CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

California Pest Rating Proposal for

Fusarium euwallaceae S. Freeman, Z. Mendel, T. Aoki & O'Donnell 2013

(Syn = *Neocosmospora euwallaceae* (S. Freeman, Z. Mendel, T. Aoki & O'Donnell) Sand. -Denis, L. Lombard & Crous 2019

Current Pest Rating: none

Proposed Pest Rating: B

Kingdom: Fungi; Division: Ascomycota
Class: Sordariomycetes; Order: Hypocreales
Family: Nectriaceae

Comment Period: 5/5/2020 through 6/19/2020

Initiating Event:

In 2003, ambrosia beetles were collected on black locust trees at the Whittier Narrows Nature Center in Los Angeles County. They were identified as *Euwallacea fornicatus* (Eichhoff), the tea shot hole borer, a new state record. Research on the genus has revealed that the tea shot hole borer is actually a different species, *E. perbrevis* (Schedl). *Euwallacea fornicatus*, which includes the beetles found in Los Angeles County, is now referred to as the polyphagous shot hole borer (PSHB) (Southeast Asian Ambrosia Beetle ID). This beetle creates galleries and causes damage to more than 100 species of trees. PSHB was evaluated in 2015 and has a B rating (Leathers, 2015).

As an ambrosia beetle, PSHB feeds on symbiotic fungi that it carries in its mandibular mycangia to inoculate and cultivate inside living trees. Within beetle galleries, fungi grow and serve as a source of food for the beetles. When PSHB was first reported 2003, there were no observations of damage to the host trees from any associated fungi. In 2012, a *Fusarium* sp. was recovered from branch cankers of several backyard avocado trees that were attacked by PSHB. Since then, studies have been done to determine the host range of the beetle–fungus complex and the influence of both on symptomology. In 2013, from isolates collected in California and Israel, the fungus was described and named *F. euwallaceae* (Freeman et al.). Growth of the fungus in the trees is associated with discoloration of the xylem and production of gums and exudates. The disease was named “fusarium dieback.” Therefore, the insect-disease complex is referred to as polyphagous shot hole borer-fusarium dieback (PSHB-FD). The interruption of transport of water and nutrients from PSHD-FD contributes to wilt and tree death

(Freeman et al., 2013). The risk to California from *F. euwallaceae* is evaluated herein and a permanent rating is proposed.

History & Status:

Background:

The PSHB is an exotic, invasive ambrosia beetle native to Southeast Asia. This beetle and its fungal symbiont *Fusarium euwallaceae* have emerged as an important pest complex with a long list of woody plant hosts in California, Mexico, Israel, and South Africa. PSHB is one of three cryptic species in the *Euwallacea fornicatus* species complex, the taxonomy of which remains unresolved. PSHB cultivates an Ambrosia *Fusarium* Clade (AFC) fungus in their galleries as a source of food. Like other scolytine beetles in the tribe Xyleborini, *Euwallacea* are thought to be obligate mutualists with their fungal symbionts (O'Donnell et al., 2015). *Fusarium euwallaceae* is the anamorphic name of the fungus and is a member of the Ambrosia clade AF2 of the telomorphic genus *Neocosmospora* (Sandoval-Denis et al., 2019).

In 2013, sycamore trees in San Diego County were found infested with ambrosia beetles and showing symptoms of PSHB-FD. However, molecular analysis of the fungal symbionts showed significant differences from *F. euwallaceae*. The beetles also appeared to be distinct at the genetic level, although phenotypically they were very close to PSHB. They were determined to a different *Euwallacea* sp. n *fornicatus* and named Kiroshio shot hole borer (KSHB) (Stouthamer et al., 2017). Subsequently, the KSHB has been found in the same counties as PSHB and even farther north along the coast to San Luis Obispo county and farther south in San Diego county. Genome sequences show there are at least two fungal symbionts used by KSHB that are closely related but distinct from the *F. euwallaceae* used by PSHB. The KSHB symbionts were named, *F. kuroshium* and *Graphium kiroshium* (Na et al., 2018). There is one report of *F. euwallaceae* associated with KSHB and causing Fusarium dieback in Mexico (Ibarra-Laclette et al., 2017) but this report predates the work of Na et al. in 2018.

