Mini Risk Assessment
Ambrosia beetle: *Platypus quercivorus* Murayama
[Coleoptera: Platypodidae]

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Figure 1. *Platypus quercivorus* adult and wood boring damage (images not to scale). [Image courtesy of: http://ss.ffpri.affrc.go.jp/research/ryoiki/07for-entom/07.html].

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Introduction

Platypus quercivorus, a wood boring ambrosia beetle, is considered a significant pest of oaks in Japan. In mythology, "ambrosia" was a term for the food or nectar of the gods, so the beetles are aptly named for their close association with ambrosia fungi which are used as a source of nutrition. *Raffaelea quercivora*, an ambrosia fungus closely associated with and vectored by *P. quercivorus*, is associated with Japanese oak disease (also known as Japanese oak wilt). Both the insect and the pathogen have contributed to significant oak mortality in Japan. *P. quercivorus* occurs in east and southeast Asia, and is not currently known to occur in the United States.

The risks posed by *P. quercivorus* to natural resources in the US have been evaluated previously. Ciesla (2003) concluded that the insect poses very high risk but recognized that this rating was very uncertain. Uncertainty stemmed from a significant lack of knowledge about how the insect and pathogen might affect oak species that occur in the US. The purpose of this "mini" pest risk assessment is to further evaluate several factors that contribute to risks posed by *P. quercivorus* itself and apply this information to the refinement of sampling and detection programs. A companion risk assessment by Kromroy and Venette (2005) evaluates potential risks posed by the pathogen, *R. quercivora*.

1. **Ecological Suitability. Rating: Medium.** *Platypus quercivorus* is common in parts of Japan and is present, but to a very limited extent, in India, Taiwan, Indonesia, and Papua New Guinea. In general, *P. quercivorus* occurs in temperate or tropical climates with adequate seasonal rainfall to support deciduous tree hosts [see 'Host Specificity']. The currently reported distribution of *P. quercivorus* suggests that the pest may be most closely associated with biomes characterized as temperate broadleaf and mixed forests and tropical and subtropical moist broadleaf forests. Consequently, we estimate that approximately 29% of the continental US would have a suitable climate for *Platypus quercivorus* (Fig. 2). See Appendix A for a more complete description of this analysis.

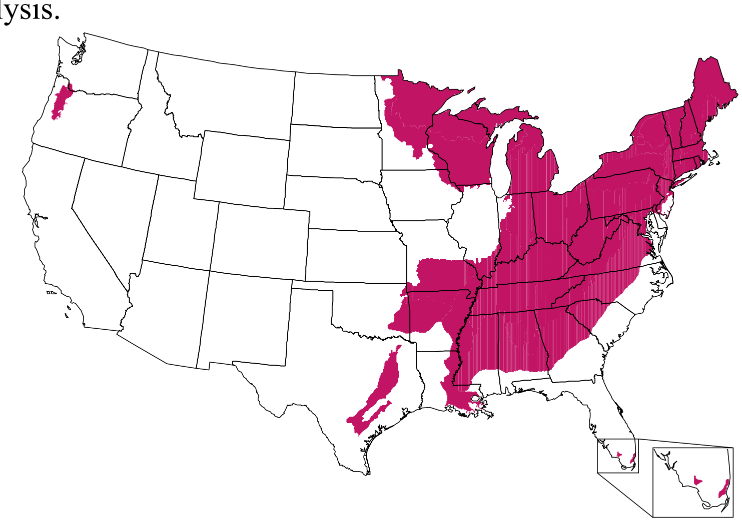

Figure 2. Predicted distribution (shaded pink) of *Platypus quercivorus* in the contiguous US.

Figure 2 illustrates where *P. quercivorus* is most likely to encounter a suitable climate for establishment within the continental US. This prediction is based only on the known geographic distribution of the species. Because this forecast is based on coarse information, areas that are not highlighted on the map may have some chance of supporting populations of this exotic species. However, establishment in these areas is less likely than in those areas that are highlighted. For initial surveys, survey efforts should be concentrated in the higher risk areas and gradually expanded as needed.

This is the first time that a complex of an ambrosia beetle and fungus has been reported to kill healthy trees (Kamata 2002, Kamata et al. 2002, Esaki et al. 2004). Kamata et al. (2002) suggest that a warmer climate may have allowed *P. quercivorus* (and associated fungi) to extend its range northward to new areas with abundant, highly-susceptible hosts (Kühnholz et al. 2001, Kamata 2002, Kamata et al. 2002). The climatic tolerances of the beetle may be wider than those of the pathogen. Although the beetle has been reported from a number of countries (Appendix A), the pathogen has only been reported from Japan (reviewed in Kromroy and Venette 2005). Specific abiotic conditions may be needed for the beetle-fungus complex to cause extensive mortality, but these conditions have not been specified.

2. **Host Specificity/Availability. Rating: Medium/Low.** True hosts of *Platypus quercivorus* are members of the family Fagaceae (Table 1), but the plant species which are known to support the growth and development of the insect are either not grown in the US or are of limited distribution (e.g., ornamental plantings). Although this pest has reportedly bored into several non-Fagaceous species adjacent to an area of mass attack, *P. quercivorus* cannot successfully reproduce on these trees (Dr. Akira Ueda, Hokkaido Research Center, personal communication). Trees that may be attacked but will not support reproduction include:

    <u>Cupressaceae [=Taxodiaceae]</u>
    Japanese cedar, *Cryptomeria japonica* (Wood and Bright 1992, Ciesla 2003, CAB 2004)

    <u>Aquifoliaceae</u>
    Chinese holly, *Ilex chinensis* (Wood and Bright 1992, Ciesla 2003, CAB 2004)

    <u>Lauraceae</u>
    Japanese silver tree, *Neolitsea sericea* (Soné et al. 1995)
    common machilus, *Persea* (=*Machilus*) *thunbergii* (Soné et al. 1995, Sato 2003)
    wild machilus, *Persea* (=*Machilus*) *japonica* (Soné et al. 1995)
    spicebush, *Lindera erythrocarpa* (Wood and Bright 1992, Ciesla 2003, CAB 2004)

Rosaceae
Korean mountain ash, *Sorbus alnifolia* (Kobayashi and Ueda 2002)
Prunus sp. (Wood and Bright 1992, Ciesla 2003, CAB 2004)

Table 1. Host plants of *Platypus quercivorus*:

Hosts	**References**
chestnut, Japanese[2] (*Castanea crenata*)	(Igeta et al. 2003)
chinkapin, Japanese (*Castanopsis cuspidata*)	(Wood and Bright 1992, Mori et al. 1995, Ciesla 2003, CAB 2004)
ichiigashi (*Quercus gilva*)	(Murayama 1925, Wood and Bright 1992, Ciesla 2003, CAB 2004)
oak (*Quercus* sp.)	(Hijii et al. 1991, Soné et al. 1998, Saito et al. 2001, Kobayashi and Ueda 2002, Beaver and Shih 2003, Ito et al. 2003b, Ueda and Kobayashi 2004)
oak, Japanese (*Lithocarpus glaber* (= *Pasania glabra*))	(Wood and Bright 1992, Ciesla 2003, CAB 2004)
oak, Japanese evergreen (*Quercus acuta*)	(Wood and Bright 1992, Mori et al. 1995, Kamata et al. 2002, Ciesla 2003, Igeta et al. 2003, CAB 2004, Esaki et al. 2004, Igeta et al. 2004b)
oak, Japanese tanbark (*Lithocarpus edulis* (= *Pasania edulis*))	(Murayama 1925, Wood and Bright 1992, Mori et al. 1995, Soné et al. 1995, Soné et al. 1998, Soné et al. 2000, Ciesla 2003, Sato 2003, CAB 2004, Kitajima and Goto 2004)
oak, Japanese white (*Quercus myrsinaefolia*)	(Wood and Bright 1992)
oak, Konara (*Quercus serrata*)	(Yamada and Ichihara, Hijii et al. 1991, Wood and Bright 1992, Kuroda and Yamada 1996, Ito et al. 1998, Kinuura et al. 1998, Kobayashi et al. 2001, Kuroda 2001, Ohya and Kinuura 2001, Ueda and Kobayashi 2001, Yamato et al. 2001, Kamata et al. 2002, Kobayashi and Ueda 2002, Kubono and Ito 2002, Ciesla 2003, Igeta et al. 2003, Kobayashi and Ueda 2003, CAB 2004, Esaki et al. 2004, Kitajima and Goto 2004, Ueda and Kobayashi 2004)

Hosts	References
oak, Mongolian[2] (*Quercus mongolica* (= *Q. crispula* (= *Q. mongolica* var. *grosseserrata*)))	(Yamada and Ichihara, Wood and Bright 1992, Kuroda and Yamada 1996, Mizobuti et al. 1996, Ito et al. 1998, Kinuura et al. 1998, Masuya et al. 1998, Kobayashi et al. 2001, Kuroda 2001, Ohya and Kinuura 2001, Ueda and Kobayashi 2001, Yamato et al. 2001, Kamata et al. 2002, Kobayashi and Ueda 2002, Kubono and Ito 2002, Ciesla 2003, Igeta et al. 2003, Kobayashi and Ueda 2003, Kobayashi et al. 2003, CAB 2004, Esaki et al. 2004, Kitajima and Goto 2004, Ueda and Kobayashi 2004)
oak, ring-cup or Japanese blue (*Quercus glauca* (= *Q. myrsinifolia*))	(Murayama 1925, Wood and Bright 1992, Ciesla 2003, CAB 2004)
oak, sawtooth[2] (*Quercus acutissima*)	(Wood and Bright 1992, Ciesla 2003, CAB 2004)
oak, ubame (*Quercus phillyraeoides*)	(Ciesla 2003, CAB 2004)
Quercus crispuloserrata	(Hijii et al. 1991)
Quercus senata[1]	(Igeta et al. 2004b)
sudajii (*Castanopsis sieboldii* (= *C. cuspidate* var. *sieboldii*))	(Kamata et al. 2002, Esaki et al. 2004)
tsukubanegashi (*Quercus sessilifolia*)	(Wood and Bright 1992, Ciesla 2003, CAB 2004)
urajirogashi (*Quercus salicina*)	(Wood and Bright 1992, Mori et al. 1995, Ciesla 2003, CAB 2004, Igeta et al. 2004b)

1. Probable misspelling for *Quercus serrata*. *Quercus* "*senata*" is not a recognized species.
2. These plants occur in the U.S.; introduced species (USDA NRCS 2004).

