

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

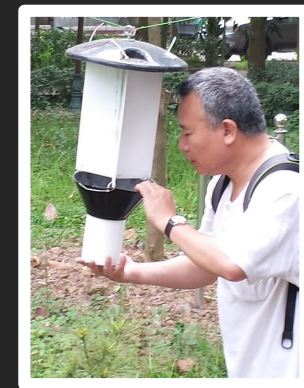
Paul Rugman-Jones & Richard Stouthamer

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University of California, Riverside, CA 92507



OUTLINE:

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

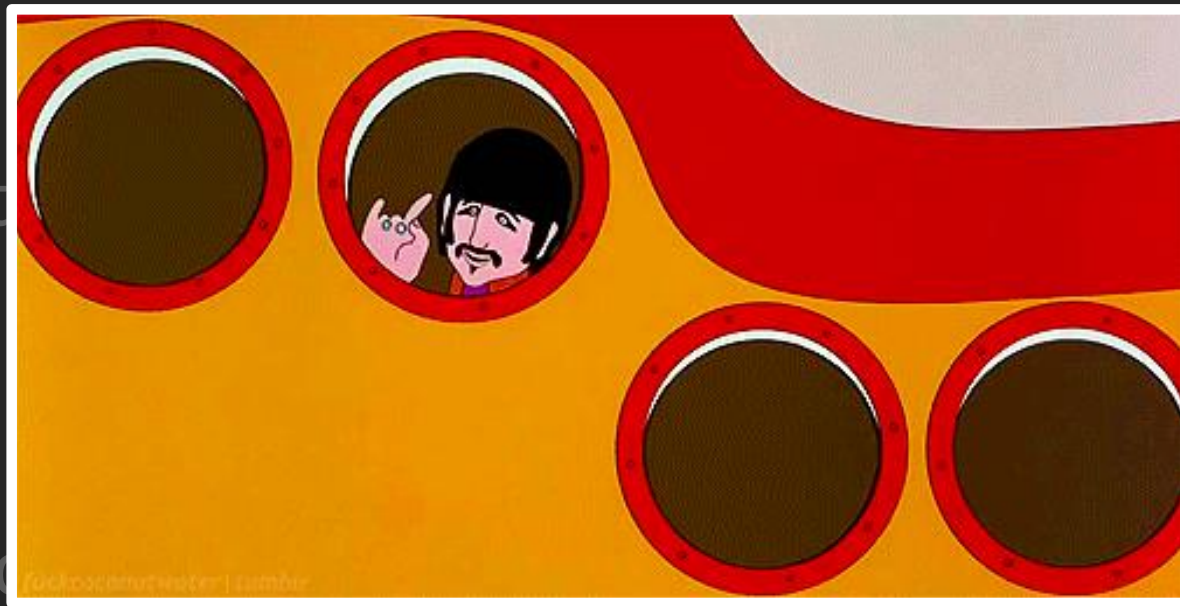


OUTLINE:

- Identity of the beetles



- Lifest



- Dete

https://38.media.tumblr.com/tumblr_m36dvnZaqT1qa4velo1_500.gif

CRYPTIC SPECIES?



DNA shows
African elephants
are in fact two
separate species.
[*Science* 293:1473-1477]

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

What shot hole borer have we got in CA?

- Morphologically - looks like *Euwallacea fornicatus* (Tea shot hole borer)

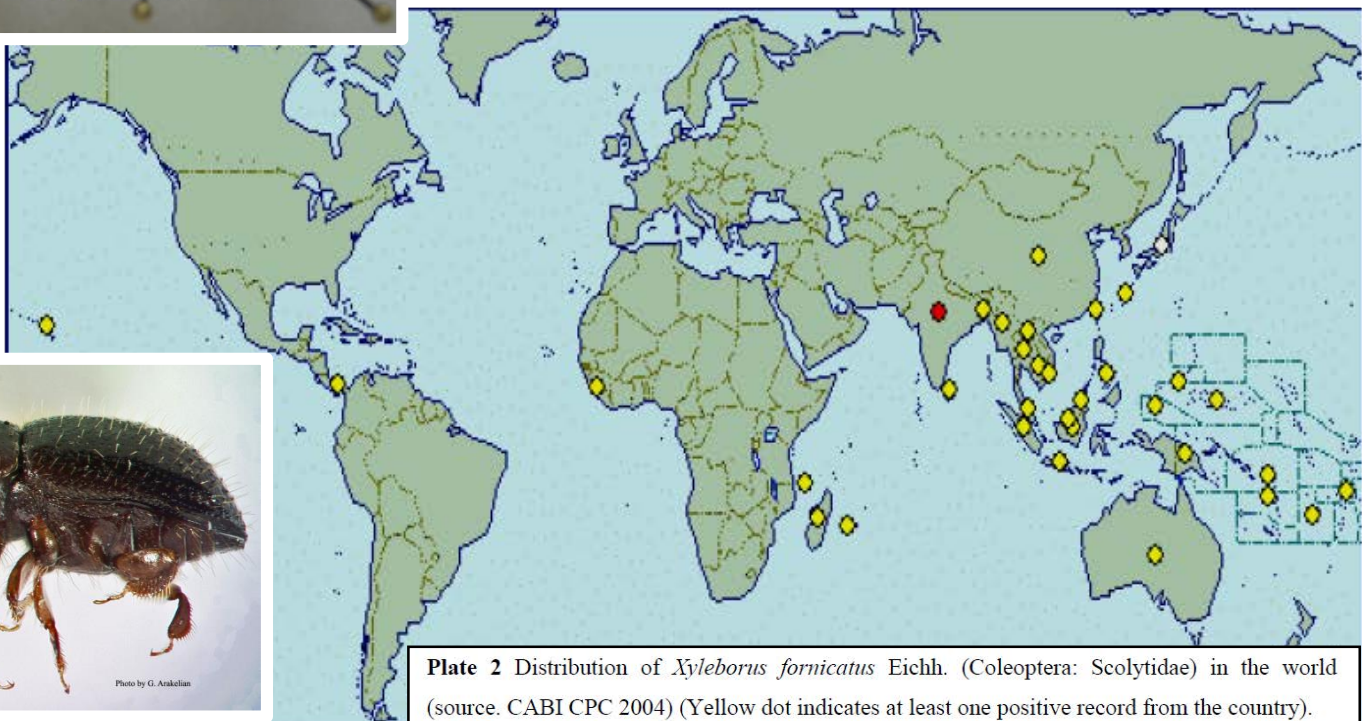
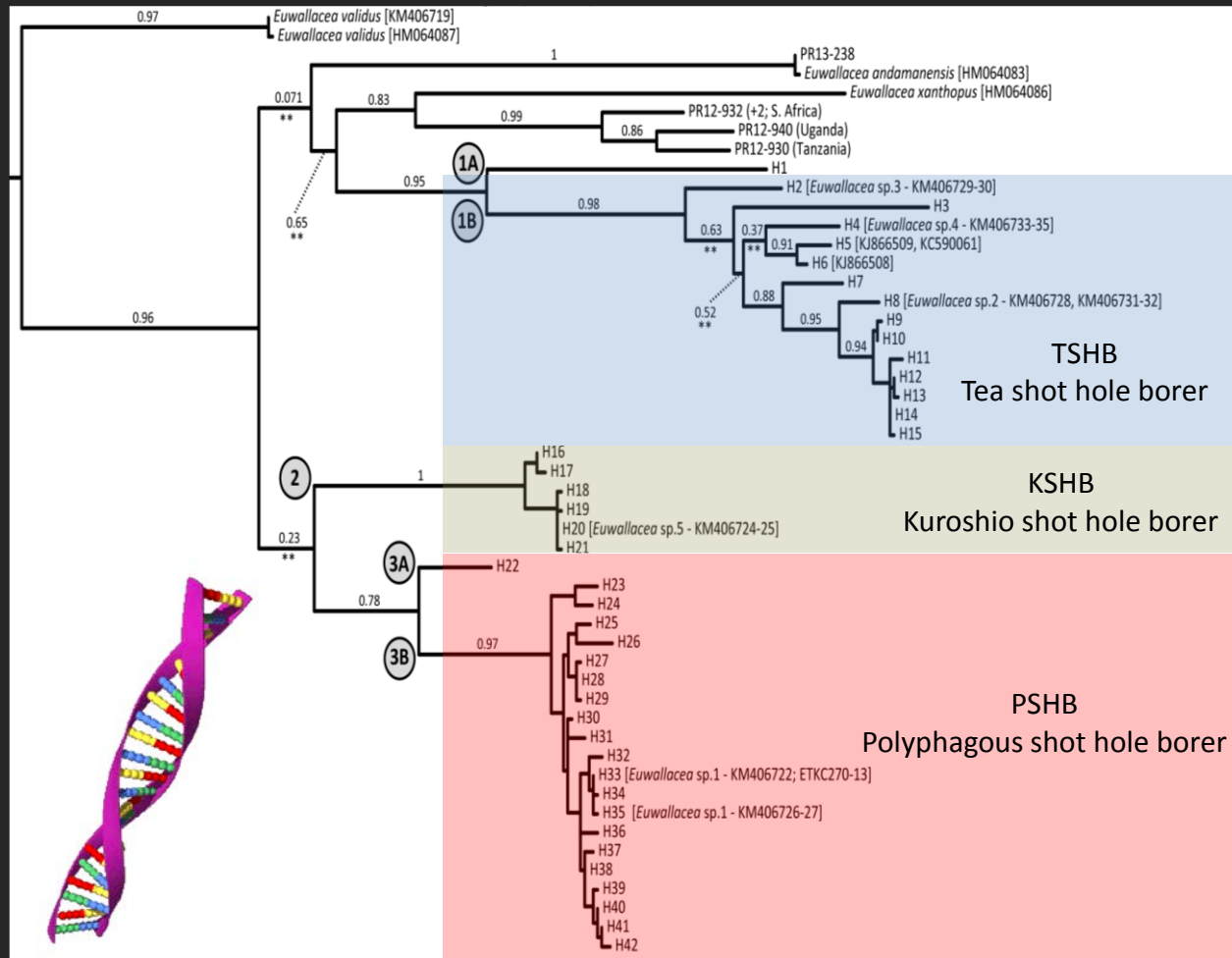


