

# Polyphagous Shot Hole Borer and *Fusarium* Dieback Disease on Palms

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I swore that until hell had frozen over I would never write again about the polyphagous shot hole borer (PSHB) and its vectored, symbiotic, pathogenic fungal complex that causes *Fusarium* dieback (FD) disease on a wide variety of trees, including some cultivated landscape palms. A general hysteria among landscape managers and officials seemed to have pervaded the atmosphere surrounding this beetle/disease association; in some cases one entry/exit hole was all it took for a tree to be marked with the dreaded red or orange “X” for removal. Well, I guess hell has frozen over, at least partially. The discovery of several more palm species in July 2016, bringing the total to 10 that the PSHB attacks and, in some cases, are susceptible to FD has prompted me to return to my keyboard, sit down, and write, albeit, I hope, in a calm and measured manner.

The PSHB/FD association has been attacking a wide variety of trees in southern California for about 14 years, including landscape trees and some palms (Fig. 1), avocado groves, and native species in urban and wild land settings (Eskalen 2016, Eskalen et al. 2013, 2016, Stouthamer et al. 2016). With a host range of over 200 woody species, the PSHB is an invasive, wood-boring, ambrosia beetle in the genus *Euwallacea* (Eskalen et al. 2013, Stouthamer et al. 2016).



Figure 1. The PSHB/FD association has been attacking a wide variety of trees in southern California, including some palms like *Howea forsteriana*.

It bores into trunks and large branches, making tunnels or galleries where it lays eggs and can infect the host with a pathogenic fungal complex that is a food source for the developing larvae (Eskalen et al. 2013). This fungal complex, which causes FD, is composed of *Fusarium euwallaceae*, *Graphium euwallaceae*, and *Paracremonium pembeum* (Eskalen 2016; Eskalen et al. 2013,

Lynch et al. 2016). The *Fusarium* is thought to be the primary pathogen; hence, the common name of this disease. FD has been found in over 137 host species (Eskalen 2016, Eskalen et al. 2013). The disease prevents movement of water and nutrients from the roots up into the trunk, branches, and leaves, which can lead to individual branch death or death of the entire tree. The relatively rapid spread of the PSHB/FD reflects the unusually diverse and large host range in southern California.

Here I provide an overview of the PSHB and its vectored FD disease, including their history, a description of the beetle and damage symptoms, hosts, and management strategies with an emphasis on palms.

### History of the PSHB/FD in Southern California

The PSHB was first found in the Whittier Narrows area about 15 km east of downtown Los Angeles in 2003 (Eskalen et al. 2013, Stouthamer et al. 2016). It was first identified as the tea shot hole borer (*Euwallacea fornicatus*), a serious pest of tea plants in Sri Lanka and India and from which it is morphologically indistinguishable (Stouthamer et al 2016). However, DNA evidence showed the PSHB to be a different and unnamed species (Eskalen et al. 2013, Eskalen 2016, Stouthamer et al 2016). The PSHB and FD were not too common for several years but by 2010 they were more widespread and were responsible for a devastating and well publicized attack on *Acer negundo* (box elder) street trees in a

several block are of northeastern Long Beach (Hodel 2012a, Hodel et al. 2012). They are now established in Los Angeles, Orange, Riverside, and San Diego counties (Stouthamer et al. 2016). In 2015 a second, invasive ambrosia beetle, the Kuroshio shot hole borer (also an unnamed *Euwallacea* sp.), was found attacking trees in San Diego and Orange counties (Dimson et al. 2015, Eskalen 2016, Eskalen et al. 2016). It is morphologically identical to the PSHB but DNA evidence can distinguish them. It, too, vectors a pathogenic fungal complex composed of new species of *Fusarium* and *Graphium* (Dimson et al. 2015, Eskalen 2016, Eskalen et al. 2016).



Figure 2. The PSHB has attacked *Brahea armata* but this palm is not susceptible to the FD.



Figure 3. The PSHB has attacked *Butia odorata* but this palm is not susceptible to the FD.



Figure 4. The PSHB/FD association has attacked *Livistona chinensis*.



Figure 5. The PSHB/FD association has attacked the California native *Washingtonia filifera*.



Figure 6. The PSHB/FD association has attacked *Archontophoenix cunninghamiana*.

