Polyphagous- and Kuroshio shot hole borers: invasive *Euwallacea* spp. threatening Californian agriculture and natural areas

Paul Rugman-Jones & Richard Stouthamer

Department of Entomology
University of California, Riverside, CA 92507
OUTLINE:

- Identity of the beetles
- Lifestyle & basic biology
- Detect, Deter, Control?
OUTLINE:

- Identity of the beetles
- Lifestyle & basic biology
- Detect, Deter, Control?
CRYPTIC SPECIES?

“two or more distinct species that are erroneously classified (and hidden) under one species name, because they are (at least superficially) morphologically indistinguishable.”

DNA shows African elephants are in fact two separate species. [Science 293:1473-1477]
What shot hole borer have we got in CA?

- Morphologically - looks like *Euwallacea fornicatus*
  (Tea shot hole borer)
Based on DNA evidence *Euwallacea fornicatus* is actually a complex of closely related cryptic species:

Stouthamer et al. submitted
- Tea shot hole borer is not present in CA
- But, polyphagous shot hole borer (PSHB) was first detected in 2003

Stouthamer et al. submitted
...and Kuroshio shot hole borer (KSHB) was subsequently detected in 2013.
In addition to accurate species ID, DNA can also be used to identify the geographic origin of an invasive pest - in much the same way that it can tell us “who’s the Daddy?”
DNA profiling has revealed that CA populations of KSHB and PSHB most likely originated from Taiwan and Vietnam, respectively.
- California has been invaded on at least 2 occasions, by 2 different species – PSHB and KSHB

- TSHB has not invaded California, BUT, it has invaded the states of Florida and Hawaii
OUTLINE:

- Identity of the beetles
- Lifestyle & basic biology
- Detect, Deter, Control?
PSHB/KSHB are ambrosia 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 females in special organs in their heads (mycangia)
- Fungus is used to infest the host plant and both adult beetles and larvae feed on fungus
Fungal Pathogens associated with PSHB and KSHB

Polyphagous shot hole borer
PSHB

Kuroshio shot hole borer
KSHB

Fusarium euwallaceae
Graphium euwallaceae
Paracremonium pembeum

Fusarium sp.
Graphium sp.
PSHB & KSHB attack many tree species!

Native species of oak, sycamore, and willow

Agricultural crops: avocado

Invasive “weeds”: castor bean

Popular ornamentals: maples, coral trees, and palms

http://eskalenlab.ucr.edu/pshb.html
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 branch
- Symbiotic fungus transferred to the gallery walls
Oviposition and larval development

- Egg laying starts about 1 week after the gallery is begun (pile at end of gallery)
- Eggs are laid on successive days
- Larvae feed on the fungus
- Development is temperature dependent, but new adults after about one month at > 26°F
- Brood size is typically 20-50! (in the lab)
Extreme inbreeding

- Sex ratio of offspring very female biased.
- Brothers mate with sisters inside the galleries.
- Mated females leave the galleries to create their own galleries for offspring production.
- Lifestyle leaves few opportunities to combat the beetle. Furthermore, a single mated female can initiate a new population.
Dispersal?

- Only females are capable of flight.
- But, on leaving the natal gallery, it often doesn’t make sense for a female to fly - why risk not finding a suitable host, if you’re already sitting on one?
- Degree day models and our own observations suggest 3-5 generations per year in southern CA for PSHB and KSHB.
Population growth (and the defeat of a tree)

- Assuming attack is initiated by a single female
- ...and 5 daughters survive from each subsequent brood (10-20%)
What determines when PSHB/KSHB leave a host tree?

- If temperatures are not sufficient for flight, females will often remain in their natal gallery for an extended period.

Photo credit: Mexican Pine Beetle - *Dendroctonus approximates*. Copyright © 2013 Nicholas Aflitto. Available at, http://bugguide.net/node/view/783186/bgimage
Air temperature in afternoon needs to be $> 68^\circ F$

- During winter beetle larvae will develop in tree when external temperatures are $> 59^\circ F$
- If afternoon temperatures are below $68^\circ F$ they are not able to fly
- When there is a hot spell in winter a peak in flight activity will take place
What determines when PSHB/KSHB leave a host tree?

- The host tree is no longer suitable
  - A water-stressed tree is unable to pull up xylem
    - the fungi (on which the beetles feed) die in the galleries
  - famine results
  - triggering those beetles that can go, to do so.
Water stressed host tree

- Toward the end of the summer, trees in unmanaged lands will experience water stress. Not enough water for food source of beetles = beetles will fly
  
e.g., September flight traps near San Diego Zoo (Balboa Park)

- If enough water is available no such peaks in flight activity
  
e.g., Huntington Library
Based on studies of flight activity in TSHB and our own observations of flight activity in both PSHB and KSHB, a conservative estimate for natural population spread in southern CA is **10 - 15 miles per year**.