Hosts: PSHB-FD has been reported to cause death of the following hosts: *Acer buergerianum* (trident maple), *Acer macrophyllum* (big leaf maple), *Acer negundo* (box elder), *Parkinsonia aculeata* (palo verde), *Platanus racemosa* (California sycamore), *Platanus x hispanica* (London plane), *Populus fremontii* (Fremont cottonwood), *Populus nigra* (black poplar), *Populus trichocarpa* (black cottonwood), *Quercus lobata* (valley oak), *Quercus robur* (English oak), *Ricinus communis* (castor bean), *Salix gooddingii* (black willow), *Salix laevigata* (red willow), and *Salix lasiolepis* (arroyo willow).

PSHB-FD causes non-lethal branch cankers on the following hosts: *Acacia melanoxylon* (Australian blackwood), *Acacia* spp. (acacia), *Acer palmatum* (Japanese maple), *Acer paxii* (evergreen maple), *Aesculus californica* (California buckeye), *Ailanthus altissima* (tree of heaven), *Albizia julibrissin* (mimosa), *Alectryon excelsus* (titoki), *Alnus rhombifolia* (white alder), *Archontophoenix cunninghamiana* (king palm), *Baccharis salicifolia* (mule fat), *Bauhinia variegata* (purple orchid tree), *Brachychiton populneus* (kurrajong), *Camellia semiserrata* (camellia), *Castanospermum australe* (Moreton Bay chestnut), *Casuarina equisetifolia* (Australian pine tree), *Cocculus laurifolius* (laurel leaf

snailseed tree), *Corymbia ficifolia* (red flowering gum), *Cupaniopsis anacardioides* (carrotwood), *Diospyros kaki* (Japanese persimmon), *Dombeya cacuminum* (strawberry tree), *Erythrina caffra* (coast coral tree), *Erythrina coralloides* (coral tree), *Erythrina falcata* (Brazilian coral tree), *Fagus crenata* (Japanese beech), *Ficus altissima* (council tree), *Ficus carica* (black mission fig), *Gleditsia triacanthos* (honey locust), *Harpullia pendula* (tulip wood), *Howea forsteriana* (kentia palm), *Ilex cornuta* (Chinese holly), *Jacaranda mimosifolia* (jacaranda), *Koelreuteria bipinnata* (Chinese flame tree), *Liquidambar styriciflua* (American sweet gum), *Magnolia grandiflora* (southern magnolia), *Magnolia virginiana* (sweet bay), *Parkinsonia florida* (blue palo verde), *Parkinsonia x sonorae* (Sonoran palo verde), *Persea americana* (avocado), *Platanus mexicana* (Mexican sycamore), *Platanus orientalis* (oriental plane), *Platanus × acerifolia* (London planetree), *Prosopis articulata* (mesquite), *Prunus dulcis* (almond), *Pterocarya stenoptera* (Chinese wingnut), *Quercus agrifolia* (coast live oak), *Quercus chrysolepis* (canyon live oak), *Quercus engelmannii* (Englemann oak), *Quercus ithaburensis* (Mount Tabor oak), *Quercus suber* (cork oak), *Salix babylonica* (weeping willow), *Spathodea campanulata* (African tulip tree), *Tamarix ramosissima* (tamarisk), *Wisteria floribunda* (Japanese wisteria), *Xylosma congesta* (shiny Xylosma) (Farr and Rossman, 2020; Eskalen et al., 2013).

Symptoms: Trees will show different symptoms of PSHB-FD depending on the response of the tree to the *F. euwallacae* infection. Affected trees will have signs of PSHB attack. The typical entry-hole to a PSHB gallery is perfectly round approximately 0.9 mm in diameter. The abdomen of the female beetle can sometimes be seen protruding from the entry-hole. The hole may also be plugged or covered by sap, exudate, or frass. Frass produced by the beetle's boring activity may be present on the host tree depending on the infestation level. Long "matchsticks" of frass have been observed on box elder, coral tree, and willow.