Appendix B provides maps with the distribution of potential hosts in the continental US. The host status of the species in Appendix B has not been confirmed (i.e., it has not yet been demonstrated that the insect will feed and develop on these plants).

3. **Survey Methodology. Rating: Medium.** Surveys for *Platypus quercivorus* are likely to be difficult. Although an aggregation pheromone has been suggested for another *Platypus* sp. (Milligan et al. 1988), *Platypus*-attractants are not yet sufficiently reliable for use with traps. *Platypus quercivorus* may have a weak attraction to ethanol (Kobayashi and Hagita 2000), but the utility of ethanol for trapping *P. quercivorus* has been questioned (as reviewed in Esaki et al. 2002).

   Visual surveys are common for the beetle in declining or suspect stands. Suspect stands have wilted canopies during the summer in the absence of drought and/or a reddish-brown discoloration of leaves (Ciesla 2003). In these stands, oaks are examined for splinter-like wood shavings at the base of a tree (Ciesla 2003, CAB

2004) or entrance holes produced by male beetles. Wood shavings (Fig. 3) are produced by males as they create galleries for mating (Kobayashi and Ueda 2002).

Figure 3. Wood shavings produced by ambrosia beetles (Platypodidae). [Image courtesy of Randy Cyr, Forest Pests, www.forestpests.org]

In Japan, Esaki et al. (2004) examined ~46-160 trees/acre for research purposes. *P. quercivorus* preferentially attacks large trees (> 15cm [6 in.] dbh) (Soné et al. 1995, Esaki et al. 2004), and entrance holes are most common on the lower portion of a tree (less than 1.5m [5 ft] above ground) (Esaki et al. 2004). *P. quercivorus* is unlikely to attack trees that are less than 8 cm [3.1in] dbh (Sato 2003). Removal of bark surrounding an entrance hole may reveal brown discoloration of sapwood near galleries (Hijii et al. 1991, Ciesla 2003). Some galleries may penetrate into heartwood (CAB 2004).

For visual surveys, the number of samples needed to detect *P. quercivorus* depends on the frequency of infested trees in a stand and the desired confidence of detecting the beetle when it is present. In areas of Japan with well established pockets of oak wilt, *P. quercivorus* may attack 7-93% of trees that are susceptible to the fungus (Soné et al. 1995, Esaki et al. 2004). For early detection, it would be desirable to detect beetles before they infest this many trees. Assuming that (i) visual inspection of a single tree will locate beetles if they are present on that tree, (ii) a stand has a large number (e.g., >1000) of trees that may be fed upon by *P. quercivorus*, and (iii) trees are selected at random for inspection, binomial statistics can be used to determine the number of trees that must be examined to achieve a desired probability of finding at least one infested tree within a stand when the beetle is present. Figure 4 illustrates how the number of required samples changes as the proportion of trees with *P. quercivorus* and/or the desired probability of detecting at least one infested tree changes. In general, more samples are required as the desired probability of detection increases and as the proportion of trees with beetles decreases (i.e., the insects become rarer in the environment).

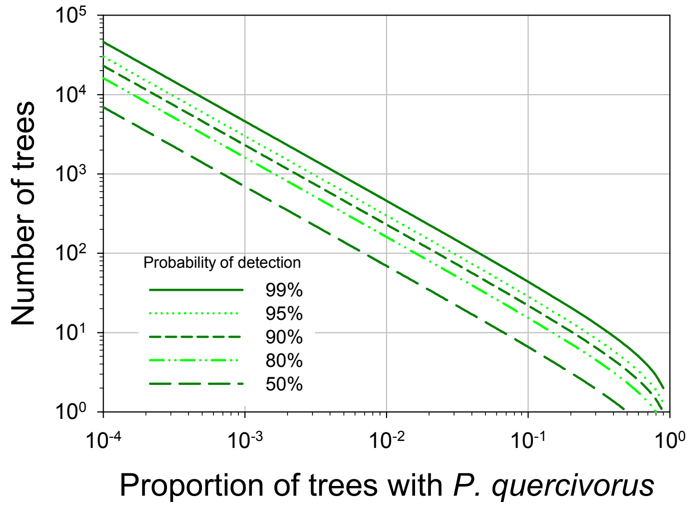

Figure 4. Required number of trees to be inspected for detection of *P quercivorus* in relation to the proportion of infested trees and the desired probability of detecting this insect. This figure assumes random sampling from a large environment.

As a complement to visual inspections, Japanese researchers recommend the use of interceptions traps, which non-selectively capture flying insects (Kinuura 1995, Esaki et al. 2002). An interception trap based on the use of nylon screen covered with a sticky coating was light, durable, and effective (Esaki et al. 2002, Esaki et al. 2004). Traps were constructed from a 1-m^2 piece of nylon mesh (mesh size = 2.4x2.6mm). Wooden stakes were attached horizontally to the top and bottom of the panel. The top stake was used to hang the trap, and the bottom stake provided weight to keep the trap straight. Traps were hung so that the bottom stake was 0.5 m [~1.6 ft] from the ground. This places the trap in the zone where most adults are captured (Hijii et al. 1991, Kobayashi and Hagita 2000, Ueda and Kobayashi 2001, Igeta et al. 2004b). This trap design is particularly convenient in areas with steep terrain or high winds.

Traps should be placed in June or July, the start of adult flight in Japan (Inoue et al. 1998, Ueda and Kobayashi 2001), near the edge of a stand where adults concentrate because of their attraction to light (Igeta et al. 2003). Traps should be checked weekly.

Bait logs have also been proposed as a monitoring tool. Logs should be >1 m long with a moisture content >60%; trap logs should be placed away from direct sunlight (Kobayashi et al. 2003, Kobayashi et al. 2004). Autoclaving logs extended their attractiveness (Ueda and Kobayashi 2004). This method cannot yet be recommended for use in the US because *Quercus crispula*, the species used for bait logs in Japan, is not widely available. Other tree species have not been tested.

4. **Taxonomic Recognition. Rating: Medium.** *P. quercivorus* adults may be confused with morphologically similar wood-boring relatives. There are hundreds of species within the genus *Platypus* worldwide, though the majority are tropical (Schedl 1972, Barbosa and Wagner 1989, Farrell et al. 2001). Available keys to species in the US are incomplete (Chamberlin 1939, Wood 1979, Atkinson 2004). Seven species reportedly occur in the contiguous US, and four of these species occur in Florida (Wood 1979, Bright and Skidmore 2002, Atkinson 2004), where our analysis also predicts *P. quercivorus* might become established (Fig. 2): *P. quadridentatus* occurs in oaks and other hardwood species in the southern and southeastern US (Drooz 1985, Atkinson 2004). *P. flavicornis* is a secondary attacker of pines and occasionally in several hardwoods in the eastern and southern US (Drooz 1985, Atkinson 2004). *P. compositus* and *P. parallelus* reportedly reproduce in a wide variety of tree hosts including oaks, with the latter considered a particularly damaging species in the souteastern US and Mexico (Drooz 1985, Cibrián Tovar et al. 1995, Atkinson 2004, CAB 2004). Adult beetles should be positively identified by a qualified taxonomist.

   Other factors may help distinguish *Platypus* spp. Certain symbiotic fungi are sufficiently species specific that identification of the fungus may assist with identification of the beetle (Baker 1963, Batra 1963). Wood-boring damage may also differentiate *Platypus* spp. For example, *P. quercivorus* produces splinters that accumulate with expelled frass near the base of infested trees during gallery construction; a fine sawdust is characteristic of other related species (Kuroda and Yamada 1996, Ciesla 2003, CAB 2004).

   For a detailed description of the morphology and taxonomy of *P. quercivorus*, see Appendix C.

5. **Entry Potential. Rating: Low.** Officers with the US Department of Agriculture, Animal and Plant Health Inspection Service or the US Department of Homeland Security have not reported an interception of *P. quercivorus* from 1985-2004 (USDA 2005). "Unspecified *Platypus* spp. have been intercepted at ports of entry at least 46 times between 1985 and 2004 (incomplete records complicate the accuracy of this count). Annually, only about 1.8 (±0.3 standard error of the mean) interceptions have been reported nationally (USDA 2005). The majority of these interceptions have been associated with permit cargo (50%) and general cargo (35%). The majority of interceptions were reported from Miami, FL (33%), Ft. Lauderdale, FL (11%), San Diego, CA (6%), Nogales, AZ (6%), and Houston, TX (6%). Similar patterns were reported for beetles identified simply as "Platypodidae; species of." Annually, 2.3 (±0.6) interceptions of unspecified Platypodidae were reported, most commonly from Ft. Lauderdale (11%), Miami (9%), and Brownsville, TX (9%). These ports are the first points of entry for infested material coming into the US and do not necessarily represent the final

destination of infested material. Movement of potentially infested material is more fully characterized in the next section.