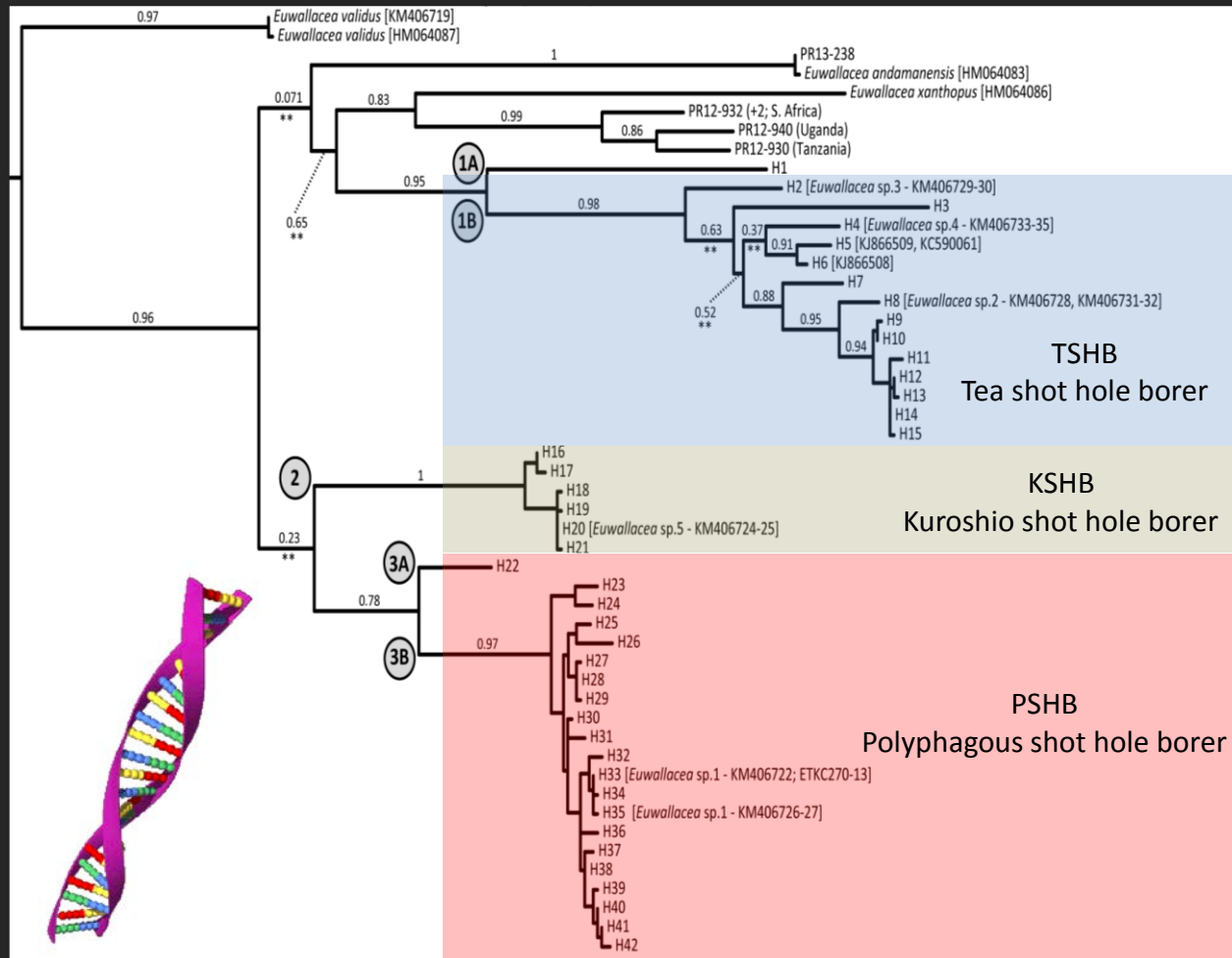
Plate 2 Distribution of *Xyleborus fornicatus* Eichh. (Coleoptera: Scolytidae) in the world (source. CABI CPC 2004) (Yellow dot indicates at least one positive record from the country).

Based on DNA evidence *Euwallacea fornicatus* is actually a complex of closely related cryptic species:



Stouthamer *et al.* submitted

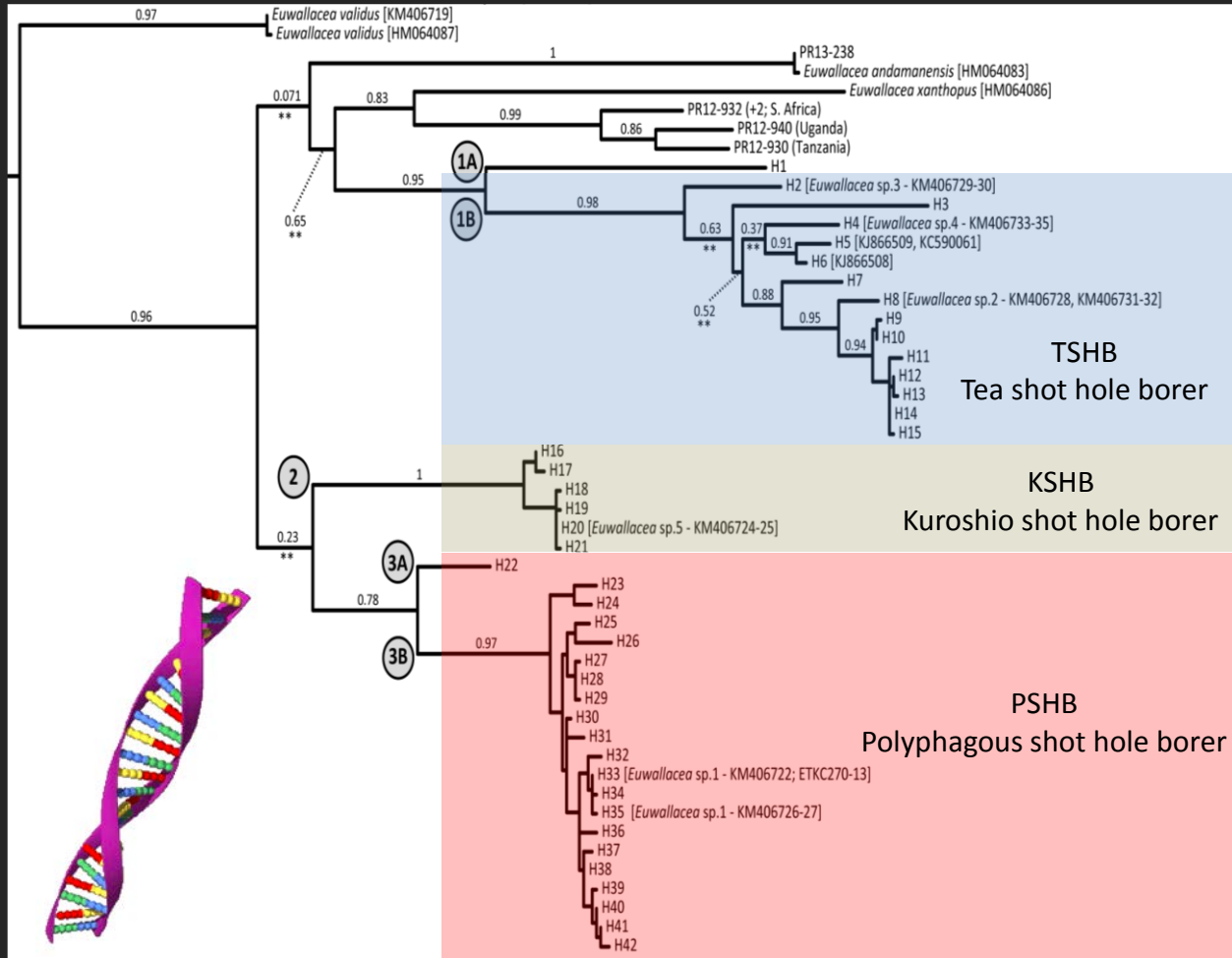
■ Tea shot hole borer is not present in CA