Symptoms caused by FD vary depending on the host tree’s response to water stress because the xylem is affected. Staining may be visible on the exterior of branches or trunk and may be wet and dark or dry and light-colored. Light colored staining is more characteristic for sycamores or oaks. Gumming from thicker resin that sometimes pushes the beetle out of the gallery can be seen in goldenrain trees. Sugary exudate from avocados is often in the form of white, powdery "volcanoes". Some of these symptoms may be washed away or obscured by rain or irrigation water. *Fusarium euwallaceae* infection causes dark discoloration of the wood beneath the bark and around the beetle gallery. Advanced infestations lead to branch dieback and overall decline. When PSHB attacks are concentrated on a branch or in the branch collar, infestations can lead to limb failure. Some trees develop large branch cankers with distal dieback and defoliation. Some trees undergo a generalized wilt leading to mortality in severe cases (Eskalen et al., 2015).

Transmission: Only the female PSHB can fly. Females bore tunnels into a wide variety of host trees forming galleries where eggs, containing more females than males, are laid. Mature siblings mate with each other allowing females, ready to lay fertilized eggs, to leave and start new galleries. They are also capable of parthenogenesis; if a female fails to mate before leaving the gallery, she can lay unfertilized eggs and later mate with a son. Through flight and natural spread, the population can expand as far as 10 miles per year. PSHB will expand its colony within a single tree until the point it is no longer a

suitable host. There can be 3-5 generations per year and trees can suffer the effects of thousands of PSHB galleries.

Both PSHB and KSHB have a special structure in their mandibles called a mycangium. Polyphagous shot hole borer carries three fungi: *Fusarium euwallaceae, Graphium euwallaceae* and *Paracremonium pembeum*. The beetle grows these fungi in their galleries for food (Eskalen et al., 2012).

Damage Potential: Damage from PSHB-FD is of concern to avocado and almond production in California. Inoculation studies with *F. euwallaceae* on avocado by Eskalen et al. (2012) and almond by Moreno et al. (2017) showed that both are hosts of this pathogen and inoculation leads to significant vascular discoloration (streaking) and stem lesions. Observations on naturally infected avocados have been made in commercial groves and residential areas of Los Angeles County and include branch dieback (Eskalen et al., 2012). In South Africa, damage from PSHB-FD was similar to damage seen in California with branch dieback of backyard trees (van den Berg et al., 2019). In Israel, damage on avocado was described as "typical of wilt" and characterized as a serious threat (Mendel et al., 2012).

PSHB-FD poses a threat of significant concern to trees in urban, residential, and natural settings. Survey data from southern California suggest PSHB-FD may potentially establish in a variety of plant communities in the state and worldwide. In a survey of botanical gardens in southern California, Eskalen et al. (2013) found many hundreds of tree species were susceptible to PSHB-FD and extrapolated that 38% of the street trees planted in southern California are potential hosts of FD. 207 tree species in 58 families representing all the continents except Antarctica are attacked by PSHB. These susceptible trees include 11 species native to California and 13 important to agriculture. *Fusarium euwallaceae* was recovered from symptomatic tissues of 113 of the 207 tree species (54%) representing 40 plant families. Not all of the trees were suffering from symptoms of FD (wilt or branch dieback). Another important host is castor bean. It is a common woody plant in urban and agricultural areas and was found to be heavily infested with PSHB-FD in Los Angeles and Orange counties.

Worldwide Distribution: Israel, United States (California) (Freeman et al., 2013), Mexico (Ibarra-Laclette, 2017) and South Africa (Paap et al., 2018; van den Berg et al., 2019)

Official Control: None

California Distribution: There is an official detection from a residential property in Orange County. University of California researchers report detections of PSHB-FD in Ventura, Los Angeles, Orange, Riverside, and San Diego counties (UCANR, 2020). The pathogen was found in one California nursery, indicating that PSHB may have been present. Infected plants were destroyed.