Specimens identified as "*Platypus* sp" or "Platypodidae" were not necessarily *P. quercivorus*. However, even if all of these specimens were *P. quercivorus* the arrival rate would still be low compared with other insect pests.

The beetle-fungus complex may not survive in logs with low moisture content (Kobayashi and Ueda 2003, Kobayashi et al. 2004). If logs or wood products were sufficiently dried or debarked, viable beetles are not likely to survive. The general importance of moisture for ambrosia beetles and fungi is discussed by Barbosa and Wagner (1989).

6. **Destination of Infested Material. Rating: Low.** When an actionable pest is intercepted, officers ask for the intended final destination of the conveyance. Materials infested with "*Platypus* sp." were destined for 8 states (USDA 2005). The most commonly reported destinations were Florida (50%), California (17%), Texas (8%), and Illinois (6%). We note that portions of Florida, Texas, and Illinois have a climate and hosts that would be suitable for establishment by *P quercivorus*. Shipments infested with unspecified Platypodidae were destined for 15 states. Florida, California, and Texas were the most commonly reported intended destinations. Although it is unlikely, if all unspecified Platypodidae were *P. quercivorus*, a medium rating for this element would be warranted. Thus, a moderate degree of uncertainty is associated with the low rating.

7. **Potential Economic Impact. Rating: High.** *Platypus quercivorus* is an important pest of Japanese oaks, chestnuts and other Fagaceae [see 'Host Specificity']. In Japan, the *R. quercivora* - *P. quercivorus* complex has killed approximately 100,000-200,000 Fagaceous trees annually since about 1980; the majority of affected hosts are *Quercus serrata* and *Q. mongolica* var. *grosseserrata* (Ito et al. 2003a, Ito et al. 2003b). This is the first time that an ambrosia beetle-fungus complex has killed healthy trees (Kamata 2002, Kamata et al. 2002, Ito et al. 2003a, Ito et al. 2003b, Esaki et al. 2004). Tree death can occur the same year as a mass attack by *P. quercivorus*, but most oaks die within three years (Kamata 2002, Kubono and Ito 2002, Kobayashi and Ueda 2003). Wilting may be evident within 10 days (Ito et al. 2003a, Ito et al. 2003b). Generally, the white oak group seems susceptible, but species of white oaks show differing degrees of susceptibility.

   The economic impact of *P. quercivorus* by itself in Japan is difficult to measure, especially because it occurs in mixed populations with other secondary attackers (Inoue et al. 1998, Soné et al. 1998, Ueda and Kobayashi 2001). Damage associated with *P. quercivorus* was reported ca. 70 years ago, but it is not clear if this damage referred to mortality or whether damage was caused by the beetle alone or the beetle and *R. quercivora* (reviewed in Hamaguchi and Goto 2003). In Japan, mortality from *P. quercivorus* was less severe in broadleaf evergreen forests than in broadleaf deciduous forests (M. Yamato, personal communication, Zhou undated). Kromroy and Venette (2005) describe *Raffaelea quercivora* in a companion risk assessment.

Platypus quercivorus can slow growth and increase mortality of host and non-host trees. Newly felled trees and cut timber contribute to mass attack and death of nearby living trees (Kobayashi and Hagita 2000, Igeta et al. 2004b). *P. quercivorus* typically will bore into trees adjacent to areas of mass attack, even nutritionally unsuitable hosts (A. Ueda, personal communication, Ueda and Kobayashi 2001).

Wood boring predisposes trees to further damage by secondary pests including other ambrosia and bark beetles, decay fungi and other microorganisms (Beaver 1989, Kozlowski et al. 1991). Damage of this nature impacts wood quality, both aesthetically (discoloration of sapwood) and structurally (Hijii et al. 1991, Manion 1991, Kuroda and Yamada 1996, Ito et al. 1998, Yamato et al. 2001, Ito et al. 2003a, Ito et al. 2003b).

If *Quercus* spp. in the US are susceptible to attack by *P. quercivorus* and susceptible to infection by *R. quercivora*, the economic impact from yield reductions, quality losses and trade restrictions could be significant. In the US, hardwood species provided 36% of the round wood products harvested in 2001 (Smith et al. 2004). Oaks provided more than 117 billion cubic feet (14%) of the total growing stock on timberland in 2002, and 95% was from the eastern US (Smith et al. 2004). Species in the white oak group comprised 43% of the growing stock volume in the eastern US. From National Forests alone, almost 17 million board feet of oak were sold in 1997 worth over $50 million, 16% of which came from white oaks (Howard 1999). In 1997, the US exported 1.2 billion board feet of hardwood lumber, 70% of which went to countries on other continents (Smith et al. 2004). Establishment and spread of the pest complex could jeopardize domestic and international trade in wood products and ornamental plants. *R. quercivora* is listed on the EPPO Alert List (EPPO 2005). There is no known control for the disease.

8. **Potential Environmental Impact. Rating: High.** In general, newly established species may adversely affect the environment in a number of ways. Introduced species may reduce biodiversity, alter forest composition or disrupt ecosystem function, jeopardize endangered or threatened plants, degrade critical habitat, or stimulate use of chemical or biological controls. *Platypus quercivorus* is likely to affect the environment in many of these ways.

   At this time, there are only a few known hosts of *Platypus quercivorus* that occur in the US and all are introduced species: Mongolian oak, sawtooth oak, and Japanese chestnut [see 'Host Specificity]. Of these, only Mongolian oak is also a known host of the pathogenic fungus *R. quercivora* which is vectored by the beetle. The result of infection by *R. quercivora* is rapid wilting and death within a year (Ito et al. 2003a, Ito et al. 2003b). Extensive oak mortality in Japan may have impacted habitat for Asian black bears, sending them into more populated areas where numerous humans were attacked (Yamazaki 2004). To prevent further bear attacks, numerous bears were killed, 170 in one district alone (Yamazaki 2004). If *Quercus* spp. in the US are susceptible to attack by *P. quercivorus* and infection by *R. quercivora*, the environmental impact could be significant. The threat of mortality associated with *P. quercivorus* and associated fungus *R. quercivora* could stimulate the use of pesticides. Because the susceptibility of US oaks to this insect-pathogen complex is not known, a substantial degree of uncertainty is associated with the 'high' rating assigned to this risk element.

Appendix D summarizes federally listed threatened or endangered plant species (USDA NRCS 2004) found within plant genera known to be hosts or potential hosts for *P. quercivorus*. Plants listed in Appendix D might be suitable hosts for *P. quercivorus*, and thus, could be adversely affected by this insect.

Oak species are one of the largest genera of native plants in the US (McWilliams et al. 2002). In the western US, *Quercus* is one of four major genera of hardwoods, which together account for 17% of 238 million acres of forest land; in the eastern U.S., oak forests account for 52% of 384 million acres of forest land (Smith et al. 2004). Oak forests are highly valued for wildlife habitat, recreation, and for their beneficial effects on soil, air and water quality. Loss, decline and mortality of oaks are already concerns in several areas of the country.

9. **Establishment Potential. Rating: Medium.** Our initial predictions suggest that nearly 29% of the US has a climate that could support populations of *P. quercivorus* (Fig. 2). Oaks are common in these climatically suitable areas. However, the susceptibility of US oaks has yet to be determined. Thus, upon arrival into the United States, the chances for establishment are relatively moderate, compared with other pests. However, we note that the likelihood for introduction seems low based on current interception records.

   See Appendix E for a more detailed description of the biology of *Platypus quercivorus*.

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Appendix A. Geographic distribution and comparison of climate zones. To determine the potential distribution of a quarantine pest in the US, we first collected information about the worldwide geographic distribution of the species (Table A1). Using a geographic information system (e.g., ArcView 3.2), we then identified which biomes (i.e., habitat types), as defined by the World Wildlife Fund (Olson et al. 2001), occurred within each country or municipality reported. An Excel spreadsheet summarizing the occurrence of biomes in each nation or municipality was prepared. The list was sorted based on the total number of biomes that occurred in each country/municipality. The list was then analyzed to determine the minimum number of biomes that could account for the reported worldwide distribution of the species. Countries/municipalities with only one biome were first selected. We then examined each country/municipality with multiple biomes to determine if at least one of its biomes had been selected. If not, an additional biome was selected that occurred in the greatest number of countries or municipalities that had not yet been accounted for. In the event of a tie, the biome that was reported more frequently from the entire species' distribution was selected. The process of selecting additional biomes continued until at least one biome was selected for each country. Finally, the set of selected biomes was compared to only those that occur in the US.