By 2013 the PSHB was documented on four species of cultivated landscape palms in southern California, including *Brahea armata* (Mexican blue palm) (**Fig. 2**), *Butia odorata* (misapplied as *B. capitata*) (**Fig. 3**), *Livistona chinensis* (Chinese fan palm) (**Fig. 4**), and *Washingtonia filifera* (California fan palm) (**Fig. 5**) (Eskalen et al. 2013). By the end of 2016, two more palm species susceptible to the PSHB were added to the list, *Archontophoenix cunninghamiana* (king palm) (**Fig. 6**) and *Howea forsteriana* (kentia palm) (**Fig. 1**) (Eskalen 2016), both joining *L. chinensis* and *W. filifera* as FD susceptible. Other landscape palm species observed that the PSHB attacked in 2016 included

*Coccothrinax argentea* (silver thatch palm) (**Fig. 7**), *Dypsis plumosa* (**Fig. 8**), and *Wallichia disticha*.

### PSHB Description and Biology

This description is from Dimson et al. (2015), Eskalen (2016), Eskalen et al. (2016), and Stouthamer et al. (2016). Likely from Southeast Asia, perhaps Vietnam, female beetles are black, 1.8-2.5 mm long (0.07-0.1 inch) (**Fig. 9**). Male beetles are brown and smaller, 1.5 mm long (0.06 inch). Fungi-carrying females land on a host and bore through the bark into the wood where they lay eggs and spread the fungi responsible for FD. Larvae feed on the fungi, thus forming the



Figure 7. The PSHB has attacked *Coccothrinax argentea* but this palm is not susceptible to the FD.



Figure 8. The PSHB has attacked *Dypsis plumosa* but this palm is not susceptible to the FD.

symbiotic relationship, and develop into adults in about one month. Populations typically have more females than males. Mature siblings mate with each other and pregnant females, carrying the fungi in their mouth, depart through entry holes made by their mothers when they entered, and fly to another host. The wingless males do not fly and mostly remain in their host for their entire life. Because it is a tropical beetle, the PSHB is less active in the winter and most active in

late summer and fall when populations and damage can spike.

### PSHB/FD Damage

Depending on the host tree, three possible scenarios can occur (Stouthamer et al. 2016):

1. The host repels the PSHB without fungal infection.
2. The PSHB successfully bores into the host trunk, spreads the fungi,



Figure 9. Female PSHBs are black, 1.8-2.5 mm long, while males are brown and smaller (*Howea forsteriana*).

- but does not produce offspring. About 50% of attacked trees are in this category.
3. The PSHB successfully bores into the host trunk, spreads the fungi, and produces offspring. These tree species are considered reproductive hosts of the PSHB and about 8% of attacked trees are in this category.

That a species is susceptible to PSHB and even FD does not necessarily mean it will always show symptoms or die. For example, I have seen *Albania julibrissin* (silk tree), *Persea americana* (avocado), and *Quercus agrifolia* (coast live oak), all reproductive hosts of the PSHB and susceptible to FD,

sustain heavy attacks for several years and yet are not only still alive but seem in good health and vigor. Why some members of these same species die while others seem to thrive is not well understood.

Damage varies among the host. In non-palm trees typically dark, dry or wet, sometimes oily-looking staining, a whitish sugary exudate (sugar volcano), gumming, and frass on the trunk and main branches are the first noticeable symptoms (Dimson et al. 2015, Eskalen 2016, Eskalen et al. 2016, Stouthamer et al. 2016). Small, precise, perfectly round, entry/exit holes 0.85 mm in diam. (0.03 inch) are visible within or near these symptoms (Dimson et al. 2015, Eskalen 2016, Eskalen et al. 2016, Stouthamer et al.



Figure 10. PSHBs typically make small, precise, round entry/exit holes in palms (*Howea forsteriana*).



Figure 11. Gumming (soft to hard, clear to dark brown, syrupy or jell-like exudate) and stained or darkened surface tissue are symptoms of a PSHB attack (*Archontophoenix cunninghamiana*).

2016). Depending on the host species, tunneling can be so extensive that the structural integrity of the branch is compromised and failure occurs. If the fungal complex has successfully colonized the host, scraping the bark around an entry/exit hole would reveal dead tissue. In advanced, successful infections, wood discolors, leaves and apical shoot tips wilt, leaves brown, branches dieback, and tree death can occur (Dimson et al. 2015, Eskalen 2016, Eskalen et al. 2016, Stouthamer et al. 2016).