California Interceptions: None

The risk *Fusarium euwallaceae* would pose to California is evaluated below.

Consequences of Introduction:

1) **Climate/Host Interaction:** To date, all detections of PSHB-FD have been in southern California. Since this is an exotic, invasive species, it is unclear if it will be able to continue to spread north from Ventura and Los Angeles into other parts of California. Low temperatures are a limiting factor with t_{min} for development of PSHB measured at 13°C (Umida and Paine, 2018).

   Evaluate if the pest would have suitable hosts and climate to establish in California.

   Score: **2**

   - Low (1) Not likely to establish in California; or likely to establish in very limited areas.
   - **Medium (2) may be able to establish in a larger but limited part of California.**
   - High (3) likely to establish a widespread distribution in California.

2) **Known Pest Host Range:** The host range of PSHB-FD is very large and includes hundreds of tree species in dozens of families, some of which are native plants.

   Evaluate the host range of the pest.

   Score: 3

   - Low (1) has a very limited host range.
   - Medium (2) has a moderate host range.
   - **High (3) has a wide host range.**

3) **Pest Dispersal Potential:** PSHB can fly and produces multiple generations per year in southern California. It could move longer distances with infested nursery stock or with firewood. PSHB carries *F. euwallaceae* in mycangia and inoculates it into its natal galleries inside suitable tree hosts.

   Evaluate the natural and artificial dispersal potential of the pest.

   Score: 3

   - Low (1) does not have high reproductive or dispersal potential.
   - Medium (2) has either high reproductive or dispersal potential.
   - **High (3) has both high reproduction and dispersal potential.**

4) **Economic Impact:** PSHB-FD has killed hundreds of thousands of trees in southern California in parks, urban landscaping, and riparian areas. It causes minor damage to commercial avocados and has potential to damage almonds. It is a significant threat to a large percentage of the trees that make up the urban forest in the Los Angeles basin.

   Evaluate the economic impact of the pest to California using the criteria below.

   Economic Impact: A, E

   A. The pest could lower crop yield.
   B. The pest could lower crop value (includes increasing crop production costs).
   C. The pest could trigger the loss of markets (includes quarantines).
   D. The pest could negatively change normal cultural practices.
   E. The pest can vector, or is vectored, by another pestiferous organism.
   F. The organism is injurious or poisonous to agriculturally important animals.

G. The organism can interfere with the delivery or supply of water for agricultural uses.

Economic Impact Score: **3**
- Low (1) causes 0 or 1 of these impacts.
- Medium (2) causes 2 of these impacts.
- High (3) causes 3 or more of these impacts.

5) **Environmental Impact:** At least 11 hosts of PSHB-FD are California native plants and the host list is likely not complete. Significant environmental impacts have already been seen in parks and riparian areas as otherwise healthy trees are damaged or killed. If insecticide treatments for PSHB are developed, they would be much in demand to protect high value trees

Environmental Impact: A, B, C, E

A. The pest could have a significant environmental impact such as lowering biodiversity, disrupting natural communities, or changing ecosystem processes.
B. The pest could directly affect threatened or endangered species.
C. **The pest could impact threatened or endangered species by disrupting critical habitats**.
D. The pest could trigger additional official or private treatment programs.
E. The pest significantly impacts cultural practices, home/urban gardening or ornamental plantings.

Environmental Impact Score: 3
- Low (1) causes none of the above to occur.
- Medium (2) causes one of the above to occur.
- High (3) causes two or more of the above to occur.

Consequences of Introduction to California for *Fusarium euwallaceae:* High

Add up the total score and include it here. **14**
-Low = 5-8 points
-Medium = 9-12 points
-High = 13-15 points

6) **Post Entry Distribution and Survey Information**: Evaluate the known distribution in California. Only official records identified by a taxonomic expert and supported by voucher specimens deposited in natural history collections should be considered. Pest incursions that have been eradicated, are under eradication, or have been delimited with no further detections should not be included.

