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

Ambrosia beetle

+

Fungus (=ambrosia)

Dead Tree

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

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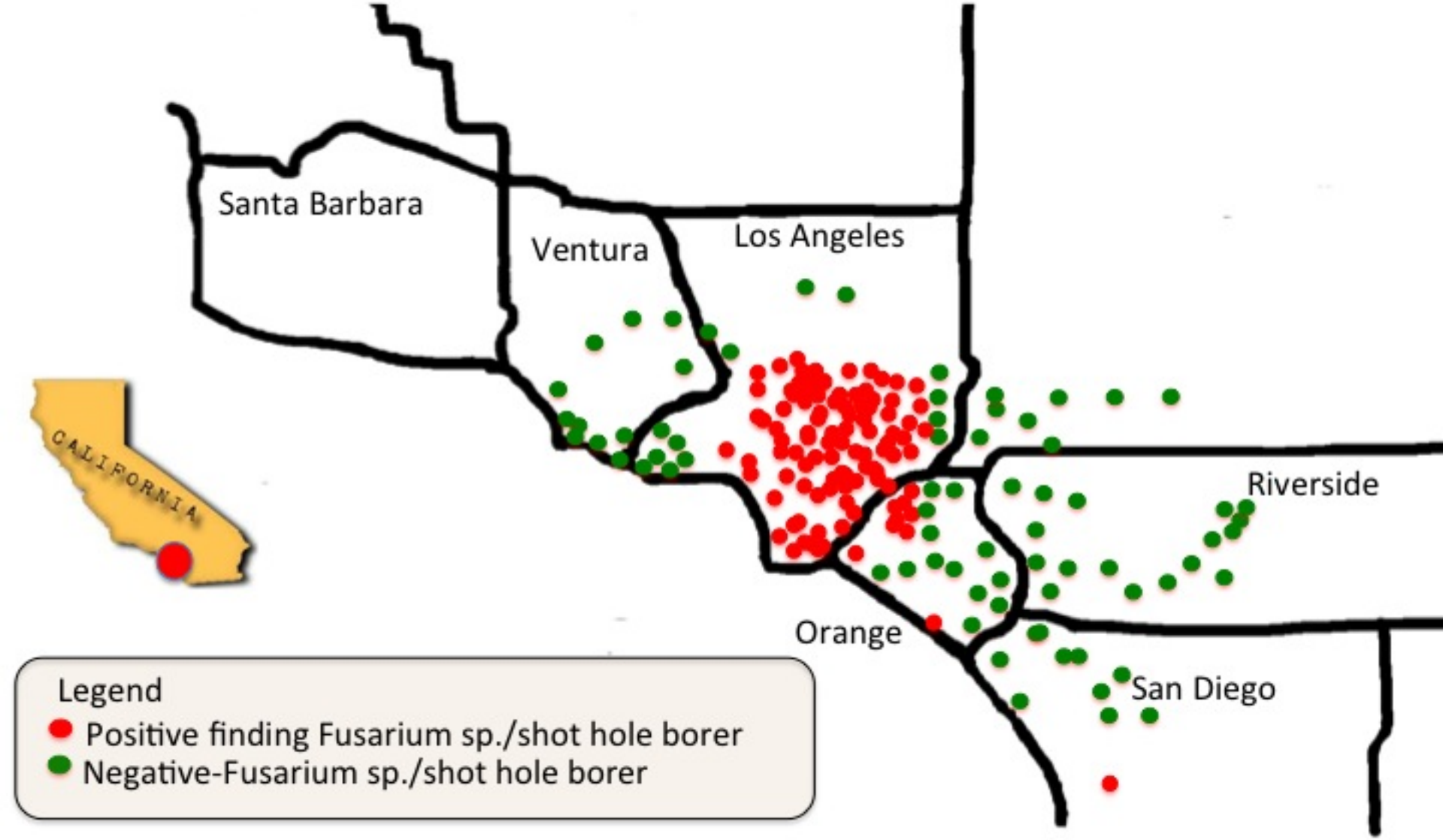
Known Distribution of Fusarium Dieback/Shot Hole Borer in Southern California 07/27/2012