Florida
Hawaii



- But, polyphagous shot hole borer (PSHB) was first detected in 2003

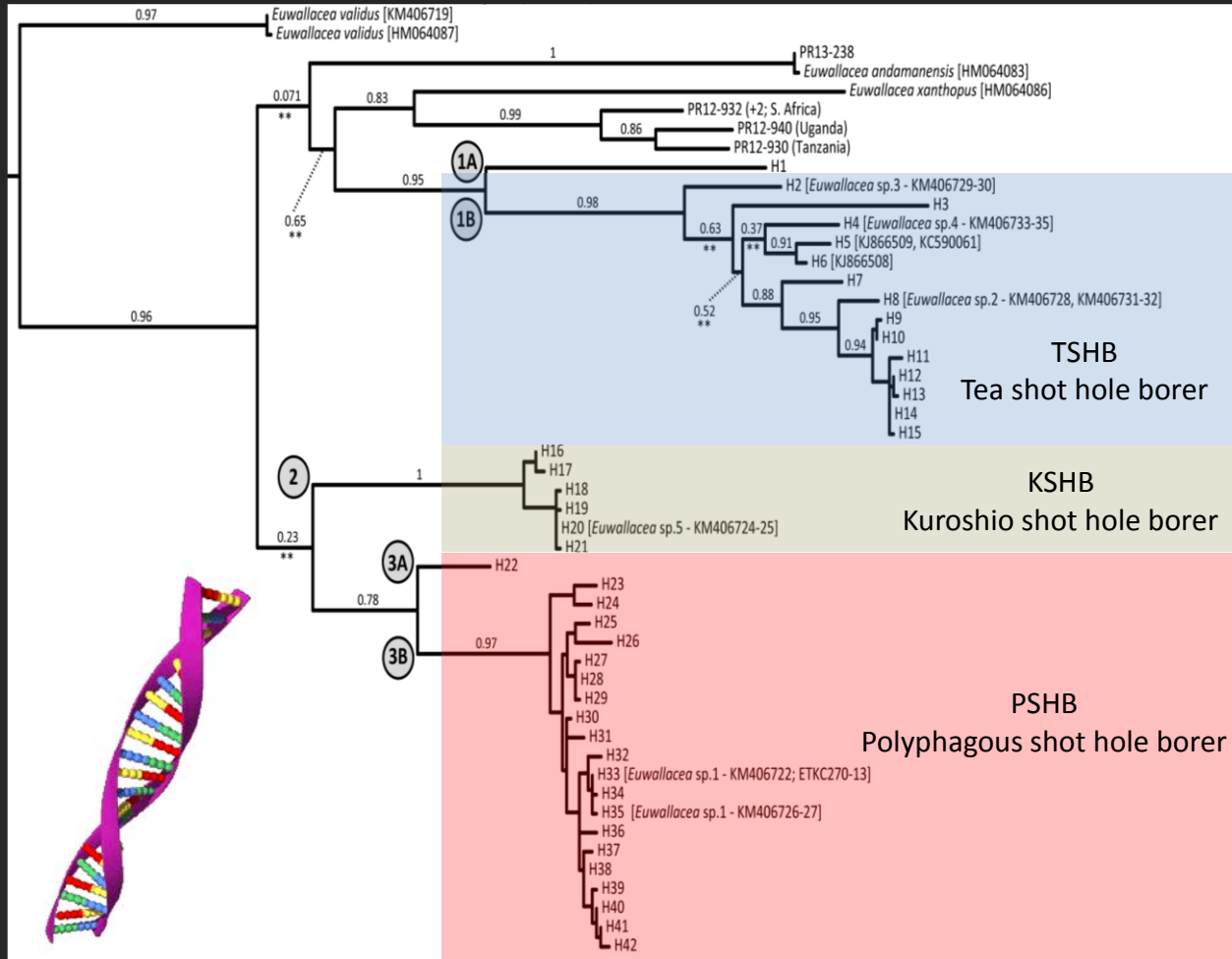


Florida
Hawaii



LA
Orange
Riverside
San Benadino
Ventura

- ...and Kuroshio shot hole borer (KSHB) was subsequently detected in 2013



Florida
Hawaii

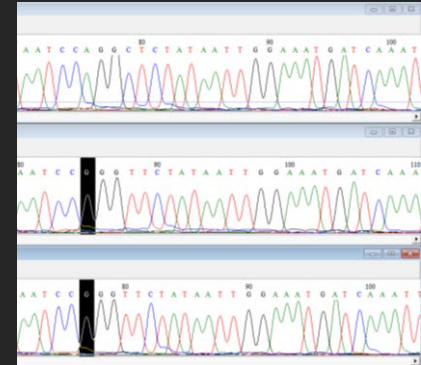


San Diego
Orange
Santa Barbara

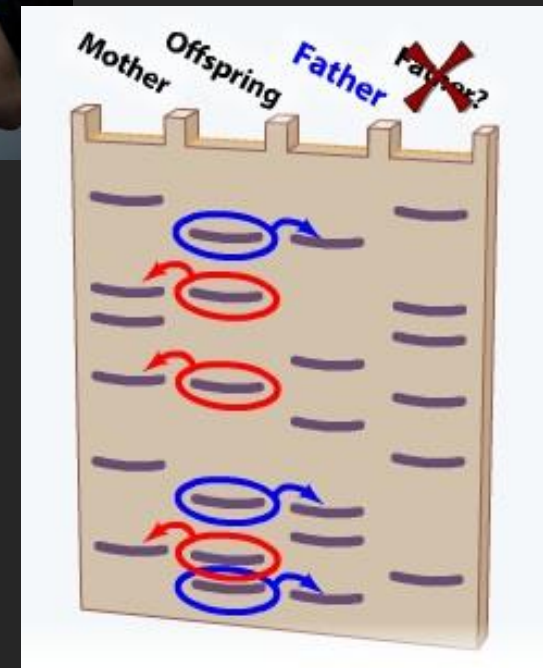


LA
Orange
Riverside
San Benadino
Ventura

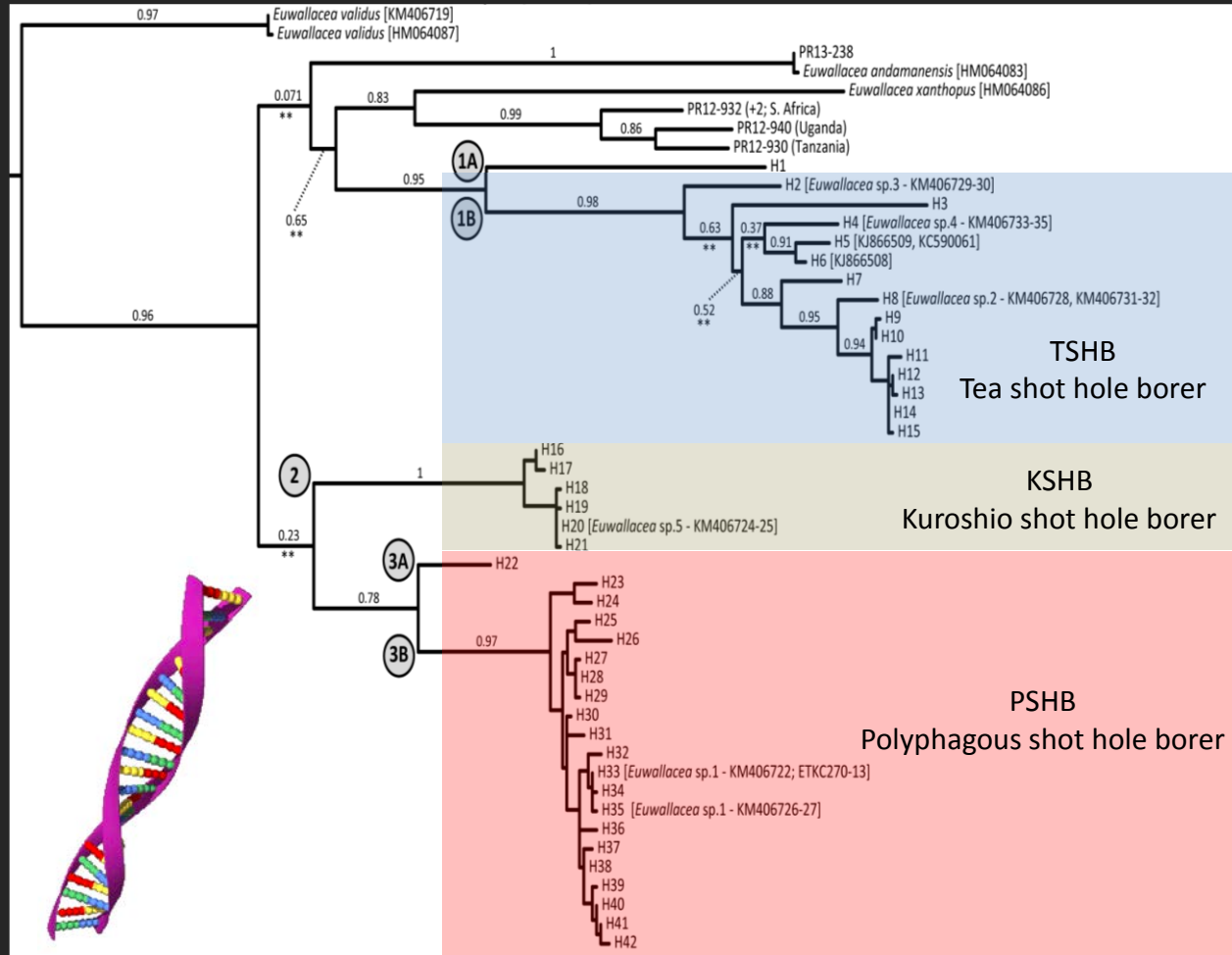




In addition to accurate species ID, DNA can also be used to identify the geographic origin of an invasive pest - in much the same way that it can tell us “who’s the Daddy?”



- DNA profiling has revealed that CA populations of KSHB and PSHB most likely originated from Taiwan and Vietnam, respectively.



ORIGIN?

Florida
Hawaii

Sri Lanka
S. Thailand
Malaysia
Australia
Taiwan

San Diego
Orange
Santa Barbara

Taiwan
Okinawa

LA
Orange
Riverside
San Benadino
Ventura

Vietnam
China
N. Thailand
Taiwan
Okinawa
Israel
S. Africa

Stouthamer *et al.* submitted

- 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:

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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



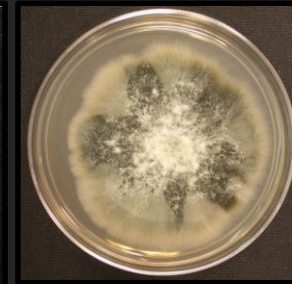
Fungal Pathogens associated with PSHB and KSHB



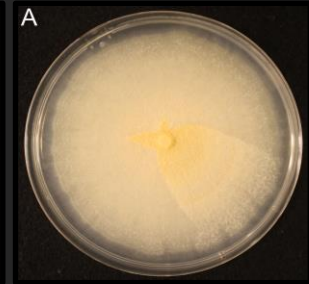
Polyphagous
shot hole
borer
PSHB



*Fusarium
euwallaceae*



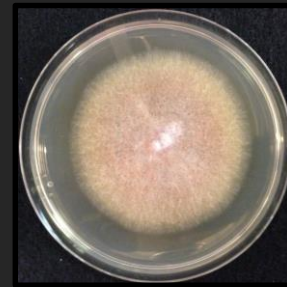
*Graphium
euwallaceae*



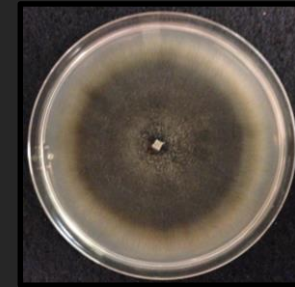
*Paracremonium
pembeum*



Kuroshio
shot hole
borer
KSHB



Fusarium sp.



Graphium sp.

PSHB & KSHB attack many tree species!

<http://eskalenlab.ucr.edu/pshb.html>



Agricultural crops: avocado



Native species of oak, sycamore, and willow



Invasive
“weeds”:
castor bean

Popular ornamentals:
maples, coral trees,
and palms



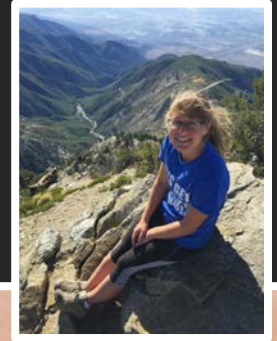
Gallery formation

- 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



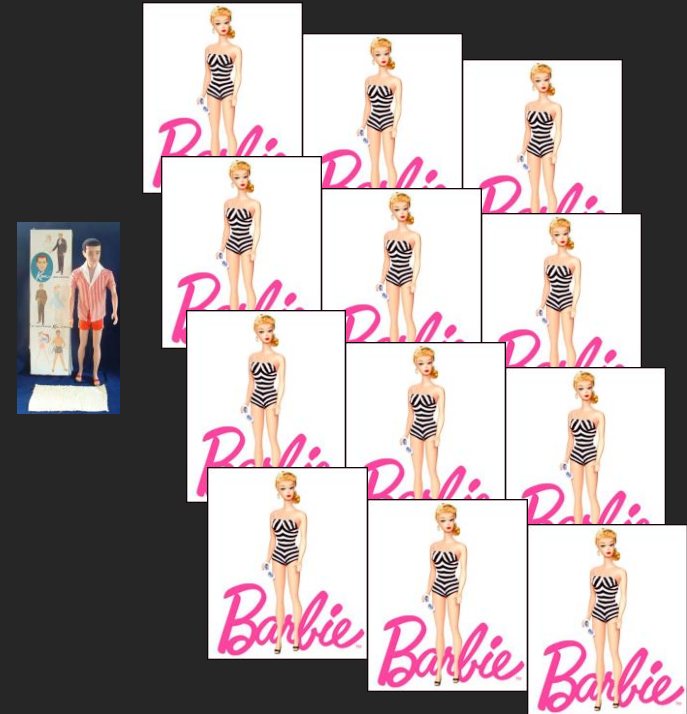
Oviposition and larval development

- 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 $> 26^{\circ}\text{F}$
- Brood size is typically 20-50! (in the lab)



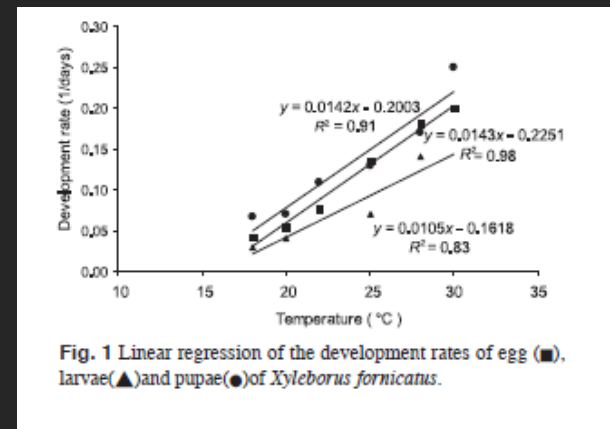
Extreme inbreeding

- 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?