Because of their radically different morphology and anatomy, symptoms on



Figure 12. Gumming on this *Howea forsteriana* and darkened surface tissue are typical of a PSHB attack.



Figure 13. Sawdust-like frass on the trunk is typical of a PSHB attack (*Howea forsteriana*).

palms differ somewhat from those on non-palm trees. Like non-palm trees, palms typically have the small, precise, round entry/exit holes (**Fig. 10**), gumming (soft to hard, clear to dark brown, syrupy or jell-like exudate) and stained or darkened surface tissue (**Figs. 11-12**), and frass on the trunk or leaf bases when attacked (**Figs. 13-14**); however, they lack the whitish sugary exudate. If the fungal complex successfully colonizes the palm, the wood discolors, becoming dark brown to black internally surrounding individual galleries (**Figs. 15-16**). White mycelia of the *Fusarium* fungal



Figure 14. Sawdust-like frass and gumping on the trunk are typical of a PSHB attack (*Howea forsteriana*).

complex are sometimes visible inside the galleries (**Fig. 17**); other, opportunistic fungi (*Phytophthora* spp., *Nalanthamala vermoeseni*), perhaps taking advantage of the wounds, also might be present and affect wood color and texture.

However, general wilt symptoms, consisting of leaf browning and sagging, starting from the lower or oldest leaves and moving progressively upwards, and eventual death, as in other *Fusarium* wilts of palms, have not yet been observed or documented with the PSHB/FD association. Perhaps palms can tolerate this pathogenic fungal complex or, we have simply not been tracking this insect/disease association sufficiently long in palms to see these wilt symptoms.

In the few palms so far that the PSHB and FD have attacked, other diseases and



Figure 15. If FD successfully colonizes the palm, the wood discolors, becoming dark brown to black internally surrounding individual galleries (*Howea forsteriana*). However, the slightly darker colored tissue in the general area of the PSHB galleries is likely due to *Phytophthora*.



Figure 16. Successful FD colonization darkens tissues internally around individual galleries (*Howea forsteriana*). Note the PSHB larva at the tip of the knife.



Figure 17. White mycelia of the *Fusarium* fungal complex are sometimes visible inside the galleries (*Howea forsteriana*).

disorders might have already been present, which could kill the palm before the FD can run its course (see below under Hosts).

### Hosts

The PSHB attacks over 200 species of a wide variety of landscape, orchard, and wild trees and palms (Eskalen et al. 2013, Stouthamer et al. 2016). For comprehensive lists of trees species susceptible to PSHB and FD see Eskalen (2016) and Eskalen et al. (2013).

Six landscape palm species are officially listed as attacked by the PSHB (**Table 1**), including *Archontophoenix cunninghamiana* (**Fig. 11**), *Brahea armata*, *Butia odorata*, *Howea forsteriana* (**Fig. 18**), *Livistona chinensis*, and *Washingtonia filifera* (Eskalen et al. 2013, Eskalen 2016). Two, *A. cunninghamiana* and *H. forsteriana*, are

reproductive hosts (Eskalen 2016) and all are susceptible to FD except *B. armata* and *B. odorata*. I have observed at least three and perhaps four additional landscape palm species that the PSHB has attacked (**Table 1**). In total, these 10 species represent two of the five subfamilies of palms: Coryphoideae and Arecoideae (Dransfield et al. 2008). Also, *Washingtonia filifera* is a California native although the PSHB has not yet been found in native stands in the desert.

### The *Archontophoenix*

*cunninghamiana* and *Howea forsteriana* were added to the official list in the last several months. In August 2016 a palm collector and grower in Orange County, California noticed small entry/exit holes, frass, and clear to dark jell-like exudate on the lower trunk of a *H. forsteriana* in his collection. He contacted me and I made collections of a small beetle from

**Table 1. Cultivated Landscape Palms Known to Be Attacked by PSHB and Their Susceptibility to FD (from Eskalen et al. 2013; Eskalen 2016; Hodel observations 2016). \* = reproductive host. \*\* = California native.**