Evaluation is 'Medium'. To date, PSHB-FD has only been reported in Southern California. It is possible the beetles with the fungus will continue to spread north and become distributed statewide, it's also possible that cooler temperatures in northern areas will limit their spread.

Score: -2
-Not established (0) Pest never detected in California or known only from incursions.
-Low (-1) Pest has a localized distribution in California or is established in one suitable climate/host area (region).
-Medium (-2) Pest is widespread in California but not fully established in the endangered area, or pest established in two contiguous suitable climate/host areas.
-High (-3) Pest has fully established in the endangered area, or pest is reported in more than two contiguous or non-contiguous suitable climate/host areas.

7) **The final score is** the consequences of introduction score minus the post entry distribution and survey information score: (Score)

Final Score: *Score of Consequences of Introduction – Score of Post Entry Distribution and Survey Information* **= 12**

Uncertainty:

A single specimen identified as *Euwallacea fornicatus* was trapped in Santa Cruz County in 2013. This could be PSHB, or it could be a different species. Low density populations of PSHB are difficult to detect; it could be present in other parts of the state.

Conclusion and Rating Justification:

Based on the evidence provided above **the proposed rating for *Fusarium euwallaceae* is B.**

References:

Farr, D. F., and Rossman, A. Y. Fungal Databases, U.S. National Fungus Collections, ARS, USDA. Retrieved April 6, 2020, from **https://nt.ars-grin.gov/fungaldatabases/**

Eskalen, A., Stouthamer, R., Lynch, S., Rugman-Jones, P., Twizeyimana, M., Gonzalez, A., Thibault, T. 2013a. Host Range of Fusarium dieback and its Ambrosia Beetle (Coleoptera: Scolytinae) Vector in Southern California. Plant disease, 97 (7): 938-951.

Eskalen, A., Gonzalez, A., Wang, D. H., Twizeyimana, M., Mayorquin, J. S., and Lynch, S. C. 2012. First Report of a *Fusarium* sp. and Its Vector Tea Shot Hole Borer (*Euwallacea fornicatus*) Causing Fusarium Dieback on Avocado in California. Plant Disease 96 (7).

Freeman, S., Sharon, M., Maymon, M., Mendel, Z., Protasov, A., Aoki, T., Eskalen, A., and O'Donnell, K. 2013. *Fusarium euwallaceae* sp. nov. - a symbiotic fungus of *Euwallacea* sp., an invasive ambrosia beetle in Israel and California. Mycologia 105: 1595-1606.

Ibarra-Laclette E, Sánchez-Rangel D, Hernández-Domínguez E, et al. 2017. Draft genome sequence of the phytopathogenic fungus *Fusarium euwallaceae*, the causal agent of fusarium dieback. Genome Announcements 5: e00881–17.

Leathers, J. 2015. California Pest Rating for *Euwallacea* sp. nr. *fornicatus*: Polyphagous Shot Hole Borer. https://blogs.cdfa.ca.gov/Section3162/?p=640

Mendel, Z., Protasov, A., Sharon, M., Zveibil, A., Ben Yehuda, S., O'Donnell, K., Rabaglia, R., Wysoki, M., and Freeman, S. 2012. An Asian ambrosia beetle *Euwallacea fornicatus* and its novel symbiotic fungus *Fusarium* sp. pose a serious threat to the Israeli avocado industry. Phytoparasitica V 40, pgs235–238

Moreno, K., Carrillo, J.D., Trouillas, F.P., and Eskalen, A. 2018. Almond (*Prunus dulcis*) is susceptible to *Fusarium euwallaceae*, a fungal pathogen vectored by the polyphagous shot hole borer in California. Pl. Dis. 102(1): 251.