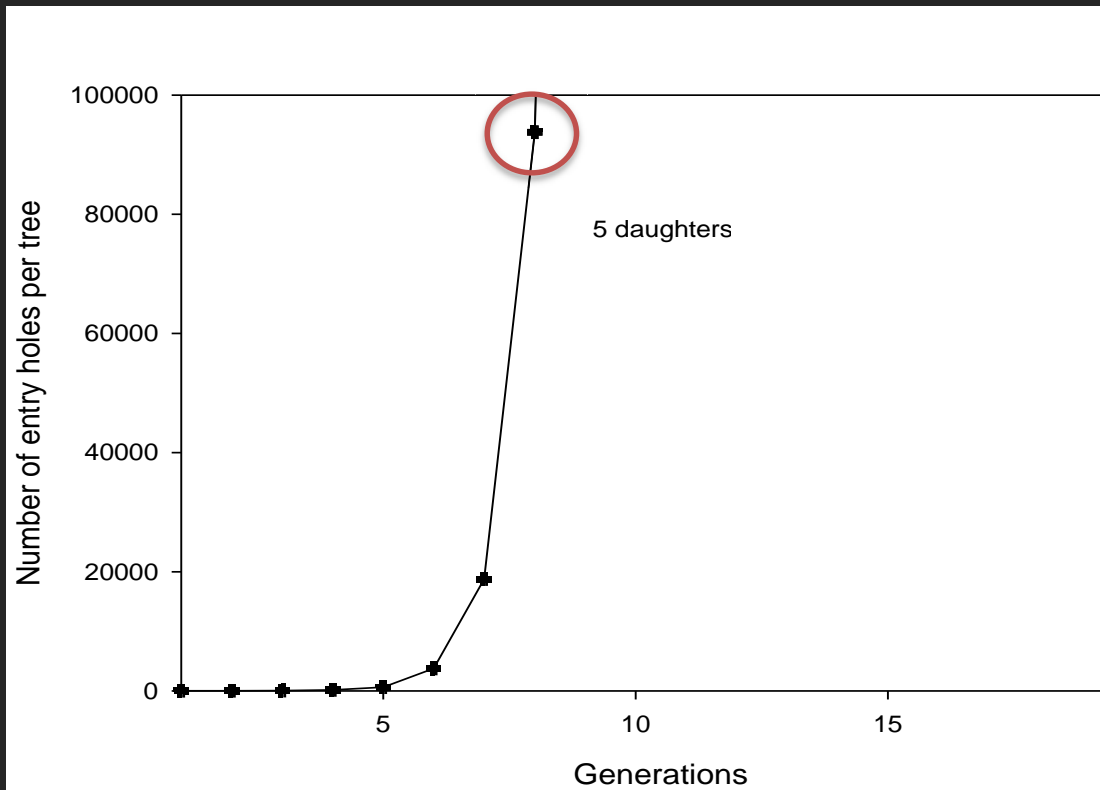
- Only females are capable of flight.
- But, on leaving the natal gallery, it often doesn't make sense for a female to fly - why risk not finding a suitable host, if you're already sitting on one?
- Degree day models and our own observations suggest 3-5 generations per year in southern CA for PSHB and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



Walgama and Zalucki 2007

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%)



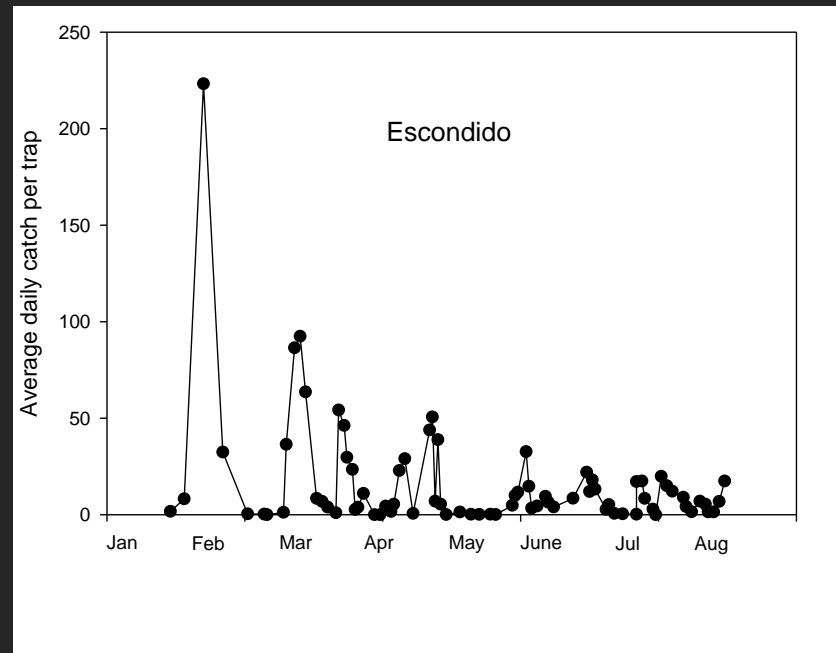
What determines when PSHB/KSHB leave a host tree?



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

Air temperature in afternoon needs to be > 68°F

- During winter beetle larvae will develop in tree when external temperatures are $> 59^{\circ}\text{F}$
- If afternoon temperatures are below 68°F they are not able to fly
- When there is a hot spell in winter a peak in flight activity will take place



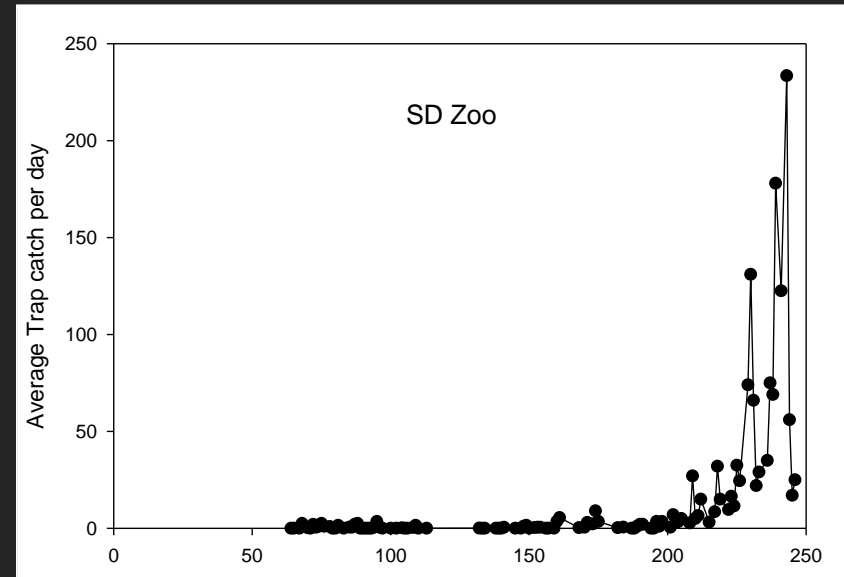
What determines when PSHB/KSHB leave a host tree?

- 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.

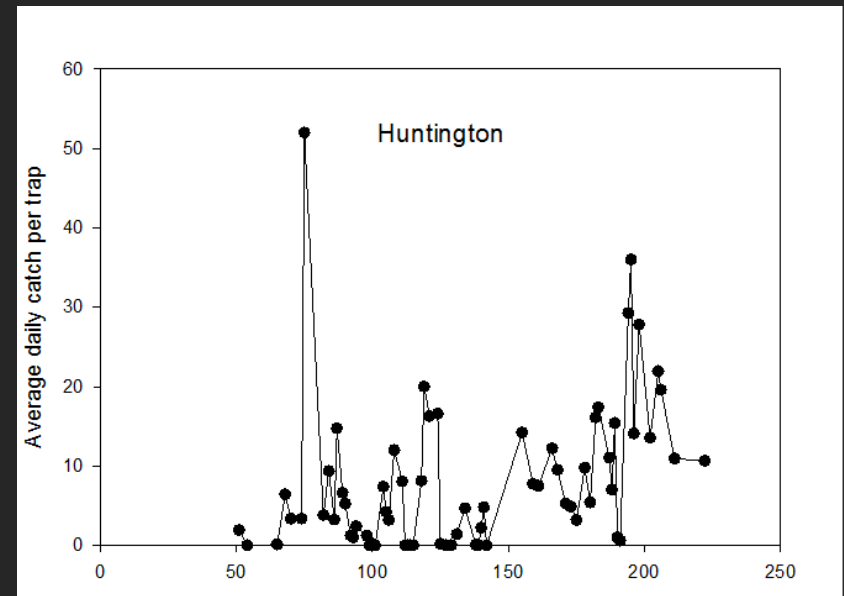
Water stressed host tree

- 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)



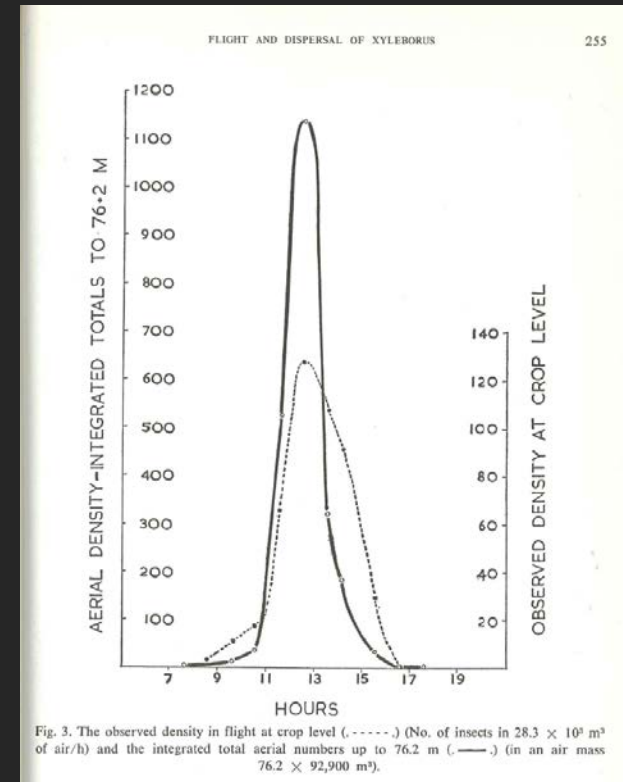
- If enough water is available no such peaks in flight activity
e.g., Huntington Library



Natural spread – how far?