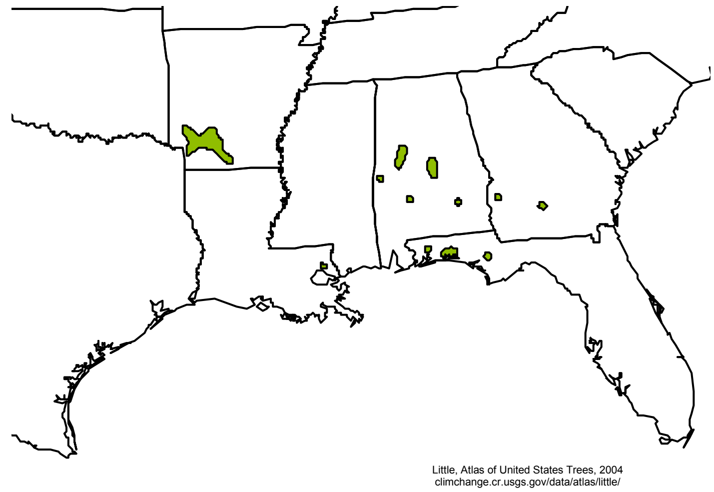
Table A1. Reported geographic distribution of *Platypus quercivorus*:

Locations	**Reference(s)**
China[1]	(CAB 2004)
India	(Schedl 1972, Kobayashi and Ueda 2002, Beaver and Shih 2003, Ciesla 2003, CAB 2004)
India (Bengal - Kalimpong)	(Beeson 1937)
India (Bengal)	(Wood and Bright 1992)
Indonesia	(Kobayashi and Ueda 2002)
Indonesia (Java - Mount Gede)	(Beeson 1937)
Indonesia (Java)	(Schedl 1972, Wood and Bright 1992, Beaver and Shih 2003, Ciesla 2003, CAB 2004)
Japan	(Yamada and Ichihara, Hijii et al. 1991, Wood and Bright 1992, Beaver and Shih 2003, Ciesla 2003, Esaki et al. 2004, Kitajima and Goto 2004)
Japan (Akita Prefecture)	(Yamada and Ichihara)
Japan (Echigo)	(Murayama 1925)
Japan (Fukui Prefecture)[2]	(Yamada and Ichihara, Hijii et al. 1991, Kuroda 2001, Kamata et al. 2002, Kubono and Ito 2002)
Japan (Gifu Prefecture)[3]	(Yamada and Ichihara)
Japan (Hokkaido)	(CAB 2004)
Japan (Honshu)	(Schedl 1972, Ito et al. 1998, Kinuura et al. 1998, Ohya and Kinuura 2001, Kobayashi and Ueda 2002, CAB 2004, Ueda and Kobayashi 2004)
Japan (Hyogo Prefecture)[3]	(Soné et al. 1998)
Japan (Ishikawa Prefecture - western)[3]	(Igeta et al. 2004a, Igeta et al. 2004b)
Japan (Ishikawa Prefecture)[3]	(Yamada and Ichihara, Esaki et al. 2002, Kamata et al. 2002, Igeta et al. 2003, Esaki et al. 2004)

Locations	Reference(s)
Japan (Kagoshima Prefecture - Sakurajima Isalnd)	(Sato 2003)
Japan (Kagoshima Prefecture)	(Yamada and Ichihara, Soné et al. 1998)
Japan (Kagoshima University - Takakuma Experimental Forest	(Mori et al. 1995, Soné et al. 1995)
Japan (Kyoto Prefecture - Maizuru City) [2]	(Ueda and Kobayashi 2004)
Japan (Kyoto Prefecture) [2]	(Yamada and Ichihara, Kobayashi and Ueda 2002, Kubono and Ito 2002)
Japan (Kyoto)	(Kobayashi and Ueda 2003)
Japan (Kyushu - southern)	(Soné et al. 1998, Ohya and Kinuura 2001)
Japan (Kyushu)	(Schedl 1972, Kinuura et al. 1998, Kobayashi and Ueda 2002, CAB 2004, Ueda and Kobayashi 2004)
Japan (Mie Prefecture) [3]	(Yamada and Ichihara)
Japan (Miyazaki Prefecture - Ayakita)	(Murayama 1925)
Japan (Miyazaki Prefecture)	(Yamada and Ichihara)
Japan (Nigata Prefecture) [3]	(Yamada and Ichihara)
Japan (Ryukyu Archipelago)	(Kamata et al. 2002, CAB 2004)
Japan (Shiga Prefecture) [2]	(Masuya et al. 1998, Kuroda 2001, Kamata et al. 2002)
Japan (Shikoku)	(Yamada and Ichihara)
Japan (Shimane Prefecture) [3]	(Yamada and Ichihara)
Japan (Tottori Prefecture) [2]	(Kubono and Ito 2002)
Japan (Yamagata Prefecture – Asahimura) [2]	(Mizobuti et al. 1996)
Japan (Yamagata Prefecture) [2]	(Yamada and Ichihara, Kinuura et al. 1998, Soné et al. 1998, Ohya and Kinuura 2001, Saito et al. 2001, Kubono and Ito 2002)
Papua New Guinea	(Schedl 1972, Wood and Bright 1992, Kobayashi and Ueda 2002, Beaver and Shih 2003, Ciesla 2003, CAB 2004)
Southeast Asia	(Kamata et al. 2002)
Taiwan (formerly Formosa)	(Schedl 1972, Wood and Bright 1992, Kamata et al. 2002, Kobayashi and Ueda 2002, Beaver and Shih 2003, Ciesla 2003, CAB 2004)

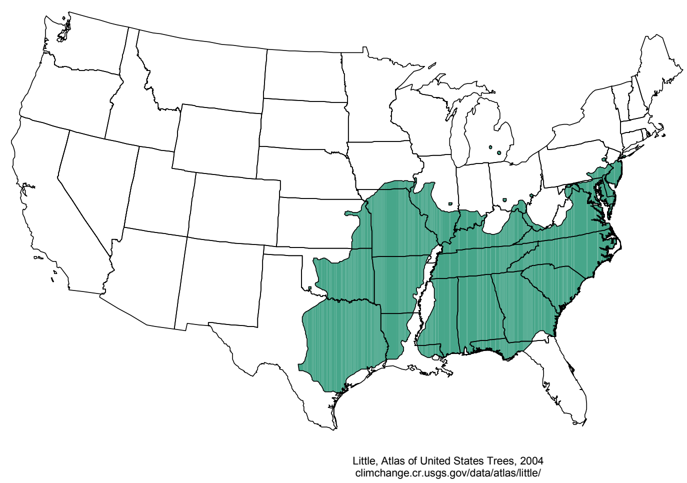
1. Questionable record. *P. quercivorus* is reportedly present in Taiwan, but not throughout China.
2. Pathogen *Raffaelea quercivora* identified in association with vector *Platypus quercivorus* and oak mortality.
3. Oak mortality associated with *P. quercivorus* and presence of *R. quercivora* is presumed but not isolated.

Appendix B. Host distribution for *Platypus quercivorus* within the contiguous US. These species are only potential hosts as the ability of *P. quercivorus* to feed and reproduce on these plants has not been confirmed

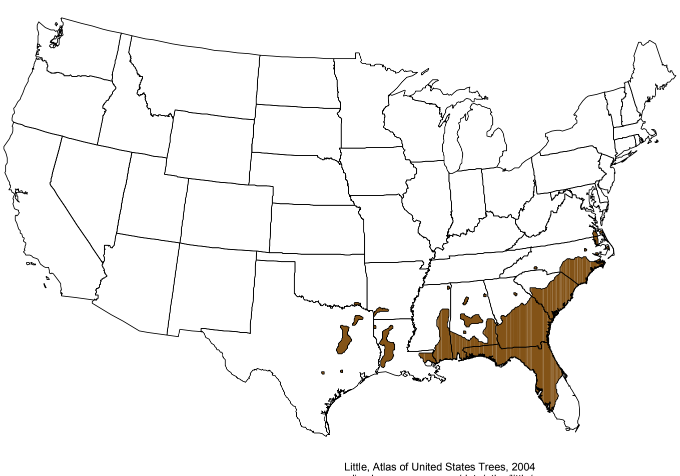


Map 1. Arkansas oak (*Quercus arkansana*)

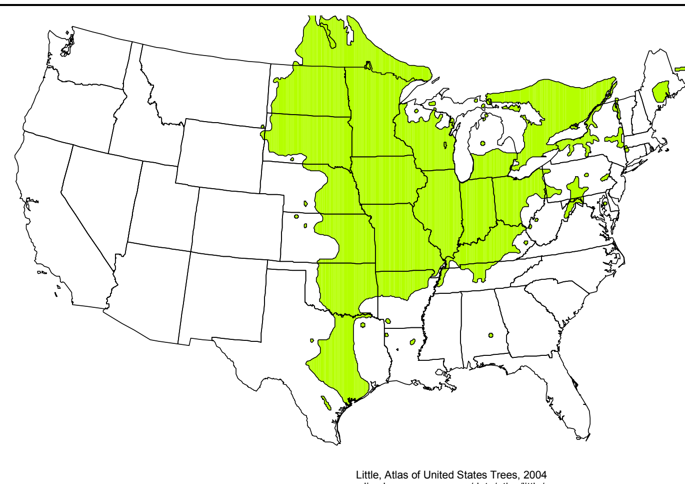
Map 2. Bear oak (*Quercus ilicifolia*)



