*, and brood production was rare, took a very long time (emergence took 4-6 months), and produced small numbers of beetles. The smallest stem section with a successful gallery was 1.7 cm diameter (Maner *et al.*, 2014).

The presence of *P. borbonia* (redbay) has been key to the epidemics observed in the USA. In Georgia, laurel wilt nevertheless persisted in counties where *Sassafras* is common but redbay is rare (Haack and Rabaglia, 2013). At several sites in South Carolina and Georgia, populations of *X. glabratus* persisted but declined to very low levels over a period of nine years after initial invasion in areas where all larger trees (of preferred diameter) had been killed. It was suggested that once the initial phase of the infestation had killed all larger trees, *X. glabratus* performed poorly, and was not infesting other hosts (Maner *et al.*, 2014).

Spread biology

X. glabratus appears to be a poor flyer. According to recent studies in a flight mill, ca. 90% flew <20 m over a 24 h period, and only a very small proportion flew between 100-200 m. It is not known how far emerging females can fly before initiating boring, and results indicated that flights >10 m per day may be rare. The potential spread was estimated to be up to 250 m within forests during a period of two weeks (Seo *et al.*, 2017). It is unknown, though, how many days the beetles can fly and whether (and how) they proceed to regeneration feeding between flights.

Nature of the damage

Damage results from the tunnelling of *X. glabratus* infecting the tree with *R. lauricola*. The susceptibility of hosts varies, and American Lauraceae have generally proved to be more susceptible to the disease in the USA (Ploetz *et al.*, 2016b). Trees of highly susceptible species such as *P. borbonia*, *P. palustris* and sassafras die. *Persea borbonia* appears to have been the most susceptible species in the USA, and has been extensively killed. The whole crown wilts within few weeks to few months, resulting in eventual tree death (Fraedrich *et al.*, 2008). In contrast, *Cinnamomum camphora* is generally not killed, but wilt and dieback can occur in infected branches (Hughes *et al.*, 2016). Fraedrich *et al.* (2011) mention that aborted attacks by *X. glabratus* also allow infection by *R. lauricola*, and this may be important even for hosts that may not support brood production.

Detection and identification

- *Symptoms.* Entrance holes in the bark are either resinous or produce light-coloured boring dust. *X. glabratus* bores characteristic galleries in the wood. It can produce frass tubes that resemble 'tooth picks' extending out from the bark. It is more common to see piles of sawdust around the base of the tree than the tubes themselves. Symptoms of laurel wilt are typical of vascular wilt pathogens: vascular black discoloration, rapid wilting, necrosis of foliage and defoliation (EPPO, 2018a). In some species, wilted leaves may persist on the dead tree for a year or more (Hughes *et al.*, 2016).
- *Trapping*. Manuka oil lure and cubeb oil are attractants (Brar *et al.*, 2012, Hanuna *et al.*, 2013) as well as 50% a-copaene lure (Hughes *et al.*, 2017b, citing others). *X. glabratus* are attracted to the leaf odors of their hosts, redbay and *P. palustris* (swamp bay) (Martini *et al.*, 2015). Methyl salicylate and verbenone are repellent and could be used in push-pull strategies together with attractants (Hughes *et al.*, 2017b).
- *Identification.* Benzel (2015) provides details on identification, and comparisons with other species and Gomez *et al.* (2018) a key to *Xyleborus* species (for the USA).