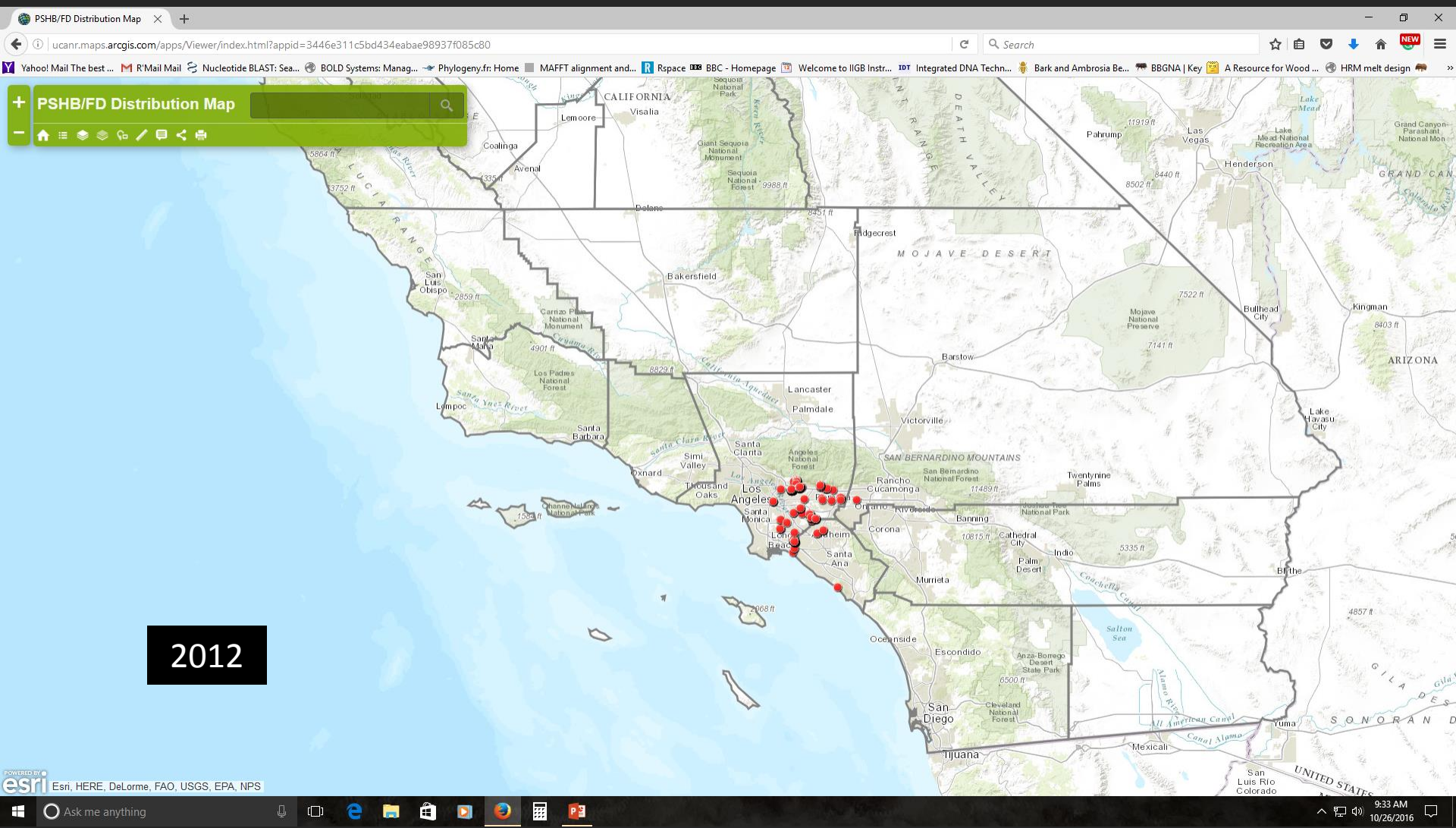
Based on studies of flight activity in TSHB and our own observations of flight activity in both PSHB and KSHB, a conservative estimate for natural population spread in southern CA is 10 - 15 miles per year

- 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)



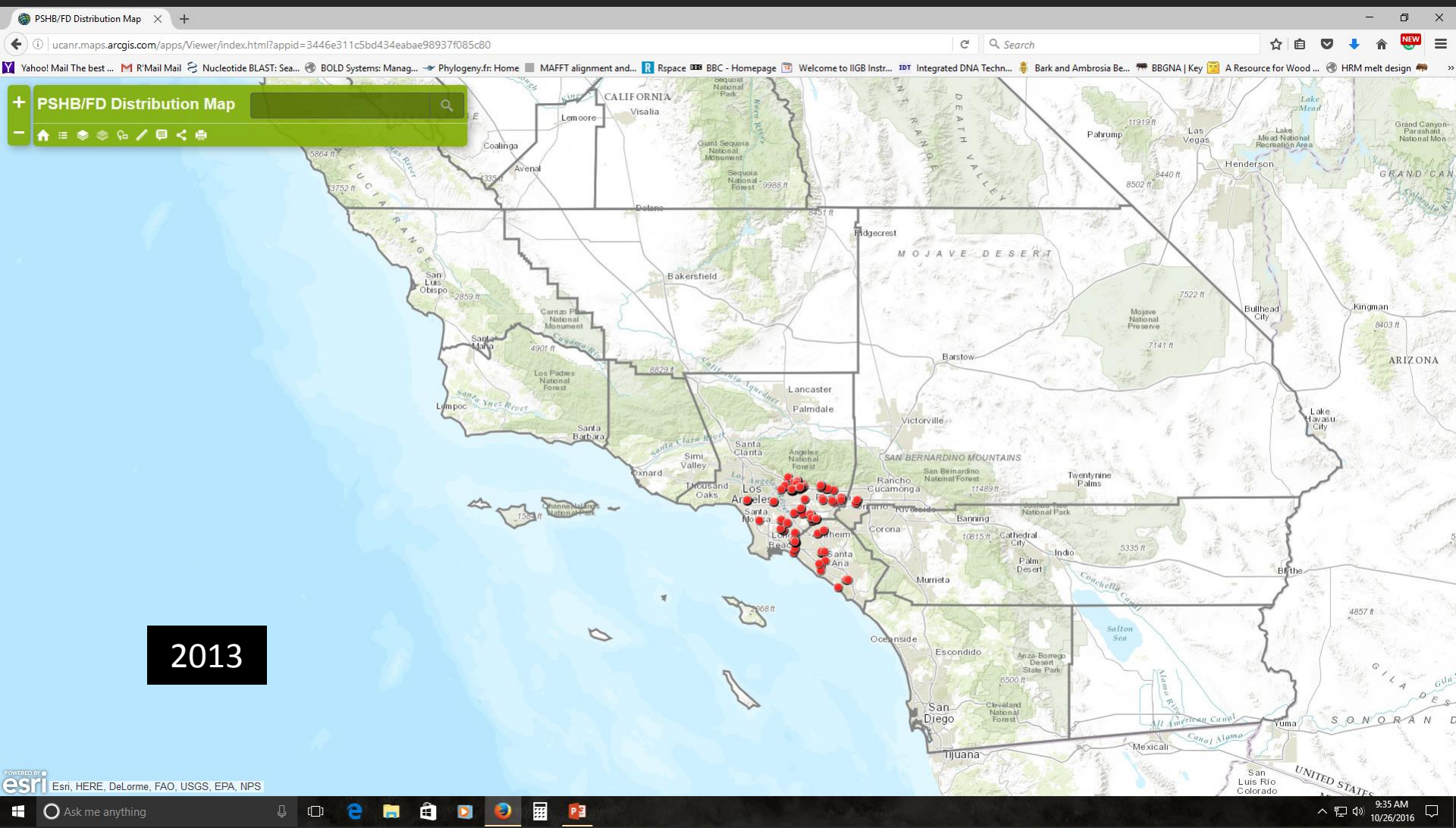
Calnaido, D (1965) Ent. Exp. Appl 8:249-262

Spread of the infestations

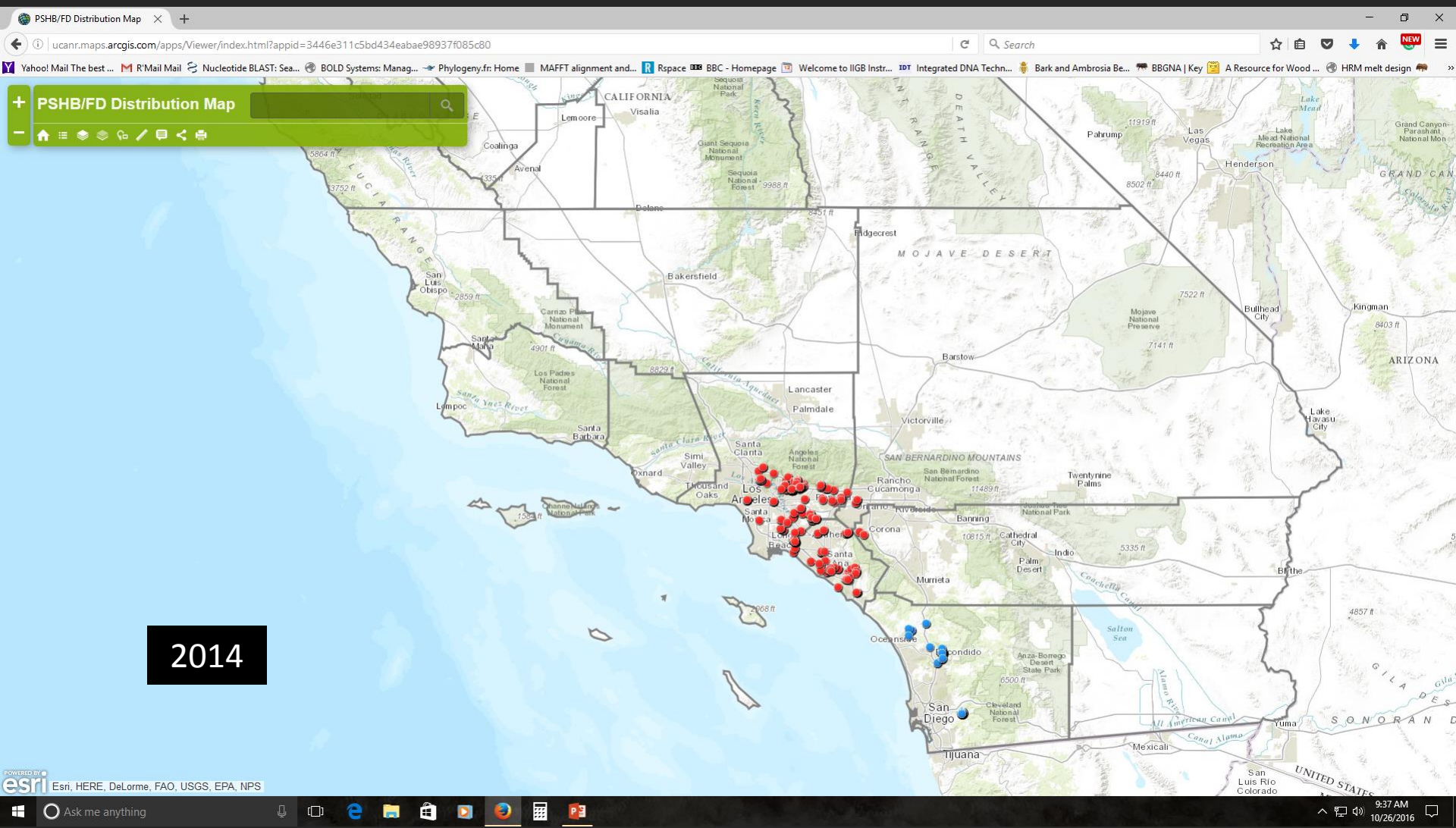


<http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=3446e311c5bd434eabae98937f085c80>