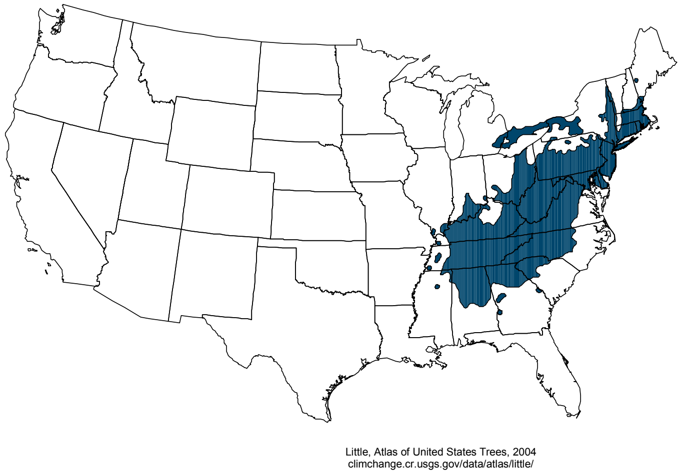
Map 3. Blackjack oak (*Quercus marilandica*)



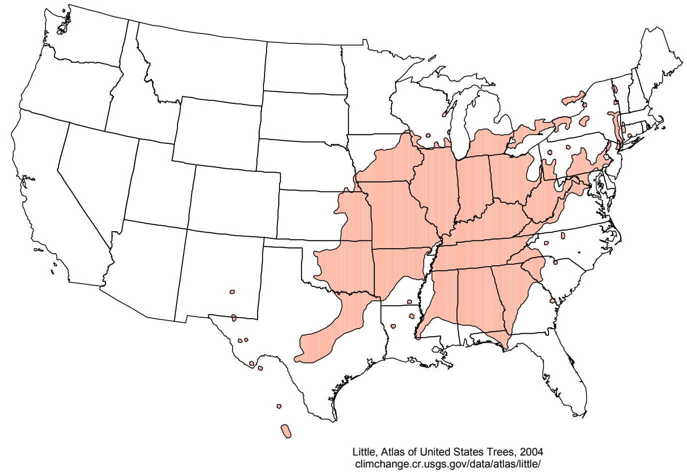
Map 4. Bluejack oak (*Quercus incana*)



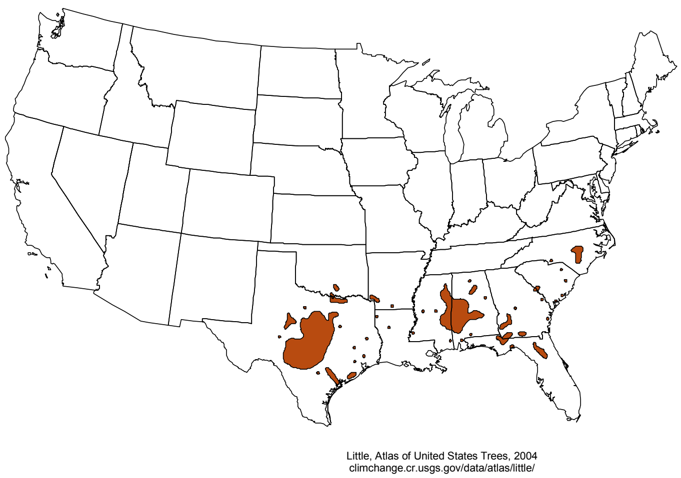
Map 5. Bur oak (*Quercus macrocarpa*)



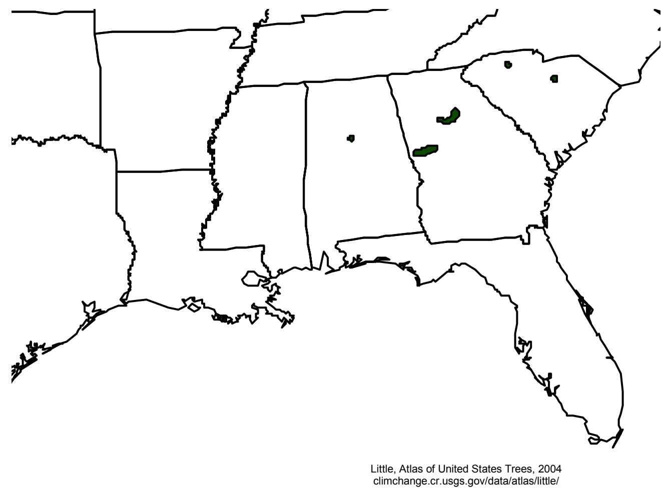
Map 6. Chestnut oak (*Quercus prinus*)



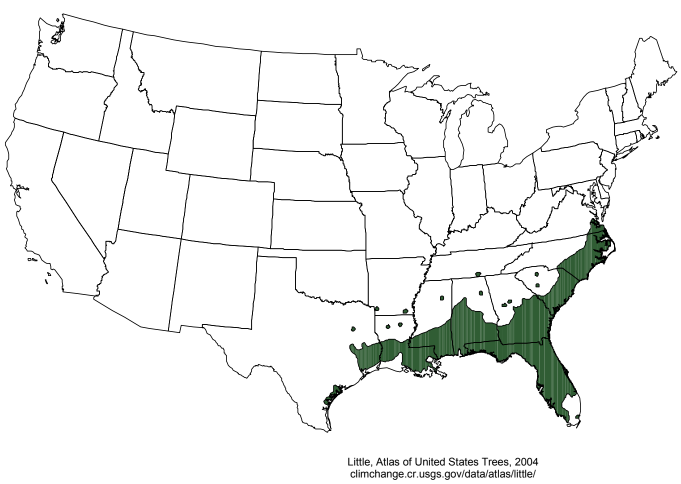
Map 7. Chinkapin oak (*Quercus muehlenbergii*)



Map 8. Durand oak (*Quercus durandii*)

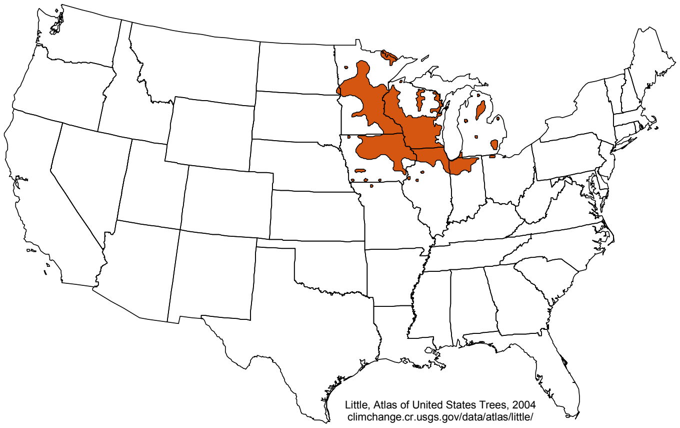


Map 9. Georgia oak (*Quercus georgiana*)

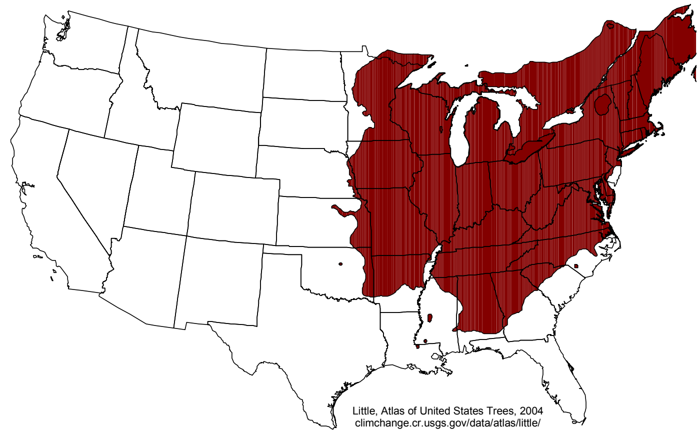


Map 10. Laurel oak (*Quercus laurifolia*)

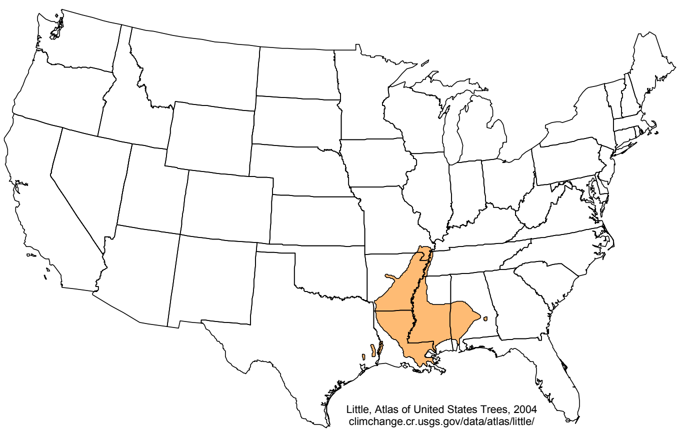
Map 11. Live oak (*Quercus virginiana*)



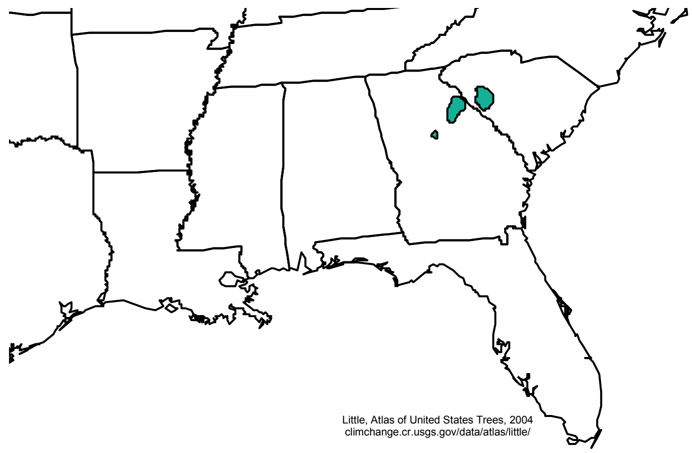
Map 12. Northern pin oak (*Quercus ellipsoidalis*)