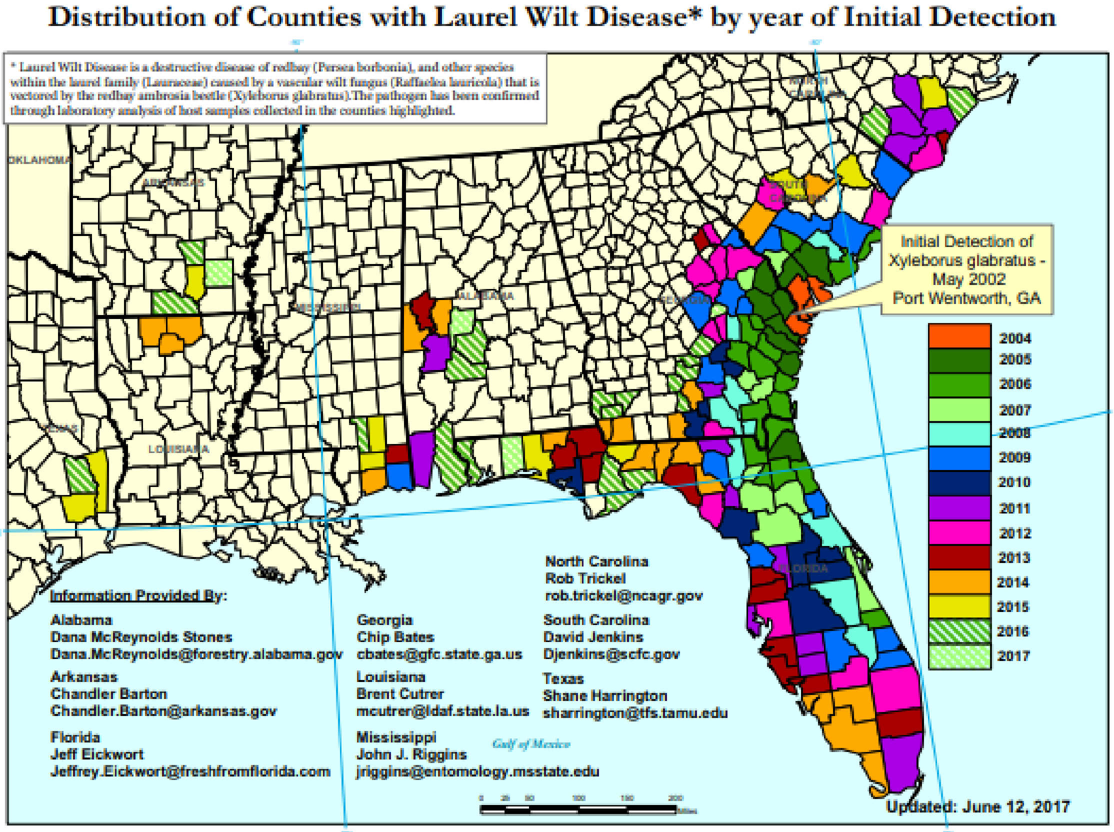
Distribution (see Table 1)

Xyleborus glabratus is native to Asia. In the USA, it was first trapped in May 2002 in a trap located at Port Wentworth (near Savannah, Georgia), and has since been recorded throughout the South-East (EPPO, 2018a; Gomez *et al.*, 2018). Formby *et al.* (2018) provides a map illustrating spread in southern USA (see Map 1).

Host plants (see Table 2)

In Asia, *X. glabratus* has been found associated with many Lauraceae species, but also on trees of other families such as: *Leucaena glauca* (Fabaceae), *Lithocarpus edulis* (Fagaceae), *Schima superba* (Theaceae), *Shorea robusta* (Dipterocarpaceae) (EPPO, 2018a). In the USA, it has been recorded on Lauraceae, and has been found on *Persea borbonia* (redbay), *P. palustris* (swampbay), *P. humilis* (silkbay), *P. americana* (avocado), *Sassafras albidum, Lindera benzoin* (northern spicebush), *Cinnamomum camphora* (camphor), *Laurus nobilis* (bay laurel) (Brar *et al.*, 2015, Hughes *et al.*, 2014; Fraedrich *et al.*, 2016). *P. borbonia*, a North American species, is a key host and the most affected in the USA. The significance of non-Lauraceae hosts is not known.

Raffaelea lauricola has also been isolated from *Lindera melissifolia* and *Litsea aestivalis,* which are considered as endangered species but the impact of laurel wilt on these tree species remains uncertain (EPPO, 2018a). In experiments, some other Lauraceae species were found to be susceptible to laurel wilt: *Umbellularia californica* (California bay laurel) *Licaria triandra* (Gulf licaria), *Persea indica* (viñátigo) (Hughes *et al.*, 2016, citing others).



Map 1. Spread of *X. glabratus* is southern USA (from Formby *et al.*, 2018)

Known impacts and control in current distribution

In Asia, neither *R. lauricola* nor *X. glabratus* had previously been reported to cause laurel wilt (Haack and Rabaglia, 2013), and *X. glabratus* was not considered of economic importance in its native range (Beaver and Liu, 2010). However, a first record of laurel wilt caused by *R. lauricola* was made in 2014 in Myanmar, killing avocado trees within 1-2 months of symptoms appearance (Ploetz *et al.*, 2016a).