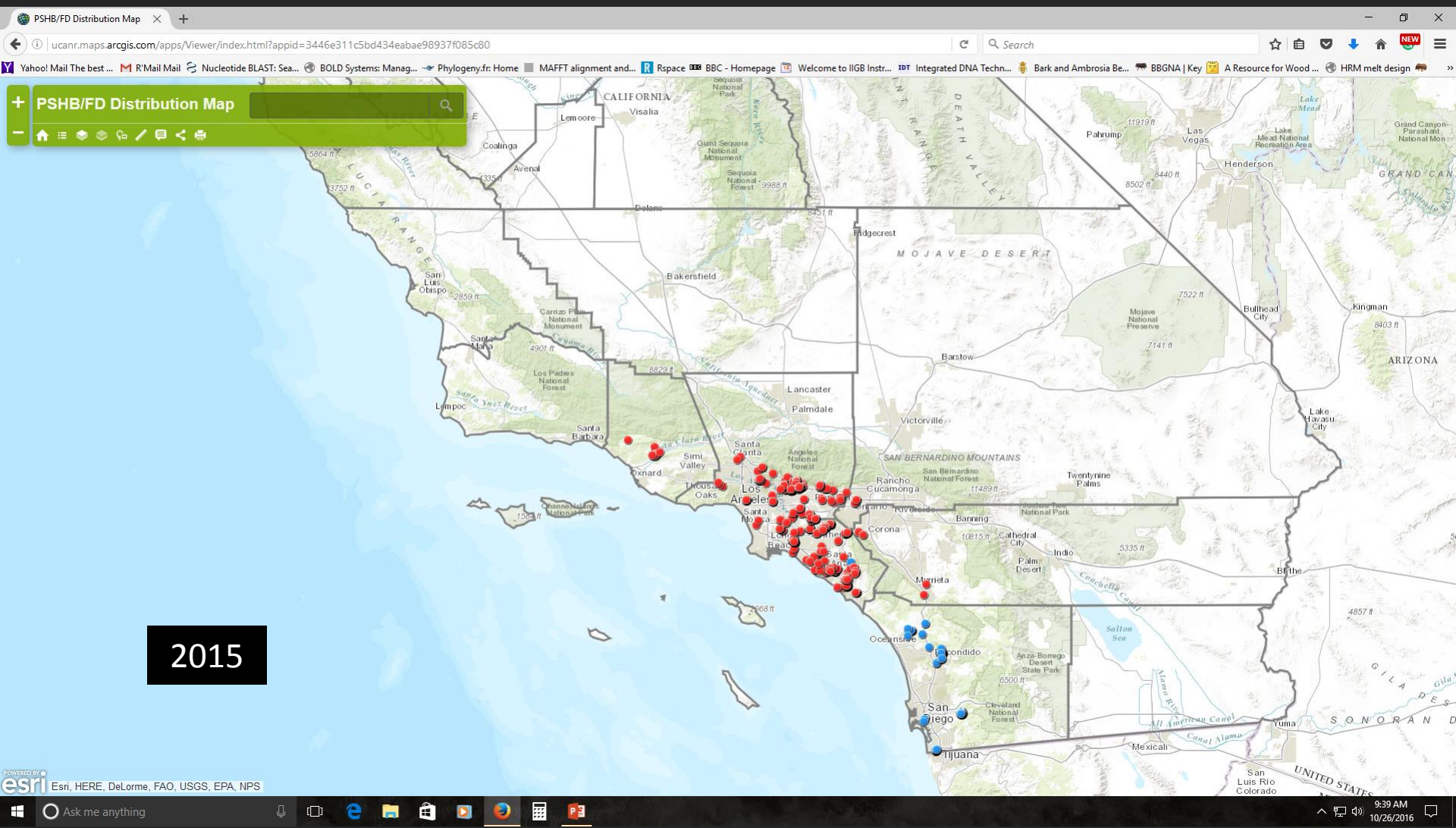
Spread of the infestations



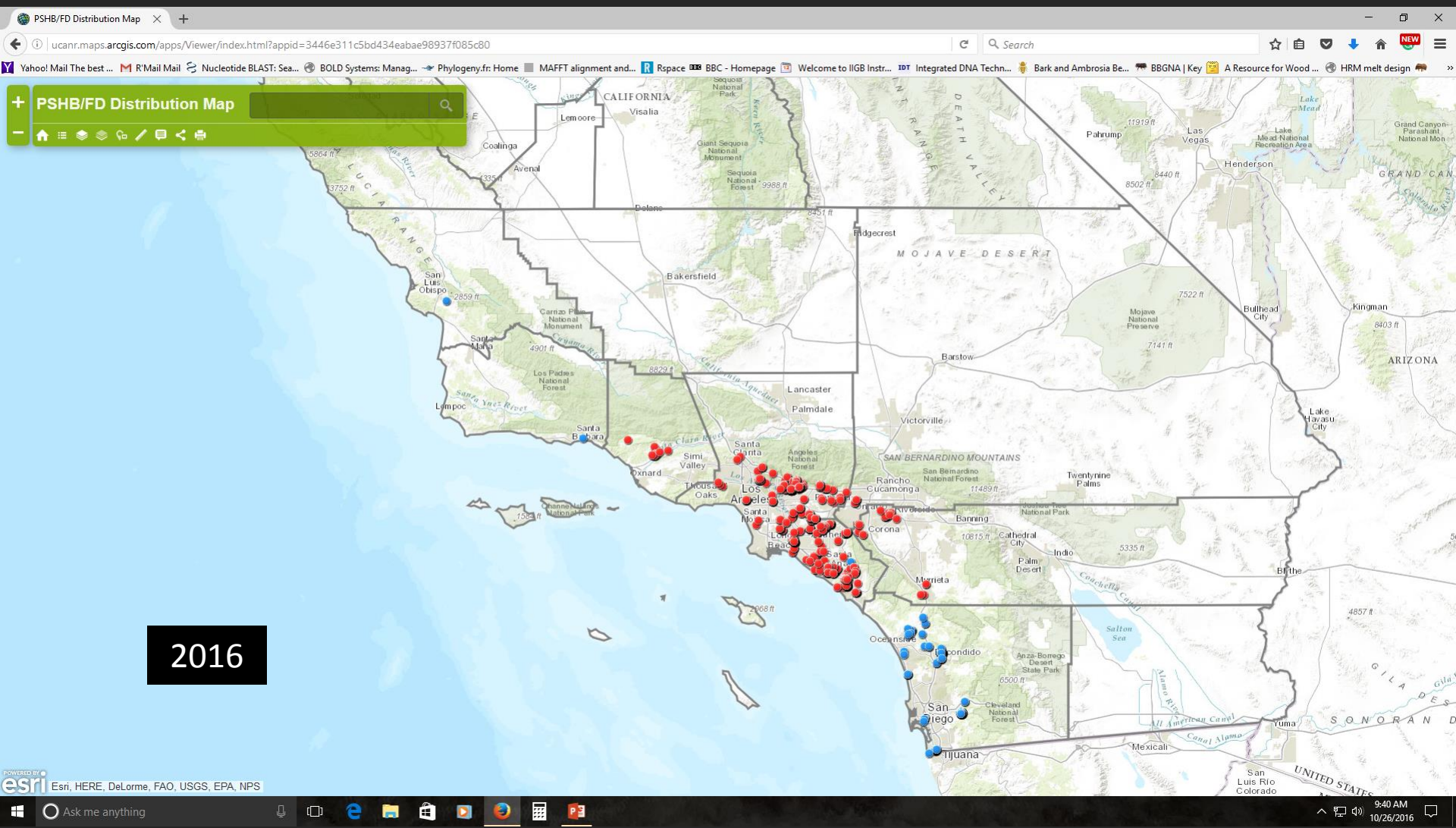
Spread of the infestations



Spread of the infestations



Spread of the infestations



Tijuana River Valley in San Diego



Tijuana River Valley in San Diego



Mortality on Arroyo willow (*Salix lasiolepis*)

OUTLINE:



- Detect, Deter, Control?



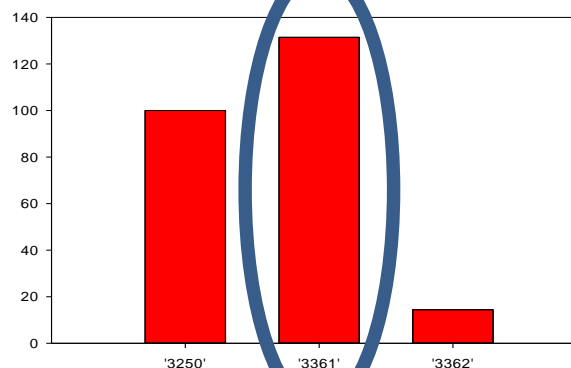
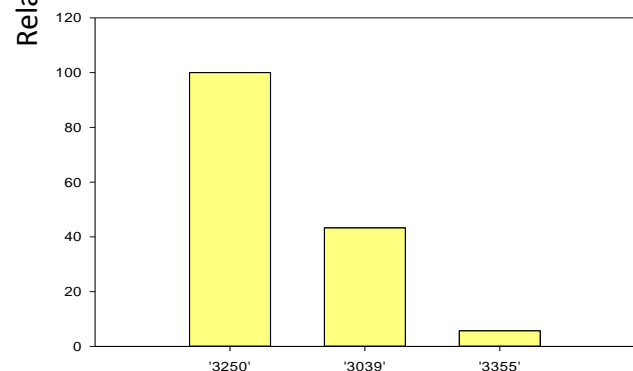
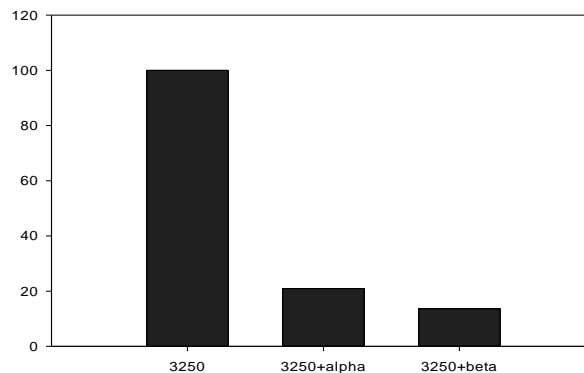
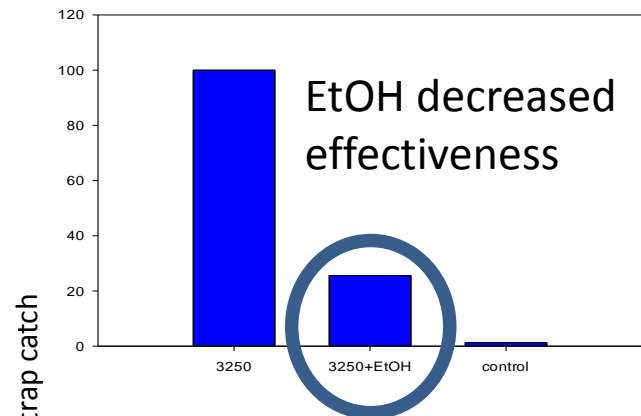
Detect:

