The Polyphagous Shot Hole Borer, *Euwallacea fornicatus*, a New Invasive Pest in Southern California

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PSHB is an ambrosia beetle

- Weevils that are related to bark beetles
- Shot hole borers are a group of ambrosia beetles that make tiny entry holes in trees
- Ambrosia refers to a symbiotic fungus
- Fungus is carried along by female in special organs in her mouth parts
- Fungus is used to infest the host plant and both adult beetles and larvae feed on fungus
- Why should we worry about this beetle/fungus complex?
Beetle fungus complex can infest many host plants and causes branch die back and may kill host trees.
Euwallacea fornicatus

- First detected in CA in 2003 in Whittier Narrows
- Since then caught a couple of times in CDFA traps in LA County
- Caused death of large number of Box Elder street trees in Long Beach in 2010
- Problem not recognized until February 2012 when Akif Eskalen found it on a backyard avocado in South Gate
- Since then surveys have shown that
  - Widely spread in LA Co. and parts of Orange Co.
  - Attacks many host tree species
Known Distribution of Fusarium Dieback/Shot Hole Borer in Southern California 07/27/2012

Legend
- Red: Positive finding Fusarium sp./shot hole borer
- Green: Negative-Fusarium sp./shot hole borer

Data source: University of California, Riverside. Department of Plant Pathology and Microbiology. 900 University Ave. Riverside, CA. http://www.eskalenlab.ucr.edu
Euwallacea fornicatus

• Where does the beetle come from?
  – Probably South East Asia, possibly Africa
  – Also an invasive species in Israel causing extensive damage to Avocado

• Beetle identity
  – Morphologically *E. fornicatus*
  – Based on DNA evidence it is another species
  – Suggested common name Polyphagous Shot Hole Borer
RELATIONSHIPS BETWEEN CALIFORNIAN SPECIMENS OF TSHB INFERRED FROM COI MTDNA SEQUENCES.
MAXIMUM-LIKELIHOOD TREE (BRANCH SUPPORT >50%)
PRODUCED USING PHYML VIA PHYLOGENY.FR
(http://www.phylogeny.fr/version2_cgi/index.cgi)

Average sequence divergence = 14.2%
Euwallacea fornicatus-like species

- *E. fornicatus*
- *E. xanthopus*
- *E. andamanensis*
- *E. velatus*
Euwallacea fornicatus-like species

- **Euwallacea xanthopus.** Synonyms: *E. rudis, E. semirudis, E. fraternus, E. sereinuus, E. dubius, E. hybridus, E. kivuensis, E. interruptus, E. neohybridus, E. artehybridus, E. longehirtus*

- **Euwallacea fornicatus.** Synonyms: *E. fornicatiior, E. whitfordiodendrus, E. perbrevis, E. schultzei, E. tapatapaoensis*

- California and Israeli form of beetle identical and different from the tea infesting form from Sri Lanka (original collection site of *E. fornicatus*).

- What do we call it? USDA needs a name.
Plate 2 Distribution of *Xyleborus fornicatus* Eichh. (Coleoptera: Scolytidae) in the world (source: CABI CPC 2004) (Yellow dot indicates at least one positive record from the country).
Life cycle beetle

- Mated female bores into tree, creates galleries in tree, in the region that transports the water from the roots to the leaves.
- Galleries are infected with symbiotic fungus (= ambrosia in this case a new *Fusarium* species) that beetle carries in mouth parts.
- Fungus grows on gallery walls and spreads through the tree.
Gallery formation

- Boring the gallery takes several days
- Starts out with a straight entrance gallery
- Terminates in the wood near the cambium and then runs parallel to the outer surface of the stem
- Fungus transferred to the gallery walls
- Spores can be seen as a fine dust on the gallery wall
- No eggs found in galleries less than 8 days old
- Egg laying starts in the second week (pile at end of gallery)
- Eggs are laid on successive days
- Larvae feed on spores
Beetle entrance
Life cycle beetle

- Female lays eggs in galleries
- Eggs hatch and larvae feed on the fungus
- New adults after about one month

From Thesis Walgama 2007
Life cycle beetle

• Sex ratio offspring very female biased, brothers mate with sisters in galleries and mated females leave the galleries to create their own galleries for offspring production

• Lifestyle leaves very few ways to combat the beetle. Single mated female can initiate new population
Gallery formation

- Galleries in Pomegranate and Castor are found in the lower part of the trunk.