- Time-limited: 11am - 3pm.
- Maximum flight duration in field < 1hr.
- Unassisted flight speed: 1.3 - 2 ft/s
- Combines with mean wind speed (e.g. Escondido - 10.5 ft/s) for maximum 12.5 ft/s
- Flying downwind for 1 h = 8.5 miles
- So, maximum dispersal per generation is 8.5 miles
- 4 - 5 generations per year in southern California (mainly from June through October)

Calnaido, D (1965) Ent. Exp. Appl 8:249-262
Spread of the infestations

http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=3446e311c5bd434eabae98937f085c80
Spread of the infestations

http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=3446e311c5bd434eaba98937f085c80
Spread of the infestations

http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=3446e311c5bd434eabae98937f085c80
Spread of the infestations

2015

http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=3446e311c5bd434eaba98937f085c80
Spread of the infestations

http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=3446e311c5bd434eabae98937f085c80
Tijuana River Valley in San Diego
Tijuana River Valley in San Diego

Mortality on Arroyo willow (*Salix lasiolepis*)
OUTLINE:

- Identity of the beetles
- Lifestyle & basic biology
- Detect, Deter, Control?
Detect:

- PSHB/KSHB spend only a short time outside the host tree
- No sex pheromones
- No aggregation pheromone
- Host attractants - Yes
Quercivorol as a lure

Availability of quercivorol lure:

Synergy Semiochemicals Corp (Canada)
Tel: 604-454-1122    Email: synergy@semiochemical.com
Lure item # 3361 — $12

ChemTica Internacional (Costa Rica)
Tel: 506-22615396    Email: cam@chemtica.com
Lure item # P548-Lure — $6

EtOH decreased effectiveness

3361 is best “racemic mix”
Detect:

Higher lure concentration does not result in higher catch!

Dosage of quercivorol does not seem to be important in the lower range (high is equivalent to a single commercial lure)
Detect:

Trap type?

- Long Lindgren
- Short Lindgren
- Vane
Influence of trap type on beetle catch

<table>
<thead>
<tr>
<th>Trap type</th>
<th>Total number of beetles in 11 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>long</td>
<td>0</td>
</tr>
<tr>
<td>short</td>
<td>50</td>
</tr>
<tr>
<td>vane</td>
<td>100</td>
</tr>
</tbody>
</table>

Long and vane catch equivalent numbers

Detect:
Influence of trap type on beetle catch

<table>
<thead>
<tr>
<th>Trap type</th>
<th>Total number of beetles in 11 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>long</td>
<td>0</td>
</tr>
<tr>
<td>short</td>
<td>50</td>
</tr>
<tr>
<td>vane</td>
<td>100</td>
</tr>
</tbody>
</table>

Long and vane catch equivalent numbers
BUT – be careful with preservative liquids!

Antifreeze preserves DNA, BUT, not all antifreezes are created equal!
- Ethanol based
- Propylene Glycol based
- Propylene/Ethanol blend

Ethanol attracts lots of unwanted by-catch
May also repel PSHB/KSHB?

Detect:

Xyleborinus saxeseni

© Jiri Hulcr
Deter: Verbenone as a deterrent

Influence of verbenone pouch on catch in trap “baited” with a quercivorol lure

Reduction in trap catch of 91% over three week period
Control: cultural?

- Firewood movement?
- Chipping?
- Solarization and composting?

Fine chipping (<1") appears very effective

Effective in summer only when ambient temp > 95°F
Control: chemical?

- Biggest problem - getting the materials to the target.
- Bifenthrin (Onyx), applied as a trunk spray, may protect trees from attack.

![Bar chart showing galleries per sq m for Control, Danitol, Onyx, and Safari]

Probably practical only for valuable specimens?
Control: biological?

Nematodes found in Vietnam & Taiwan (and CA).

Parasite or mutualist?

Parasitoid wasps found in Taiwan.
Parasitic(?) flies found in Vietnam.

*Beauveria bassiana* - Entomopathogenic fungus shows promise in the lab but dry climate & difficulty “delivering” it to the beetles make it an unlikely candidate!
Conclusions

- PSHB and KSHB are invasive ambrosia beetles most likely originating from Vietnam and Taiwan, respectively.
- Attack lots of tree species including avocado
  - (list available at http://eskalenlab.ucr.edu/pshb.html)
- Potential for rapid population growth and spread in CA
  - ...and elsewhere!
Conclusions (cont.)

- Querciverol is an effective lure for monitoring using Lindgren and vane traps (no ethanol in collection cup)
  - But, while traps are a good indication that PSHB/KSHB are there, the only chance to trap beetles is during their flight.
Conclusions (cont.)

- Querciverol is an effective lure for monitoring using Lindgren and vane traps (no ethanol in collection cup)
  - But, while traps are a good indication that PSHB/KSHB are there, the only chance to trap beetles is during their flight.
  - The presence of beetles inside a tree may be evident much earlier, but requires vigilant observation.
Conclusions (cont.)

- Querciverol is an effective lure for monitoring using Lindgren and vane traps (no ethanol in collection cup)
  - But, while traps are a good indication that PSHB/KSHB are there, the only chance to trap beetles is during their flight.
  - The presence of beetles inside a tree may be evident much earlier, but requires vigilant observation.
- Best chance of trapping beetles in an area that is not known to be infected?
  - end of the summer (when host trees are water-stressed)
- Verbenone shows promise as a deterrent.
Conclusions (cont.)

- Potential biological control agents have been identified and are under further investigation
  - Nematodes
  - Parasitoid wasps
  - Parasitic flies
  - Entomopathogenic fungi
Acknowledgements:

Stouthamer Lab (UCR)
Chrissy Dodge, Amanda Alcaraz, Veronica Fernandez, Crystal Johnston, Deena Husein

The Huntington Library and Botanical Garden
Dan Berry, Tim Thibault

Eskalen Lab (UCR); Paine Lab (UCR)

California Avocado Commission

USDA-APHIS
Miriam Cooperband, Allard Cossé

Funding sources:

California Avocado Commission

USDA Farm Bill

APEAM
(Avocado Producers and Exporting Packers Association of Mexico)