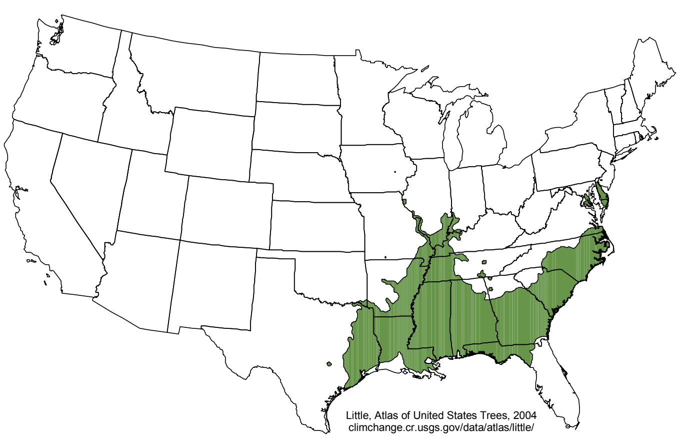
Map 13. Northern red oak (*Quercus rubra*)



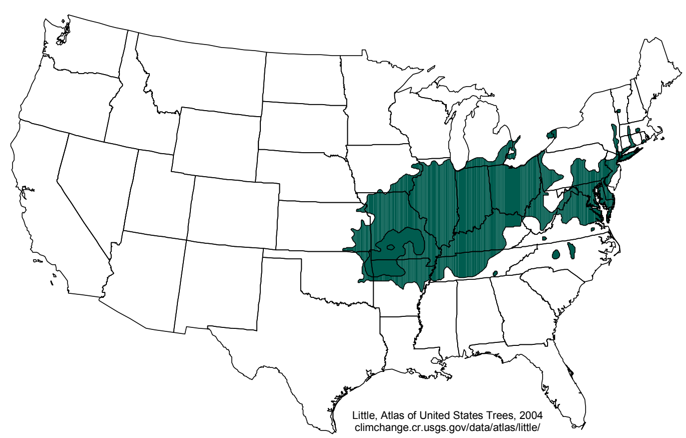
Map 14. Nuttall oak (*Quercus nuttallii*)



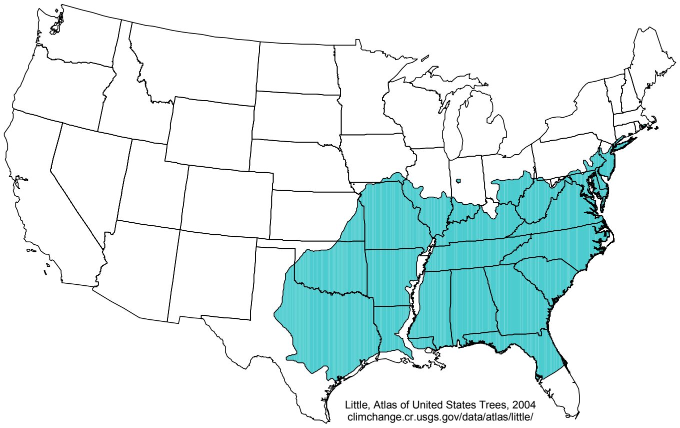
Map 15. Oglethorpe oak (*Quercus oglethorpensis*)



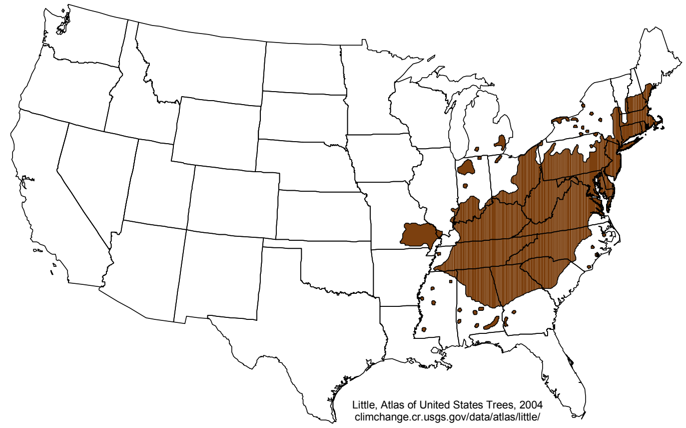
Map 16. Overcup oak (*Quercus lyrata*)



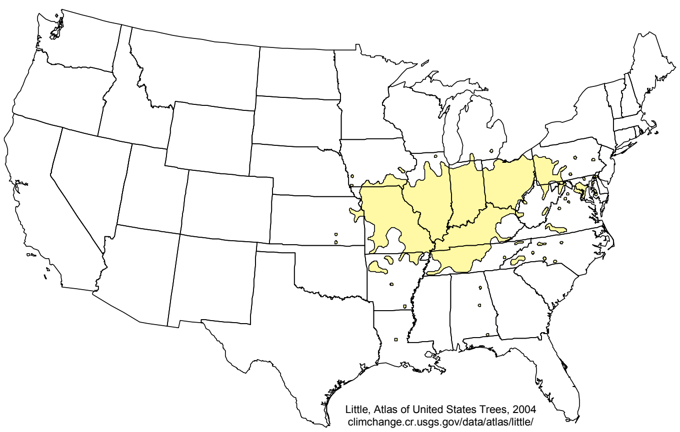
Map 17. Pin oak (*Quercus palustris*)



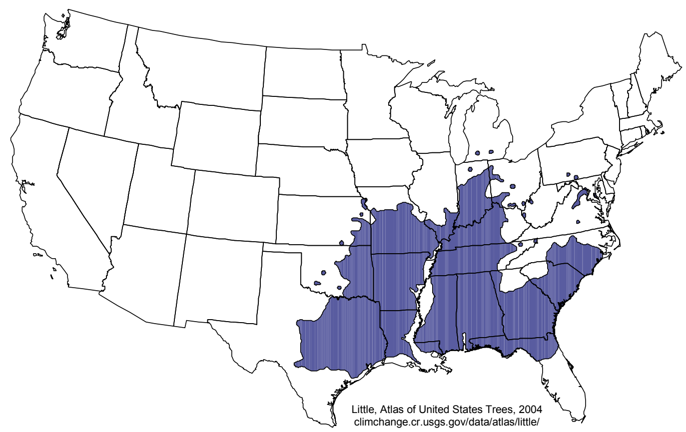
Map 18. Post oak (*Quercus stellata*)



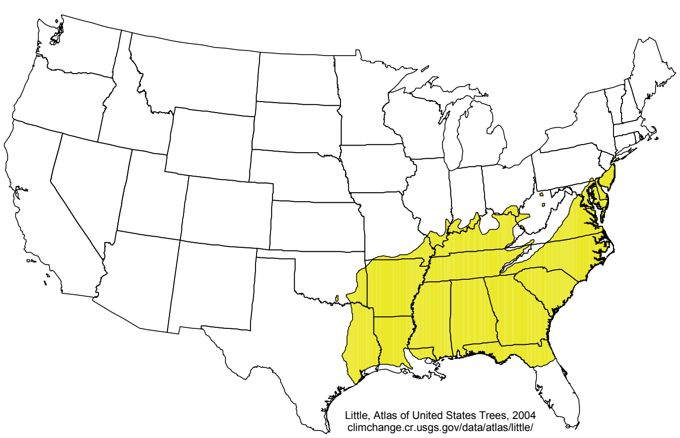
Map 19. Scarlet oak (*Quercus coccinea*)



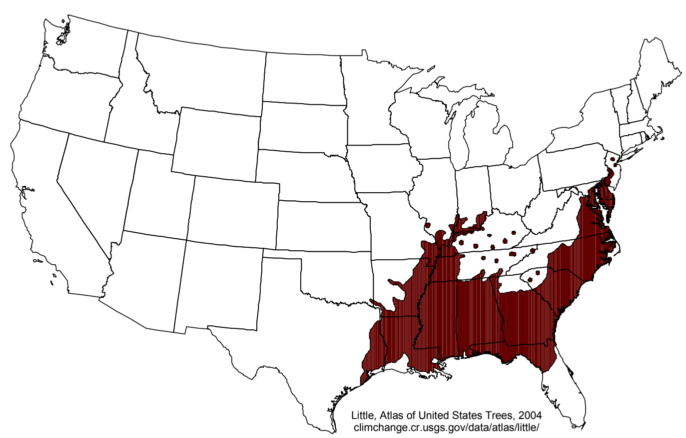
Map 20. Shingle oak (*Quercus imbricaria*)