In the USA, laurel wilt has caused widespread mortality of *P. borbonia* and *P. palustris*, killing nearly all trees in the colonized areas within 3-5 years after *X. glabratus* was first detected in 2002. In some areas, up to 90% tree mortality has been recorded. Both wild and urban populations of *P. borbonia* and *P. palustris* have been killed (Martini *et al.*, 2015). In South Carolina, laurel wilt has killed *P. borbonia* trees along the coast, and continues to spread (SCFH, 2016). Over 300 million *P. borbonia* are estimated to have been killed in the USA since the early 2000s (ca. 1/3 of the pre-invasion population). Based on genetic analysis, there was only one single introduction of *X. glabratus* and *R. lauricola* (Hughes *et al.*, 2017a). In some areas in Georgia, the composition of forest communities was altered by *R. lauricola*, as after the destruction of *P. borbonia*, and other tree species (e.g. *Magnolia virginiana* and *Gordonia lasianthus*) became dominant (EPPO, 2018a; Brar *et al.* 2015 citing others).

In the USA, the role of *X. glabratus* on avocado is not clear. In Florida, the first avocado tree killed by *R. lauricola* was found in 2006 and by 2011, the fungus had spread to the main avocado production area (Ploetz *et al.*, 2016b). As of July 2013, *R. lauricola* had been detected on 90 avocado trees in various commercial groves, and more than 1900 symptomatic trees had been removed as part of a suppression and sanitation strategy (EPPO, 2018a). Where the implementation of control measures was insufficient, laurel wilt has spread rapidly, resulting in loss of commercial viability and orchard abandonment. Rapid spread has especially been observed in areas with high density of *P. borbonia* and *P. palustris*. However, *X. glabratus* has rarely been trapped in affected commercial avocado orchards. *R. lauricola* has been found able to be associated (experimentally or naturally) to nine other ambrosia beetle species (e.g. *Xyleborus affinis, X. ferrugineus, X. volvulus, Xyleborinus gracilis, X. saxeseni, Xylosandrus crassiusculus*) (Ploetz *et al.*, 2016b). It is not known yet if the spread of the fungus in avocado is due to another species or to other factors.

Finally, numerous Lauraceae shrub and tree species native to North America are susceptible and threatened. *X. glabratus* and *R. lauricola* may also have negative impacts on the associated fauna and flora, as well impacts on ecosystems due to the death of hosts (Hughes *et al.*, 2017a).

Control. In the USA, cultural practices promoting the health of trees yield positive results. Removal and on-site destruction (by chipping or burning) of all infested trees (down to below soil surface) may reduce populations and slow the spread of the disease (Hughes *et al.*, 2016).

On avocado, the main control method against laurel wilt also consists of destroying infected trees. Surrounding trees can be protected from infection, temporarily, by injections of propiconazole (Hughes *et al.*, 2016; Ploetz *et al.*, 2016b). No efficacious and cost-effective control measures have been identified to date. Chemical control strategies had been developed for *X. glabratus*, in the expectation that it would pass from its natural habitats to avocado production, but it does not appear to be the main vector on avocado, and these strategies would need to be redesigned for other vectors, once identified (Ploetz *et al.*, 2016b).

POTENTIAL RISKS FOR THE EPPO REGION

Pathways

Entry

Life stages are associated with the wood of host trees. Haack and Rabaglia (2013) report only one interception, from China, in the period 1984-2008. In the USA, it is suspected that *X. glabratus* carrying *R. lauricola* was introduced with wood packaging material from Asia, and the movement of infested firewood was considered to be an important means of dissemination within the USA. Processes applied to produce wood commodities would destroy some individuals. The survival of *X. glabratus* and *R. lauricola* in wood chips made from infested *P. borbonia* trees has been studied. Chipping can significantly reduce the number of *X. glabratus* and limit the persistence of *R. lauricola* but does not completely eliminate them (EPPO, 2018a). The likelihood of entry on wood chips, hogwood and processing wood residues would be lower than on round wood, as individuals would have to survive processing and transport, and transfer to a suitable host is less likely. The wood would also degrade and not be able to sustain development of the pest. Bark on its own is an unlikely pathway.