Species	Common Name	Susceptibility to FD	Palm Subfamily
* <i>Archontophoenix cunninghamiana</i>	king palm	Yes	Arecoideae
<i>Brahea armata</i>	Mexican blue palm	No	Coryphoideae
<i>Butia odorata</i> (misapplied <i>B. capitata</i> )	pindo palm	No	Arecoideae
<i>Coccothrinax argentea</i>	silver thatch palm	No	Coryphoideae
<i>Dypsis plumosa</i>		No	Arecoideae
* <i>Howea forsteriana</i>	kentia palm	Yes	Arecoideae
<i>Livistona chinensis</i>	Chinese fan palm	Yes	Coryphoideae
<i>Wallichia disticha</i>		No	Coryphoideae
<i>Washingtonia filifera</i> **	California fan palm	Yes	Coryphoideae
<i>Wodyetia bifurcata</i>	foxtail palm	No	Arecoideae



Figure 18. The base of the trunk of this *Howea forsteriana* shows the symptoms of a PSHB attack.



Figure 19. Most of the darkened tissue toward the trunk perimeter of this *Howea forsteriana* that was attacked by the PSHB/FD association is mostly due to a basal trunk rot from *Phytophthora* sp., which likely would have killed the palm before the FD could kill it.

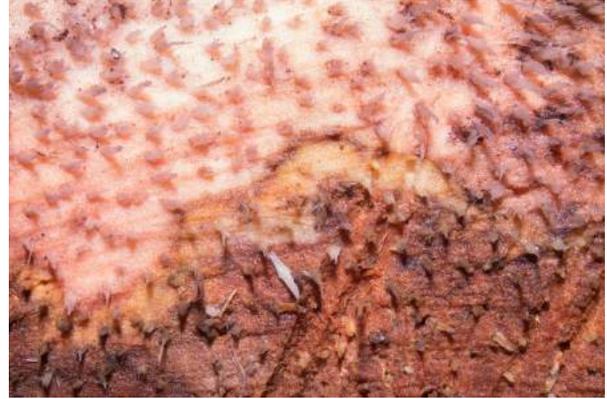


Figure 20. Darkened, mostly *Phytophthora*-diseased tissue (bottom), advancing infection margin (center yellow), and healthy, white tissue (top) are evident in this trunk cross-section from the *Howea forsteriana* that the PSHB/FD association had attacked.

the palm that entomologists at the California Department of Food and Agriculture and entomologist Richard Stouthamer and plant pathologist Akif Eskalen at the University of California, Riverside tentatively identified as the PSHB. In September 2016 the palm collector and I felled the still alive and mostly healthy appearing palm and I took new material to Stouthamer and Eskalen where the PSHB and FD were confirmed, making *H. forsteriana* the first palm to be a known reproductive host of this potentially serious and damaging beetle/fungi association. Not long thereafter, an *A. cunninghamiana* in Long Beach in Los Angeles County was found with PSHB and FD.

Both the *Archontophoenix cunninghamiana* and *Howea forsteriana* might not have succumbed to FD. In the case of the *A. cunninghamiana* in Long Beach, it was declining for several years prior to the PSHB attack with a condition known as penciling (Hodel 2012b), where the trunk becomes progressively narrower, leaves

shorter or stunted, and the palm loses vigor. Such palms are typically extremely susceptible to pink rot, an opportunistic disease caused by the fungus *Nalanthamala vermoeseni*. Indeed, the owner's description of the upper part of the narrowed trunk collapsing and bending over is vintage pink rot symptoms. The *H. forsteriana* in Orange County had a basal trunk rot from *Phytophthora* sp. (Figs. 19-20). So in both cases, while the fungal complex that causes FD was present, the palms likely died or would have died from these other pathogens before the FD could kill them, if it could have killed them at all.

At the Orange County site I observed the PSHB also attacking the palms *Coccothrinax argentea* (Figs. 21-23), *Dypsis plumosa* (Fig. 24), and *Wallichia disticha*; in the latter two, though, the borer only advanced into the persistent leaf bases clothing the trunk, not the trunk itself. While it did advance into the trunk of the *C. argentea*, the infestation was unusually light, indicating this species is not a reproductive host of the PSHB. Nonetheless, it appears that the PSHB was present at the site in sufficient numbers to sample a variety of palms, and I suspect it will attack more palm species in the future.



Figure 21. The PSHB also attacks the palm *Coccothrinax argentea*.