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

Detect:



Quercivorol as a lure



3361 is best
“racemic mix”

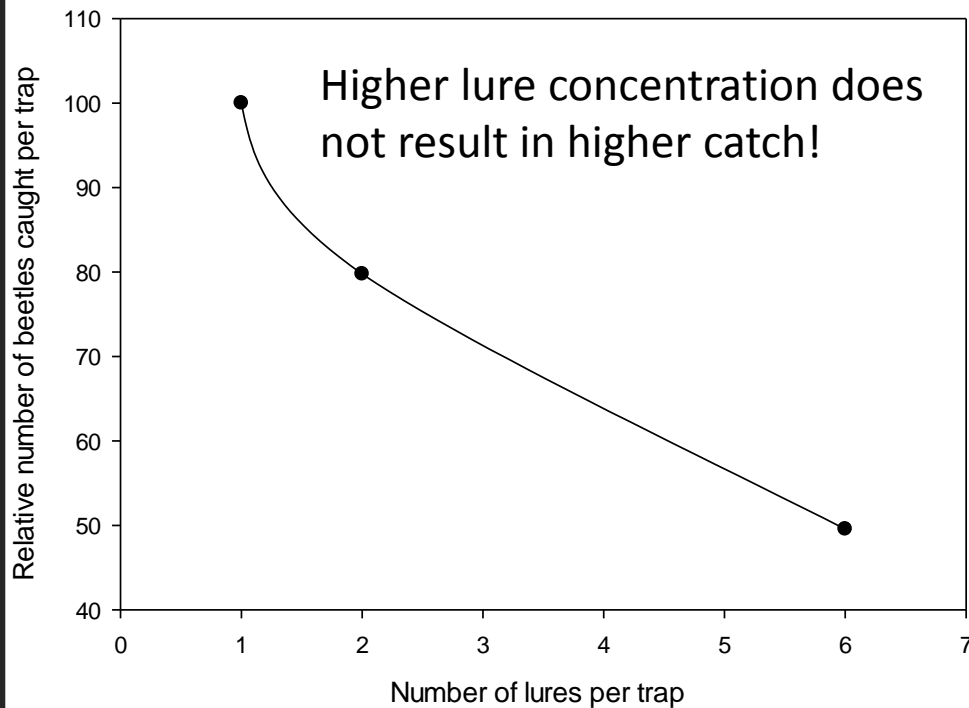
Availability of quercivorol lure:

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

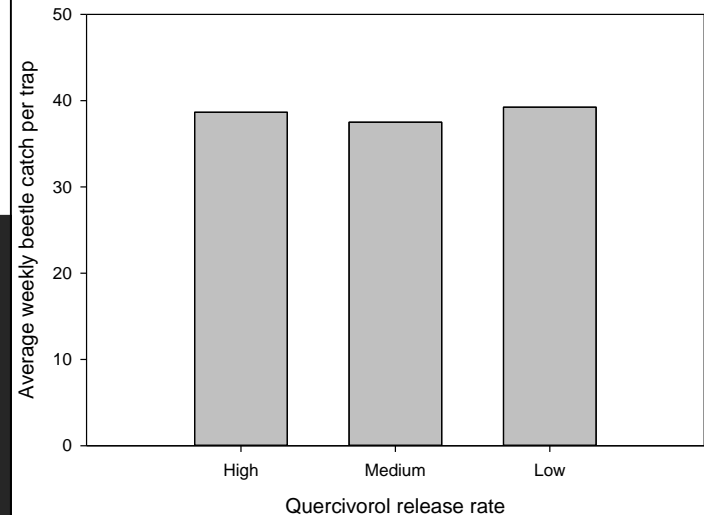
ChemTica Internacional (Costa Rica)
Tel: 506-22615396 Email: cam@chemtica.com
Lure item # P548-Lure — \$6

Detect:

Influence of number of lures per trap
of relative trap 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?

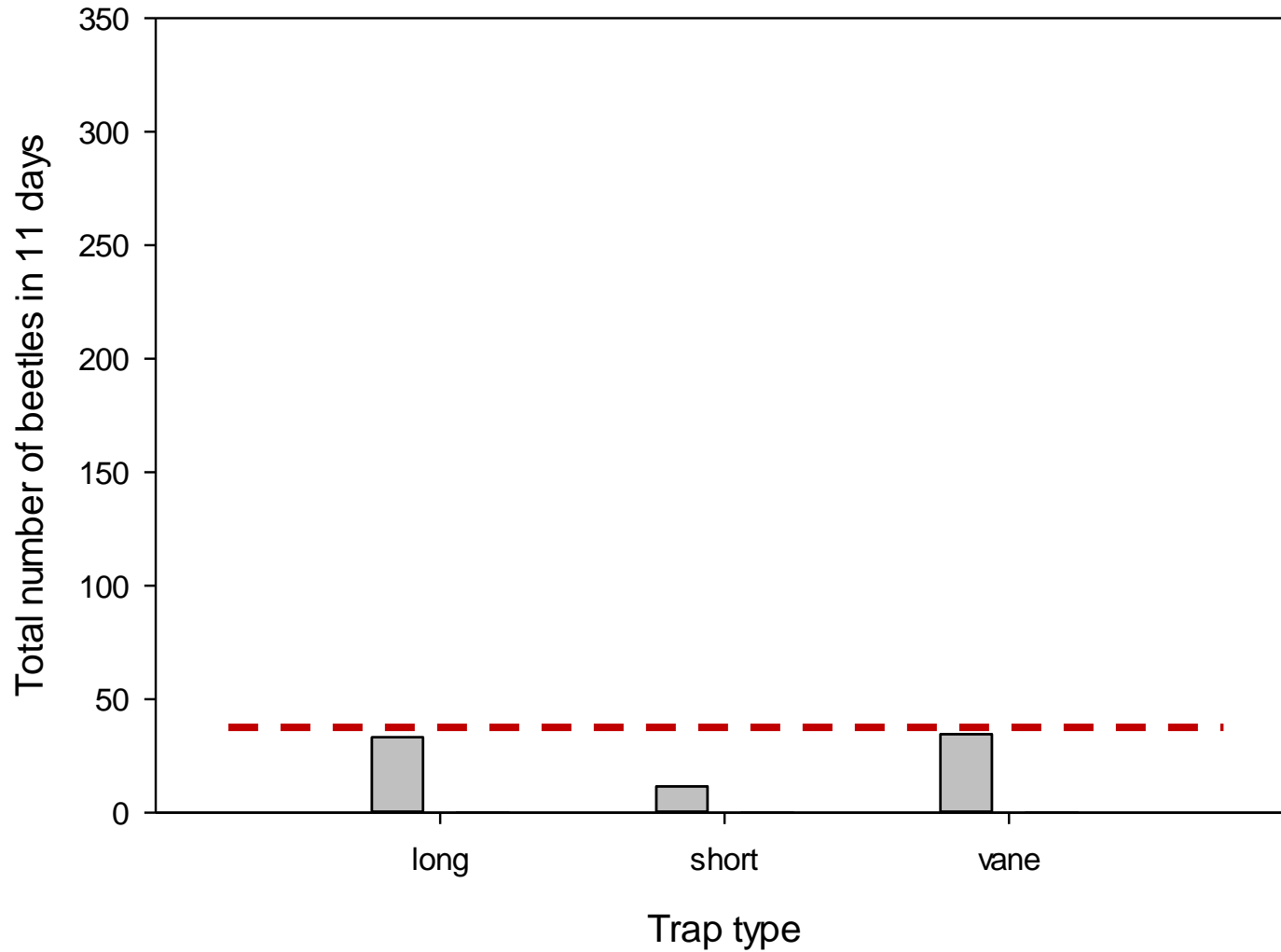


Long — Lindgren — Short

Vane

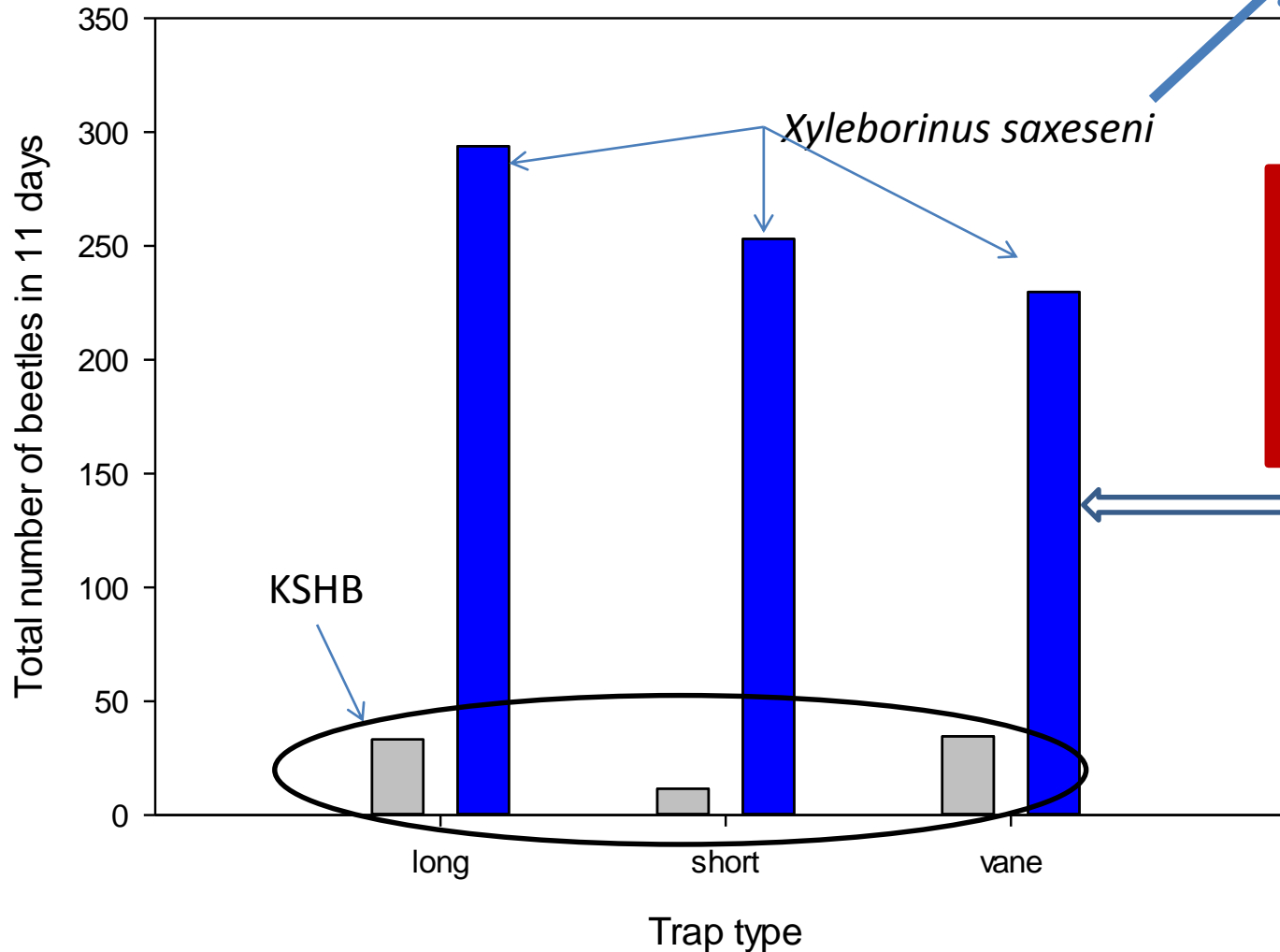
Detect:

Long and vane catch equivalent numbers



Detect:

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



1.0 mm

© Jiri Hulcr

Antifreeze preserves DNA, BUT, not all antifreezes are created equal!