A major issue for this pest is whether infested wood from host species is traded internationally. From Asia, it is not known how prevalent *X. glabratus* is on its known hosts, and it is not clear if non-Lauraceae are reproductive hosts. From the USA, it is unlikely that the main hosts *Persea borbonia* and *P. palustris* are traded as round (or sawn) wood, and it is not known if infested firewood would be traded internationally, or if these species may also be traded as wood chips, hogwood or processing wood residues. The wood of some other Lauraceae hosts such as *Cinnamomum camphora*, *Umbellaria californica* (experimental host only) is used and traded worldwide (www.wood-database.com; EPPO, 2017), but no data was available on trade into the EPPO region.

Entry on plants for planting may also be possible if these species are traded (e.g. hosts used as ornamentals in the EPPO region, such as *C. camphora* - EPPO, 2017). *X. glabratus* may also be associated with small diameter material, although trees < 2.5 cm are poor quality hosts and produce small numbers of beetles (Maner *et al.*, 2014). Data from the EU Project Isefor (Increasing sustainability of European forests: Modelling for security against invasive pests and pathogens under climate change) for the period 2001-2010 reports 4 *Persea* plants imported from the USA in 2003 and 10 from China in 2010. Plants for planting are normally subject to controls during production, and attacked plants may be detected and discarded. It is not clear if *X. glabratus* would be associated with the pathways, and some data is lacking on the trade of hosts. Cut branches are a less likely pathway, as they are used indoors, and the pest is unlikely to be able to transfer to a suitable host; in addition it is not known if the hosts are used and traded as cut branches. Avocado fruit is not a pathway.

Raffaelea lauricola has been found on more hosts than *X. glabratus* and associated with other ambrosia beetle species, which may have additional implications for entry.

Finally, inbreeding is favourable to entry and establishment.

Summary of pathways (uncertain pathways are marked with '?'):

- *wood packaging material if not treated according to ISPM 15*
- *wood (round or sawn, with or without bark, incl. firewood) of hosts*
- *non-coniferous wood chips, hogwood, processing wood residues (except sawdust and shavings)*
- *plants for planting (except seeds) of hosts*
- *cut branches of hosts?*

Because X. glabratus has attacked new Lauraceae hosts, in addition to known hosts, pathways may cover all Lauraceae.

Spread (following introduction, i.e. within EPPO region)
In the USA, natural spread has occurred, but human-assisted movement of infested host material has been suspected where long-distance spread occurred (Haack and Rabaglia, 2013). In the EPPO region, the known hosts are mostly ornamental trees and would have a restricted distribution (e.g. *C. camphora* – EPPO, 2017). Only *Laurus nobilis* is more widespread in natural environments and in gardens, but its suitability for the development of *X. glabratus* is not known to date (only one record appears to have been made to date in the USA). *X. glabratus* is also not a good flyer, and finding hosts in areas where they are scarce (e.g. only ornamentals) may be difficult and limit spread. According to recent information, *P. americana* does not appear to be a good host for *X. glabratus*, although some mortality was recently reported in Asia. Therefore, spread would be limited, unless *X. glabratus* finds a suitable and susceptible host, as happened with *P. borbonis* and *P. palustris* in the USA. In this case, human-assisted pathways may also lead to multiple introductions from which local spread could occur.

Establishment
Establishment in the EPPO region is considered possible as areas with suitable conditions and host plants are available in the EPPO region.
In most of its range, *X. glabratus* occurs mostly in tropical and subtropical countries. However, based on the climate classification of Köppen-Geiger (see Annex 6 of the study), in the USA *X. glabratus* has established in Cfa[1] type climates, which occur in Northern Italy, Balkans and around the Black Sea. In addition, cold temperatures are limiting (via chill injury), and establishment may not occur in areas where minimum winter temperatures are -6.2° C or colder for 12 h (Formby *et al.,* 2018). This would exclude a large part of the EPPO region. There is therefore a strong uncertainty about whether it could establish in more temperate areas.
Establishment would also be limited by the presence of hosts, and would be influenced by whether *X. glabratus* is able to find new hosts. The known hosts *Laurus nobilis* and *Persea americana* are more widespread in the Mediterranean area, and Lauraceae are otherwise used mostly as ornamentals, but there are also some native Lauraceae in the EPPO region (see below).