Table 2. Total number of holes on tree trunk of castor plant.

<table>
<thead>
<tr>
<th>Castor (year plant)</th>
<th>No. of holes/30 cm from ground level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
</tr>
<tr>
<td>One</td>
<td>18</td>
</tr>
<tr>
<td>Two</td>
<td>67</td>
</tr>
<tr>
<td>Two</td>
<td>75</td>
</tr>
</tbody>
</table>

From: Mote and Tambe 1989, J. Maharashtra Agric Univ 16: 439-440
Development time

**Gadd 1941**

- Entrance of female to laying of first egg: 8.4 days
- Egg stage: 6.9 days
- Larval stages (3): 15.2 days
- Pupal stage: 7 days
- Adult before emergence: 2-3 days
- Total: 40 days
Walgama and Zalucki 2007

- Detailed studies on development as a function of temperature on tea shoots
- Degree day model made
- Once we figure out the relationship between stem temperature and ambient temperature we should be able to determine the number of generations we can expect (if it our beetle is TSHB)
- 9 generations per year in Sri Lanka
- Using this model from 2-4 generations per year in So Cal
Emergence from stems

- Most beetles emerge between 11am and 2 pm
- About half of them take off
- What happens to the non-dispersers?

Calnaido, D (1965) Ent. Exp. Appl 8:249-262
Flight activity in Tea in Sri Lanka

**Flight activity**

- Trapped with suction traps
- Only females fly
- Generally fly vertically up 6-9 m, in spiraling pattern
- Velocity w/o wind 0.3-0.6 m/sec
- Longest flight in room was 24 min.
- Estimated that they could fly 430-860 m without wind
- Estimated flight duration in field <1 hr

Calnaido, D (1965) Ent. Exp. Appl 8:249-262
Emergence pattern of males and females

- Only females fly
- Assumed only inseminated females fly
- There is a time period after emerging from the pupae, before the beetles can fly

Calnaido, D (1965) Ent. Exp. Appl 8:249-262
How many species are vulnerable to beetle attack?

• Botanical gardens
• Total 341 species
• Attacked by beetle 203 sp
  – 113 the fungus grew in
  – ~19 species the beetle also reproduces on
    • Coast life oak
    • Avocado
    • Sycamore
    • Liquidambar
    • Coral tree
    • Castor bean
Table 3. PSHB/Fusarium sp. complex in sample of tree species found in the botanical gardens found in a heavily infested part of Los Angeles County.

<table>
<thead>
<tr>
<th></th>
<th>Number of tree species</th>
<th>Fraction of all species (%)</th>
<th>Fraction of attacked species (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number</td>
<td>335</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attacked by PSHB</td>
<td>207</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Host for Fusarium sp.</td>
<td>112</td>
<td>33</td>
<td>54</td>
</tr>
<tr>
<td>Weeping spots on bark</td>
<td>147</td>
<td>44</td>
<td>71</td>
</tr>
<tr>
<td>Powder depositions</td>
<td>22</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Gumming on bark</td>
<td>69</td>
<td>20</td>
<td>33</td>
</tr>
<tr>
<td>Reproductive hosts for the beetle</td>
<td>19</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>

What happens when beetle attacks a tree?

• Appears to try out many different tree species in S. Cal. (207/335 in botanical gardens sample)

• Outcome of attack:
  – Beetle in repelled, no fungus infection (95/207)
  – Beetle drills into the tree, transmits fungus to the tree but does not produce offspring on the tree (93/112)
  – Beetle is not repelled, fungus infects tree, beetle reproduces in tree (true host) at least 19/112 species
103 species of common street trees

Table 5. Number of tree species and abundance of tree specimens susceptible to the PSHB/Fusarium sp. complex in the southern Californian urban forest. Estimations were made using a representative tree species list (City of Orange, 1999) and susceptibility of tree species determined in botanical garden survey.