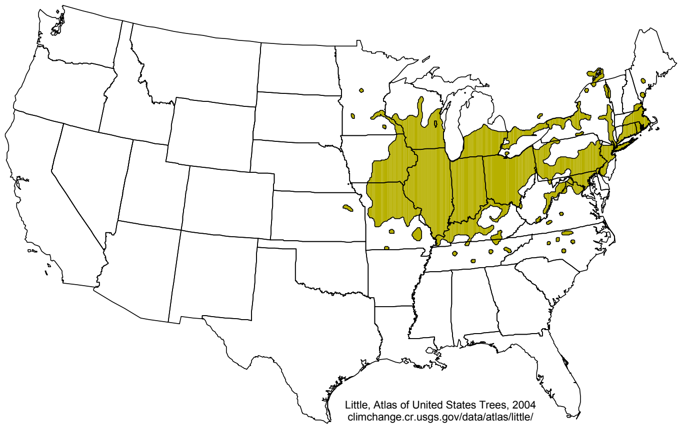
Map 21. Shumard oak (*Quercus shumardii*)



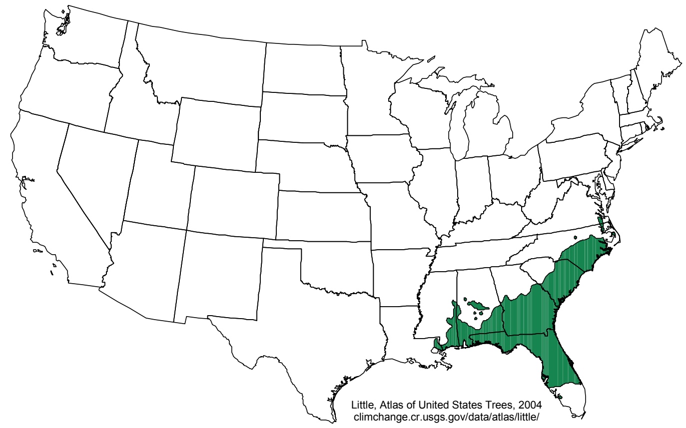
Map 22. Southern red oak (*Quercus falcata*)



Map 23. Swamp chestnut oak (*Quercus michauxii*)

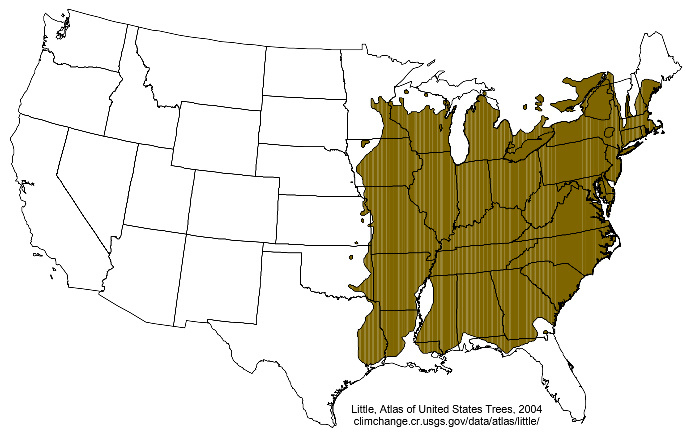


Map 24. Swamp white oak (*Quercus bicolor*)

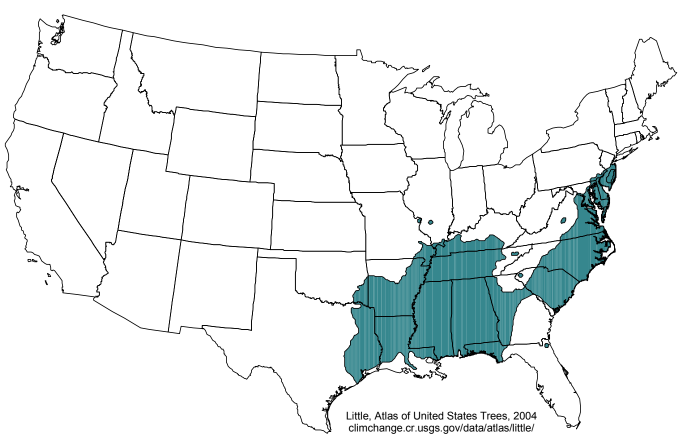


Map 25. Turkey oak (*Quercus laevis*)

Map 26. Water oak (*Quercus nigra*)



Map 27. White oak (*Quercus alba*)



Map 28. Willow oak (*Quercus phellos*)

Appendix C. Taxonomy and morphology of *Platypus quercivorus* Murayama
Platypus [=*Crossotarsus*] *quercivorus* was first described by Muryama in 1925 (Murayama 1925). A subsequent morphological description was published by Beeson (1937), and in 1972 the genus was reassigned to *Platypus* by Schedl (1972).

<u>Synonyms</u>

Crossotarsus quercivorus Murayama, 1925
Crossotarsus sexfenestratus, 1937

<u>Diagnostic features</u>

For complete accuracy, the following morphological description and table are quoted from Murayama (1925).

"*Crossotarsus quercivorus* Murayama n. sp.
Ferruginous brown, the head and the apex of elytra darker, underside yellowish brown.

♂ Head with front flat, covered with an irregular rugose reticulation, a short depressed median line between the bases of the antennae; vertex rather abruptly separated from the front, with a narrow black median line, sparse rugose punctures, and long aureous hair. Prothorax subquadrate, shining, sprinkled with fine punctures rather denser and larger towards the borders, the anterior border with sparse aureous hair; median sulcus short, wider towards anterior, not reaching the posterior border.

Elytra elongate, with sides parallel in the anterior two thirds and gradually diminished about one third of the breadth towards the apex; upper surface with a slight declivity in the posterior third, with the apex abruptly truncated, with punctured striae which are wider and deeper towards the bases and apices where the punctures are larger and more irregular, the 1st and 2nd, 3rd and 4th striae being conjoined at the bases; interstices slightly convex, with scattered punctures, higher and broader towards anterior, pointed towards posterior, the 1st and 4th narrowed towards posterior, the 2nd strongly produced behind, the 3rd the shortest and dual, the others united at the posterior ends and form an outer semicircular fence at the apical plane, the declivity and the apical plane sparsely ciliated with long aureous hair. Underside with scanty long yellow hair and large porelike punctures, abdominal segments convex, the 7th with a large transversal shallow oval depression.

♀ Front and vertex the same as in the male. Prothorax subquadrate, shining, with fine punctures and median sulcus, as in the male, on each side of the sulcus with 3-5 large round touched depressions in two rows, each depression being surrounded by a black bar.
Elytra as in the male, excepting in the more gently rounded sides and declivity, striae and interstices a little weaker than in the male and these continued throughout the apical plane, the border of which is without dentation. Underside a little paler than in the male, with stronger convexity on each abdominal segment."

	♂	♀
Length	4.46 mm	4.54 mm
Length of prothorax	1.29 mm	1.33 mm
Breadth of prothorax	1.15 mm	1.08 mm
Length of elytra	2.38 mm	2.42 mm
Breadth of elytra (at the base)	1.15 mm	1.15 mm

Appendix D. Threatened or endangered plants potentially affected by *Platypus quercivorus*.

Platypus quercivorus has the potential to adversely affect threatened and endangered plant species. However, because *P. quercivorus* is not known to be established in the US and threatened and endangered plant species do not occur outside the US, it is not possible to confirm the host status of these rare plants from the scientific literature. From available host records (see 'Host Specificity'), *P. quercivorus* is known to develop only on hosts belonging to the family Fagaceae (supported by A. Ueda, personal communication). From these host records, we infer that threatened and endangered plant species which are closely related to known host plants might also be suitable hosts (Table D1). For our purposes, closely related species belong to the same genus.

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Platypus quercivorus*.

Reported Hosts	Threatened and/or Endangered Plant		Protected Status[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
Castanea crenata[2]	*Castanea dentata*	American chestnut		KY (E) MI (E)
	C. pumila	chinkapin		KY (T) NJ (E)
Quercus sp., *Q. acuta*, *Q. acutissima*[2], *Q. crispuloserrata*, *Q.gilva*, *Q. glauca* [= *Q. myrsinifolia*], *Q. mongolica*[2] [= *Q. crispula* [= *Q. mongolica* var. *grosseserrata*]], *Q. myrsinaefolia*, *Q. phillyraeoides*, *Q. salicina*, *Q. serrata*, *Q. sessilifolia*	*Quercus acerifolia*	mapleleaf oak		AR (T)

Table D1: Threatened and endangered plants in the conterminous U.S. that are potential hosts for *Platypus quercivorus*.

Reported Hosts	Threatened and/or Endangered Plant		Protected Status[1]	
	Scientific Name	**Common Name**	**Federal**	**State**
	Quercus bicolor	swamp white oak		ME (T)
	Q. coccinea	scarlet oak		ME (E)
	Q. falcata	southern red oak		OH (T) PA (E)
	Q. hinckleyi	Hinckley oak	T	TX (T)
	Q. ilicifolia	bear oak		VT (E)
	Q. imbricaria	shingle oak		NJ (E)
	Q. lyrata	overcup oak		NJ (E)
	Q. macrocarpa	bur oak		CT (E)
	Q. muehlenbergii [= *Q. prinoides*]	chinkapin oak		IN (E)
	Q. nigra	water oak		NJ (E)
	Q. oglethorpensis	Oglethorpe oak		GA (T)
	Q. phellos	willow oak		IL (T) NY (E) PA (E)
	Q. prinus [= *Q. montana*]	chestnut oak		IL (T) ME (T)
	Q. shumardii	Shumard's oak		MD (T) PA (E)
	Q. sinuata var. *sinuata* [= *Q. durandii*]	bastard oak		AR (T)
	Q. texana [= *Q. nuttallii*]	Texas red oak		IL (E)

Source of threatened and endangered species: National Plants Database (USDA NRCS 2004)
1. E= Endangered; T=Threatened.
2. These plants occur in the U.S.; introduced species (USDA NRCS 2004).