Potential impact (including consideration of host plants)
The known hosts of *X. glabratus* are not widely present in the EPPO region and are mostly used as ornamentals. Only *Laurus nobilis* (host status unclear) is native to the Mediterranean area and widespread in Europe (EPPO, 2018a), in the wild in its native range and as an ornamental in other parts of the region. However, *X. glabratus* has found new hosts in the USA, and this may also happen in the EPPO region. Potential impacts would depend on the susceptibility of these species to *R. lauricola* and *X. glabratus*. Laurel forests of high patrimonial value (including Lauraceae genera such as *Apollonias, Ocotea, Persea*) are found in the Azores, Madeira (PT) and Islas Canarias (ES), but their susceptibility is not known (EPPO, 2018a).

Avocado is not widely grown in the EPPO region, but is of economic importance at least in Israel and Spain (EPPO, 2018a). Laurel wilt caused by *R. lauricola* could certainly threaten avocado production, but the role of *X. glabratus* in laurel wilt on avocado is not clear. In the USA, other ambrosia beetle species are suspected to vector the fungus in orchards, while in Myanmar, the possible vector was not mentioned. In the EPPO region the potential impact on avocado may arise from other vectors carrying the fungus. Until these vectors are known, *X. glabratus* is the only species that can be targeted to try and avoid the introduction and impacts by *R. lauricola* on avocado.

Table 1. Distribution of *X. glabratus*

	Reference	**Comments**
EPPO region		
Absent		Also *R. lauricola*
Asia		
Bangladesh	EPPO, 2018b	

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[1] **Cfa**: warm temperate climate, fully humid, hot summer.

	Reference	**Comments**
China (Fujian, Hunan, Sichuan)	EPPO, 2018b	
India (Assam, West Bengal)	EPPO, 2018b	
Japan (Kyushu)	EPPO, 2018b	Also *R. lauricola*
Myanmar	EPPO, 2018b	Also *R. lauricola*
Taiwan	EPPO, 2018b	Also *R. lauricola*
North America		
USA (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas)	EPPO, 2018b	Alabama and Mississipi, 2010 (Formby *et al.*, 2012) *R. lauricola* recorded in the same states

Table 2. Hosts of *X. glabratus*, and other known hosts of *R. lauricola* only

Family	**Genus/Species**	**Reference**
Lauraceae	*Cinnamomum camphora*	Hughes *et al.*, 2016
Lauraceae	*Cinnamomum osmophloeum*	EPPO, 2018b
Lauraceae	*Laurus nobilis*	Hughes *et al.*, 2016
Lauraceae	*Lindera benzoin*	Fraedrich *et al.*, 2016
Lauraceae	*Lindera latifolia*	EPPO, 2018b
Lauraceae	*Litsea elongata*	EPPO, 2018b
Lauraceae	*Machilus nanmu*	EPPO, 2018a
Lauraceae	*Persea americana*	Hughes *et al.*, 2016
Lauraceae	*Persea borbonia*	Hughes *et al.*, 2016
Lauraceae	*Persea humilis*	Hughes *et al.*, 2016
Lauraceae	*Persea palustris*	Hughes *et al.*, 2016
Lauraceae	*Phoebe lanceolata*	EPPO, 2018a
Lauraceae	*Phoebe neurantha*	EPPO, 2018a
Lauraceae	*Phoebe zhennan*	EPPO, 2018a
Lauraceae	*Sassafras albidum*	Hughes *et al.*, 2016
Dipterocarpaceae	*Shorea*	EPPO, 2018b
Dipterocarpaceae	*Shorea robusta*	EPPO, 2018a
Fabaceae	*Leucaena*	EPPO, 2018b
Fabaceae	*Leucaena glauca*	EPPO, 2018a
Fagaceae	*Lithocarpus*	EPPO, 2018b
Fagaceae	*Lithocarpus edulis*	EPPO, 2018a
Theaceae	*Schima superba*	EPPO, 2018a
Species on which *R. lauricola* has been isolated		
Lauraceae	*Lindera melissifolia*	EPPO, 2018a
Lauraceae	*Litsea aestivalis*	EPPO, 2018a
Experimental hosts of *R. lauricola*		
Lauraceae	*Umbellularia californica*	Hughes *et al.* 2016
Lauraceae	*Persea indica*	Hughes *et al.* 2016
Lauraceae	*Licaria triandra*	Hughes *et al.* 2016

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