Na, F., Carrillo, J. D., Mayorquin, J. S., Ndinga-Muniania, C., Stajich, J. E., Stouthamer, R., Huang, Y-T., Lin, Y-T, Chen, C-Y, and Eskalen, A. 2018. Two novel fungal symbionts, *Fusarium kuroshium* sp. no. and *Graphium kiroshium* sp nov. of Kuroshio shot hole borerer (*Euwallaceae* sp nr. *fornicatus*) cause fusarium dieback on woody host species in California. Plant Disease 102:1154-1164

O'Donnell, K., Libeskind-Hadas, R., Hulcr, J., Bateman, C., Kasson, M. T., Ploetz, R. C., Konkol. J. L., Ploetz, J. N., Carrillo, D., Campbell, A., Duncan, R. E., Liyanage, P. N. H., Eskalen, A., Lynch, S. C., Geiser, D. M., Freeman, S., Mendel, Z., Sharon, M., Aoki, T., Cossé, A. A., and Rooney, A. P. 2016. Invasive Asian *Fusarium–Euwallacea* ambrosia beetle mutualists pose a serious threat to forests, urban landscapes and the avocado industry. Phytoparasitica 44:435– 442.

Paap, T., De Beer, Z.W., Migliorini, D., Nel, W.J., and Wingfield, M.J. 2018. The polyphagous shot hole borer (PSHB) and its fungal symbiont *Fusarium euwallaceae*: a new invasion in South Africa. Australas. Pl. Pathol. 47(2): 231-237.

Sandoval-Denis, M., Lombard, L., and Crous, P.W. 2019. Back to the roots: a reappraisal of *Neocosmospora*. Persoonia 43: 90-185.
Southeast Asian Ambrosia Beetle ID. Accessed April 9, 2020: http://idtools.org/id/wbb/sea-ambrosia/index.php

Stouthamer, R., Rugman-Jones, P., Thu, P. Q., Eskalen, A., Thibault, T., Hulcr, J., Wang L-J., Jordal, B. H., Chen C-Y., Cooperband, M., Lin, C-S, Kamata, N., Lu S-S., Masuya, H., Mendel, Z., Rabaglia, R., Sanguansub, S., Shih, H-H., Sittichaya, W., Zong S-X. 2017. Tracing the origin of a cryptic invader: phylogeography of the *Euwallacea fornicatus* (Coleoptera: Curculionidae: Scolytinae) species complex. Agricultural and Forest Entomology 2017 Vol.19 No.4 pp.366-375

Umeda, C., and Paine, T. 2018.T emperature can limit the invasion range of the ambrosia beetle *Euwallacea* nr. *fornicatus*. Agricultural and Forest Entomology (2019), 21,1–7

University of California Agriculture and Natural Resources. 2020. ISHB-FD Distribution in California. https://ucanr.edu/sites/pshb/pest-overview/ishb-fd-distribution-in-california/ accessed 4/8/2020

van den Berg, N., du Toit, M., Morgan, S.W., Fourie, G., and De Beer, Z.W. 2019. First report of *Fusarium euwallaceae* causing necrotic lesions on *Persea americana* in South Africa. Pl. Dis. 103(7): 1774-1775.

Responsible Party:

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***Comment Period: 5/5/2020 through 6/19/2020**

***NOTE:**

You must be registered and logged in to post a comment. If you have registered and have not received the registration confirmation, please contact us at permits[@]cdfa.ca.gov.

Comment Format:

- Comments should refer to the appropriate California Pest Rating Proposal Form subsection(s) being commented on, as shown below.

  Example Comment:

  Consequences of Introduction: 1. Climate/Host Interaction: [Your comment that relates to "Climate/Host Interaction" here.]

- Posted comments will not be able to be viewed immediately.
- Comments may not be posted if they:

  Contain inappropriate language which is not germane to the pest rating proposal;

  Contains defamatory, false, inaccurate, abusive, obscene, pornographic, sexually oriented, threatening, racially offensive, discriminatory or illegal material;

  Violates agency regulations prohibiting sexual harassment or other forms of discrimination;

  Violates agency regulations prohibiting workplace violence, including threats.

- Comments may be edited prior to posting to ensure they are entirely germane.
- Posted comments shall be those which have been approved in content and posted to the website to be viewed, not just submitted.

Proposed Pest Rating: B