<table>
<thead>
<tr>
<th>Trees species</th>
<th>% of all tree specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number</td>
<td>103</td>
</tr>
<tr>
<td>Attacked by PSHB</td>
<td>53</td>
</tr>
<tr>
<td>Host for fungus</td>
<td>36</td>
</tr>
<tr>
<td>Reproductive host</td>
<td>6</td>
</tr>
</tbody>
</table>

Beetle drills into the tree, transmits fungus to the tree but does not produce offspring on the tree

- We do not know the final outcome of this interaction
  - Often leakage of xylem fluid noticed on trunk and branches: can the tree leak to death?
  - Could still mean that the tree will suffer if the xylem vessels are clogged up and this will cause dieback of branches
  - Maybe nothing bad will happen to tree
Beetle is not repelled, fungus infects tree, beetle reproduces in tree (true host)

- These trees suffer
- Mild symptoms will be branch dieback, severe symptoms tree death.
- Known hosts:
  - Castor bean
  - Box elder
  - Coast live oak
  - Avocado
  - Sycamore
Host Species: Castor Bean

External symptoms

Galleries inside trunk

Photos
Akif Eskalan
Host species

Coast live oak (*Quercus agrifolia*)
Host species Box Elder

Box Elder (Acer negundo)
Host Species Avocado

- Sugar volcanoes
Host species avocado (cv. Hass)
In Israel PSHB has invaded commercial avocado

- First detected in 2005
- Now a serious problem in their avocado production area
- In Israel it also infects Castor and it is the same genetic form as we have here in CA
- Spreads at a rate of about 12 miles per year

Ambrosia Beetles are difficult to control

- Generally only short time outside the tree
- Attract
  - Sex pheromones- No
  - Aggregation pheromone No
- Repel
  - Anti aggregation pheromone- Maybe
- Influence reproduction
  - Potassium acetate added to fertilizer
  - Substantial reduction in # of eggs and # pupae
  - Not in the number of galleries
  - No evidence that this is used
Bark Beetles are difficult to control

- Biocontrol
  - Unlikely (generalist predators)
  - One of our contacts in India has seen parasitoids

- Pesticides
  - Old literature in tea, many nasty chemicals DDT etc.
  - Fenthion is used in tea twice a year
  - Not allowed any longer in the US
  - Other bark beetles can be killed by putting pyrethroids (Bifentrin) on the bark
  - Systemic pesticides (fungicide) may be the most promising?
  - Sofar no good insecticidal strategy found in Israel where they have worked on it for several years
What to do if you think you have an infestation?

• Go website of the Eskalen lab at UCR
• A submission form can be downloaded to submit a wood sample containing the fungus for identification
• Fungus will be identified to determine if it is the Fusarium species associated with the beetle
• If it appears that you have the beetle/fungus complex, we do not have as yet recommendations for you
• Pesticide trials underway, both chemicals and entomopathogens are tried
Please fill out the following form. You cannot save data typed into this form. Please print your completed form if you would like a copy for your records.
Conclusion

• New invasive ambrosia beetle
• Tries out many different trees (~50% of all tree species)
• Infects some of these trees with fungus (~60% of attacked tree species)
• Beetle reproduces in ~ 6% of attacked tree species
• Avocado, Coastal life oak, Box elder, Liquidambar, Sycamore
• Fungus infection and beetle reproduction can cause dieback of tree branches and death of trees
• We know little about the outcome of fungus-only infection
• No known methods to control the beetle or fungus infection once it is in tree
• Looks to be a major problem in urban forest, commercial avocado and forests once it gets there.
Funding and Collaborators

Funding: California Avocado Commission

Collaborators:
Paul Rugman-Jones, Entomology, UC Riverside
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Andrew Trotter, West Coast Arborists