▪ Ethanol based



▪ Propylene Glycol based



▪ Propylene/Ethanol blend

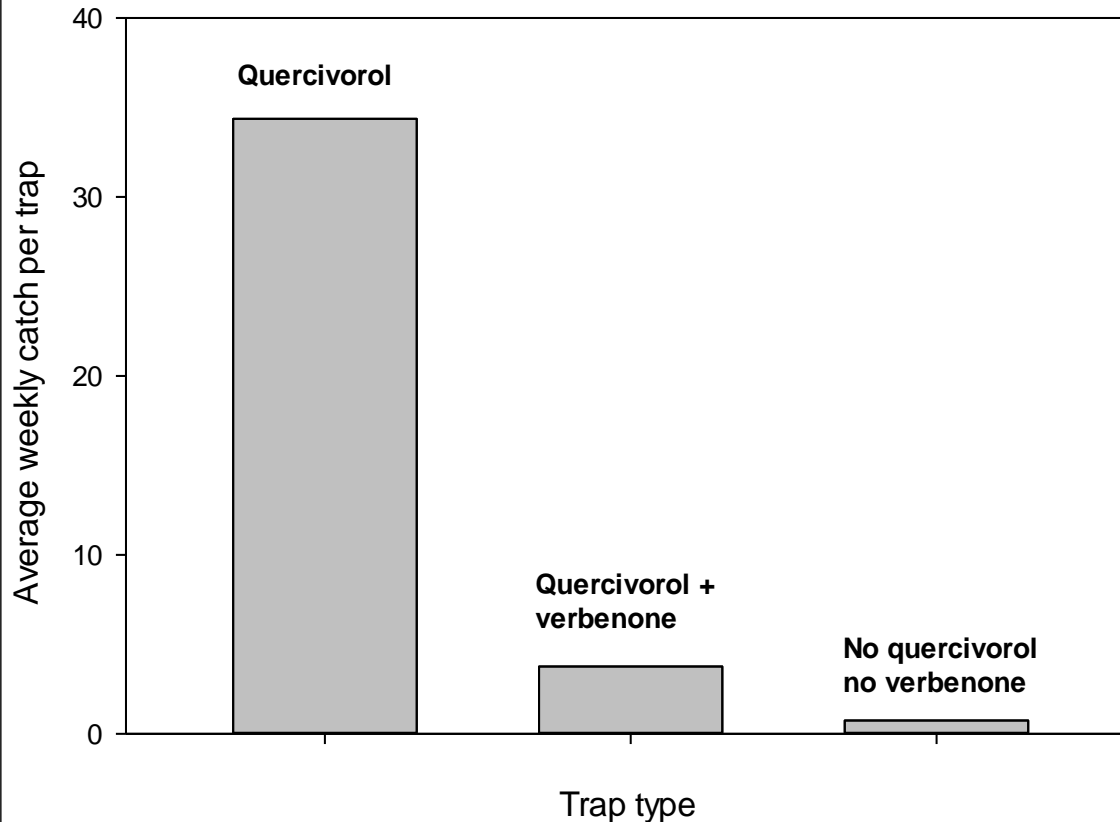
Ethanol attracts
lots of unwanted
by-catch

May also repel
PSHB/KSHB?

Deter: Verbenone as a deterrent

Deter: Verbenone as a deterrent

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



Reduction in
trap catch of
91% over three
week period

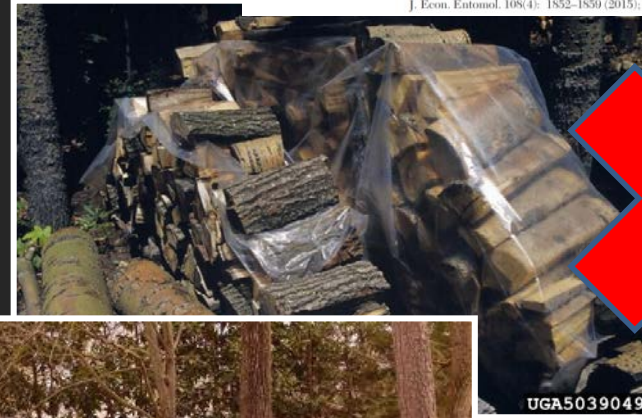
Control: cultural?

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

FOREST ENTOMOLOGY
Effect of Chipping and Solarization on Emergence and Boring Activity of a Recently Introduced Ambrosia Beetle (*Euwallacea* sp., Coleoptera: Curculionidae: Scolytinae) in Southern California

MICHELE EATOUGH JONES¹ AND TIMOTHY D. PAINE
Department of Entomology, University of California Riverside, Riverside, CA 92521.

J. Econ. Entomol. 108(4): 1852–1859 (2015); DOI: 10.1093/jee/tox169



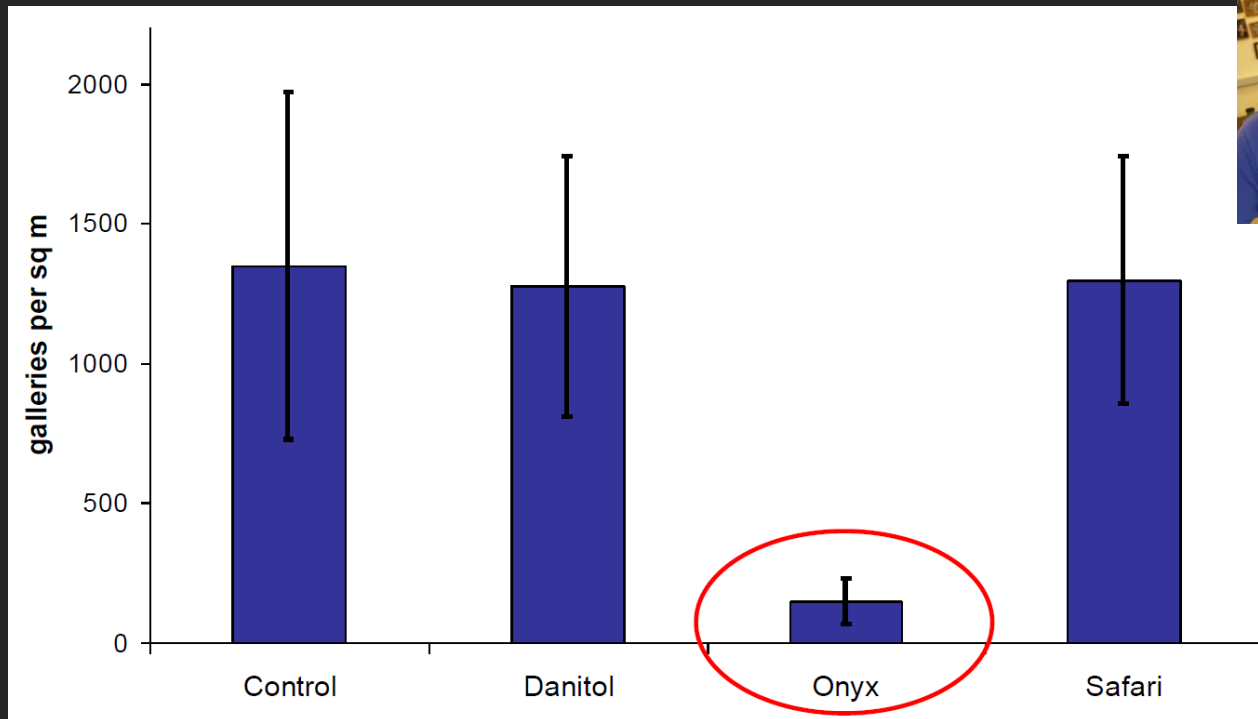
Fine chipping (<1") appears very effective



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.



Probably
practical only
for valuable
specimens?

Control: biological?

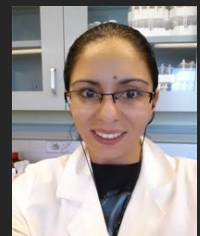
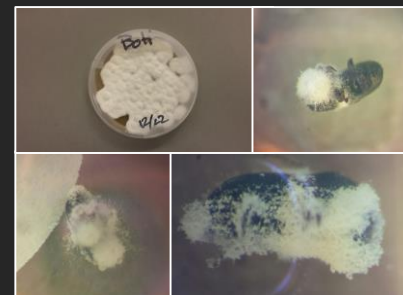
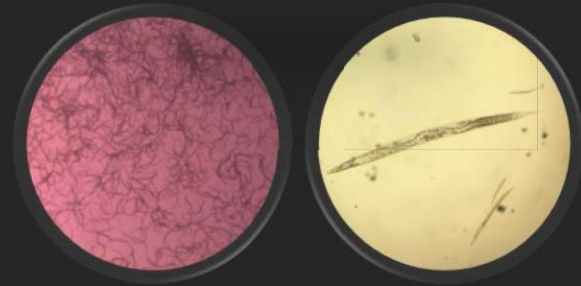
Nematodes found in Vietnam & Taiwan
(and CA).

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.)

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 - The presence of beetles inside a tree may be evident much earlier, but requires vigilant observation.

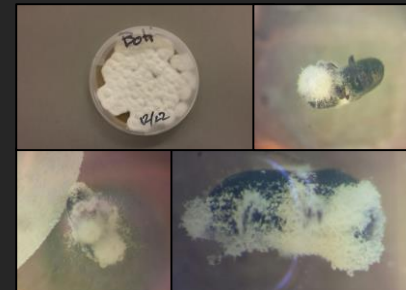


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 - But, while traps are a good indication that PSHB/KSHB are there, the only chance to trap beetles is during their flight.
 - The presence of beetles inside a tree may be evident much earlier, but requires vigilant observation.
- Best chance of trapping 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:

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California Avocado Commission

USDA-APHIS

Miriam Cooperband, Allard Cossé

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USDA Farm Bill

APEAM

(Avocado Producers and Exporting
Packers Association of Mexico)