Figure 22. The PSHB also attacks the palm *Coccothrinax argentea*.



Figure 23. The PSHB attack on *Coccothrinax argentea* was not extensive although it did enter the trunk.



Figure 24. The PSHB also attacks the palm *Dypsis plumosa*.



Figure 25. This *Wodyetia bifurcata* in San Diego was likely attacked by the PSHB in 2010.

The PSHB might also attack *Wodyetia bifurcata* (foxtail palm). In June, 2010, prior to the incident with *Acer negundo* street trees in Long Beach, I was called to inspect a *W. bifurcata* in San Diego that had small, precise, round, entry/exit holes, frass, and dark staining on the lower part of the trunk (Figs. 25-26) that looked similar if not identical to the damage I observed recently on *Archontophoenix cunninghamiana* in Long Beach and *Howea forsteriana* in Orange County. If it was the PSHB, which I think it was, it is one of the earlier infestations in San Diego and the first for a palm anywhere in California.

### Management

While the PSHB attacks even healthy trees, providing optimal culture will help trees that are not killed recover more quickly (Stouthamer et al. 2016). Select an appropriate tree for the location and plant and care for it appropriately. For palms appropriate culture means correct planting depth, irrigation, well drained soil, palm-special fertilizer, and mulch (Hodel 2012b).

Early detection and proper removal and disposal of infested wood can reduce PSHB populations and spread of FD (Eskalen 2016, Eskalen et al. 2016, Faber et al. 2016).



Figure 26. Trunk details of the *Wodyetia bifurcata* in San Diego shows the precise, round entry/exit holes, frass, and stained tissue that characterize the PSHB.

On-site chipping and solarizing infested wood can limit spread of the PSHB/FD association. Chip wood into pieces smaller than 2.5 cm (1 inch) (Faber et al. 2016, Stouthamer et al. 2106). If a branch or trunk is too large to chip, solarize it under a clear plastic tarp (0.15mm/0.006 inch) for six weeks in the summer (July to August) and six months at other times of the year (Faber et al. 2016). Do not move infested woods or chips out of an infested area (Faber et al. 2016). Chips can also be moved to a professional composting facility, biogeneration facility, or landfill if these are not outside the infested area (Faber et al. 2016). To help prevent spread of FD, sterilize pruning tools with either 5%

household bleach, Lysol cleaning solution, or 70% ethyl alcohol when pruning infested or diseased wood (Faber et al. 2016).

Only preliminary work has been performed on chemical and biocontrol strategies. Eskalen et al. (2016) reported that, in preliminary, ongoing pesticide experiments on landscape trees [*Platanus* (sycamore)], a combination of trunk-injected [into the xylem (5 to 7.5 cm, 2 to 3 inches)] of emamectin benzoate (4%) and propiconazole (14.3%) or emamectin benzoate (4%) and tebuconazole (16%) reduced new beetle attacks over time on lightly infested trees. On moderately to heavily infested trees, trunk sprays of

bifenthrin (23.4%) and a soil drench of imidacloprid (75%) produced some level of control. However, the chance of saving a moderately to heavily infested tree is very low.

Because of their different anatomy and morphology (Hodel 2012b), including lack of a vascular cambium, trunk injections are not recommended for palms; trunk wounds, including those from injections, never cover over, are permanent and unsightly, and can serve as entry sites for pests and diseases. However, pest control applicators have used prophylactic sprays on the trunk with dinotefuran and soil applications of imidacloprid to protect especially valuable palms although this strategy has not been independently verified.

### Summary

The PSHB attacks over 200 species of trees, including at least 10 species of palms. The pathogenic fungal complex the borer vectors, which causes the serious and potentially deadly FD, attacks at least four of these palm species although no palm deaths can be unequivocally attributed to the disease at this time. The PSHB/FD association is likely to attack more palm species in the future. Vigilance and proper removal and disposal of infested/infected palms will help to reduce PSHB populations and FD incidence. Prophylactic trunk and soil treatments might be beneficial in some instances.

### Acknowledgements

I thank Richard Stouthamer and Akif Eskalen of UC Riverside for examining the *Howea forsteriana* and confirming the reproductive nature of the PSHB and the presence of FD, and Akif Eskalen for reviewing an early draft of the manuscript. Arborist Jen Greby assisted with collecting the *H. forsteriana*.

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