Appendix E. Biology of *Platypus quercivorus*

Population phenology

Little is known about the biology of *P. quercivorus* because of its cryptic nature. What is known is based on observations of attack and emergence from living trees and felled logs, and from observations in fresh logs by computer tomography (Soné et al. 1998). Reproductive success rate of *P. quercivorus* is reportedly higher in fresh logs than in living trees which is attributed to a large number of offspring and diligent parental care (Soné et al. 1998). Fewer adults emerged from living trees (3.5-9.7 adults) than logs (40-60 adults) (Sato and Arai 1993, Soné et al. 1998, Ciesla 2003, CAB 2004). As many as 161 individuals may inhabit a gallery, and an average of 20-30 new adults may emerge from a gallery in summer and spring, respectively (Soné et al. 1998).

In Japan, *Platypus quercivorus* is typically a univoltine species, however adults may emerge in late spring and autumn, of the same year (Kinuura 1995, Soné et al. 1998, Kinuura 2002). In their native range with temperate to tropical conditions, beetles are active from June to October or November (Soné et al. 1998, Soné et al. 2000). In Japan, the greatest infestation of standing trees and logs occurs from June to early July (Mori et al. 1995, Soné et al. 1998).

Vector-pathogen association

Platypus quercivorus is the only known means for dispersal and inoculation of the ambrosia fungus *Raffaelea quercivora* in oaks (Kinuura 2002, Kubono and Ito 2002, Ito et al. 2003a, Ito et al. 2003b). *R. quercivora* has been isolated from necrotic tissue of inner bark, stained sapwood and heartwood, body surfaces of male and female *P. quercivorus*, the proventriculus or terminal foregut of males and females, the mycangia (specialized integumentary pores in the pronotum) of females, and gallery systems constructed by adults prior to emergence (Ito et al. 1998, Kinuura 2002, Ito et al. 2003a, Ito et al. 2003b, CAB 2004). Though the exact mechanism of host inoculation is not known (e.g., active or passive, or a combination), *R. quercivora* is introduced by adult *P. quercivorus* beetles as they bore into new hosts (Kinuura 2002). All life stages of *P. quercivorus* use this particular fungus as a food source, if not its primary one (Baker 1963, Cooke 1977, Kinuura 2002).

The biology of the fungus, *Raffaelea quercivora*, and the cycle of Japanese oak disease are fully described by Kromroy and Venette (2005).

Impacts on host physiology

Pest invasion can damage woody plants by several mechanisms, none of which is well understood (Manion 1991, Farrell et al. 2001). The production of tyloses, in which membranes and parenchyma cells expand into xylem vessels, can plug vessels from the current year's growth of ring porous oak trees where primary water transport takes place. This may account for the rapid wilting (within one growth season or the same year of pest attack) of susceptible hosts, particularly those belonging to the white oak group. Tyloses occur naturally in areas of older growth (sapwood) where water conductance no longer takes place. Numerous chemical compounds are produced by the tree during the formation of tyloses and serve to protect the wood from decay fungi. In contrast to ring porous white oaks, evergreen oaks are semi-ring- to diffuse-porous trees in which water transport takes place in a number of vessels, not limited to areas of new growth. Pest invasion may not cause wilting as quickly or extensively as in more porous oak species (Agrios 1988, Manion 1991).

Stage specific biology

Adult

New adults emerge and disperse beginning in late June through early October or November (Soné et al. 1998, Kinuura 2002). Adult males initiate the attack of Fagaceous hosts and trigger a mass attack; possible attractants include plant volatiles from wound response of host, aggregation pheromones, and sound released by male beetles (Ohya and Kinuura 2001, Kinuura 2002, Kobayashi and Ueda 2003, Atkinson 2004). Entry holes on standing trees typically occur on the lower portion of the trunk, within about a meter of the ground (Hijii et al. 1991, Igeta et al. 2004b). Degree of tree infestation reportedly increases with tree diameter. Trees measuring 16-40 cm (diameter at breast height or dbh) were preferred over smaller trees, and hosts measuring between 9.5-16 cm dbh were attacked to a lesser extent (Soné et al. 1995). Although the density and position of entry holes may be affected by several factors, males create entrance holes where tree diameter and moisture content are optimal (Soné et al. 2000, Esaki et al. 2004, Igeta et al. 2004b).

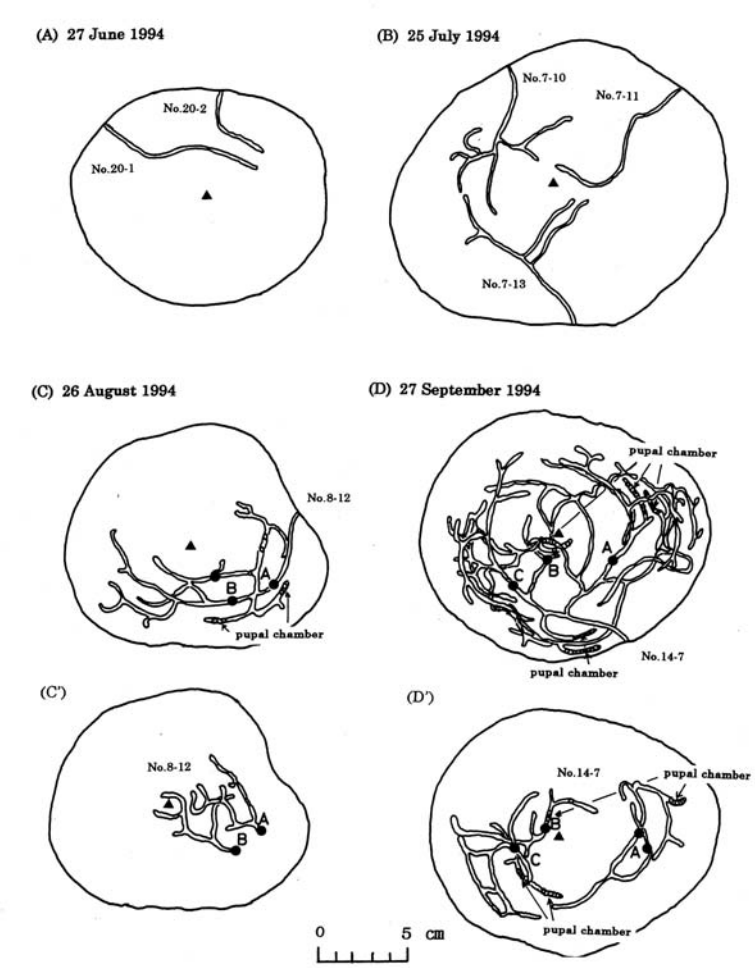


Figure E1. Gallery construction by *P. quercivorus* in logs. [Reproduced from Soné et al. (1998).]

The female joins the male at the entrance of the horizontal mating gallery, mates and initiates construction of the oviposition gallery (Fig E1, Soné et al. 1998). The oviposition gallery is branched several times both laterally and vertically to allow developing larvae to bore extensively throughout a tree (Kinuura 2002). Well-developed gallery systems over 387 cm in length with up to seven layers of horizontal tunnels have been described (Soné et al. 1998). The female carries fungi in a mycangia, a highly specialized structure reflecting the close association between the beetle and the fungus. Fungi distributed in the oviposition chamber will be cultivated as a food source. Eggs are laid in horizontal gallery walls. The female carries debris to the male who remains at the entrance hole, presumably to protect against predators (Soné et al. 1998). Males expel frass and splintered wood debris from the gallery system. Frass and debris may be detected around the base of the host tree (Kuroda and Yamada 1996, Ciesla 2003). Adult beetles are monogamous and remain in the gallery until their brood fully develops; afterwards, the adults die (Soné et al. 1998).

The reported sex ratio is approximately 1:1 but may vary depending on the time of day, seasonality, location and light conditions in the forest (Kinuura 1995, Kitajima and Goto 2004). Specific behaviors during mating have been documented by Kobayashi and Ueda (2002), and Ohya and Kinuura (2001). Dispersal, trapping and rearing techniques have been investigated by Kitajima and Goto (2004), Kinuura (1995), Esaki et al. (2002, 2004), and Igeta et al. (2003, 2004a, 2004b).

Egg
Eggs are laid in individual notches at terminal ends within the horizontal gallery walls about 2-3 weeks after gallery construction is initiated (Kinuura 2002, Ciesla 2003). Egg hatch occurs in about one week (Kinuura 1995, Esaki et al. 2004).

Larva
Newly hatched larvae are whitish with amber colored mouthparts (Kinuura 1995). Larvae feed on the fungi lining the gallery wall (Kinuura 2002). There are typically 5 instars. Depending on the season, final instar larvae may or may not enter hibernation and overwinter in the larval gallery (Soné et al. 1998). Fifth instars pupate in specially formed vertical cradles (Kinuura 2002).

Pupa
Pupation occurs in 1 cm-long pupal chambers within the larval gallery (Soné et al. 1998). Pupae are larger than adults and white (Kinuura 1995). Gender can be differentiated in this stage (Kinuura 1995). Pupation occurs in May followed by emergence of adults in June and July. Beetles complete development between August and October and leave their parental galleries to find new hosts. The beetle may overwinter as a pupa or adult; however, adults that remain in the host until the following spring may not survive (Soné et al. 1998).