California AVOCADO COMMISSION



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

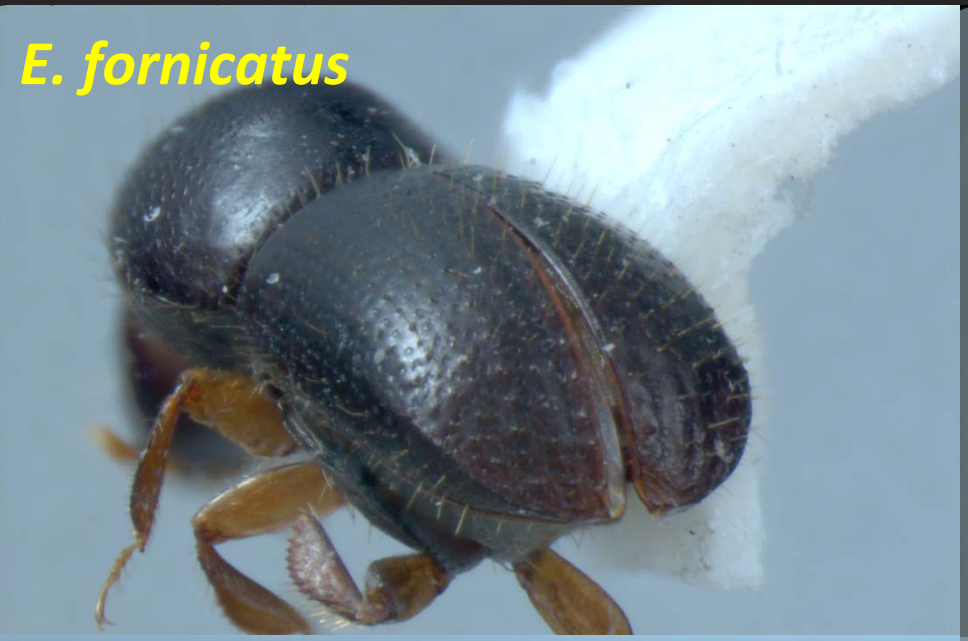
Euwallacea fornicatus

- 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

Euwallacea fornicatus-like species



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.*** **Synomyms:** ***E. fornicatior*** **, 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.**

Distribution of the TSHB

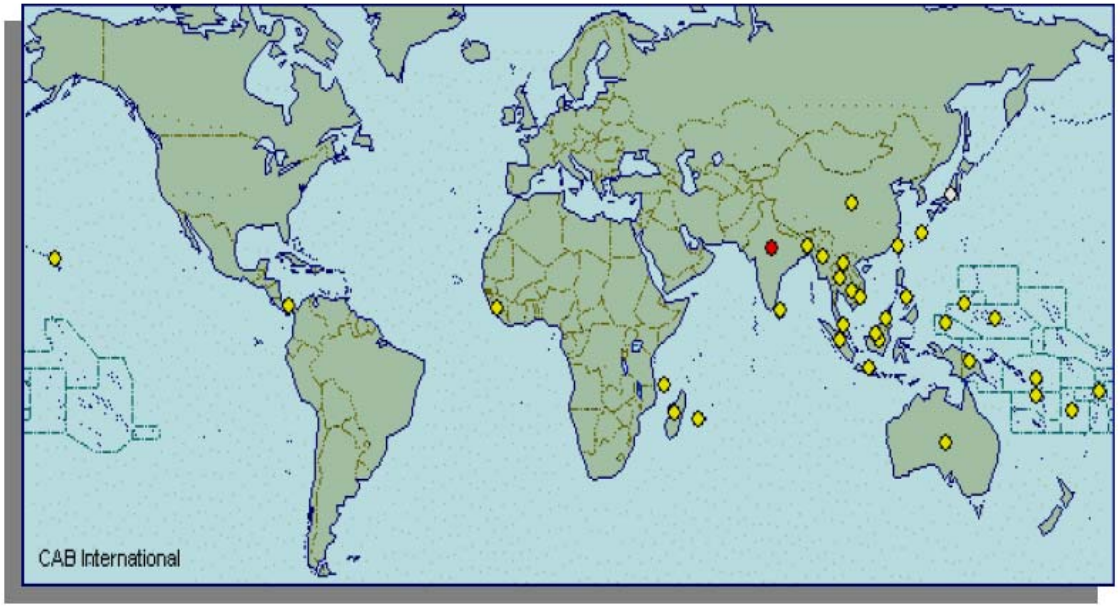
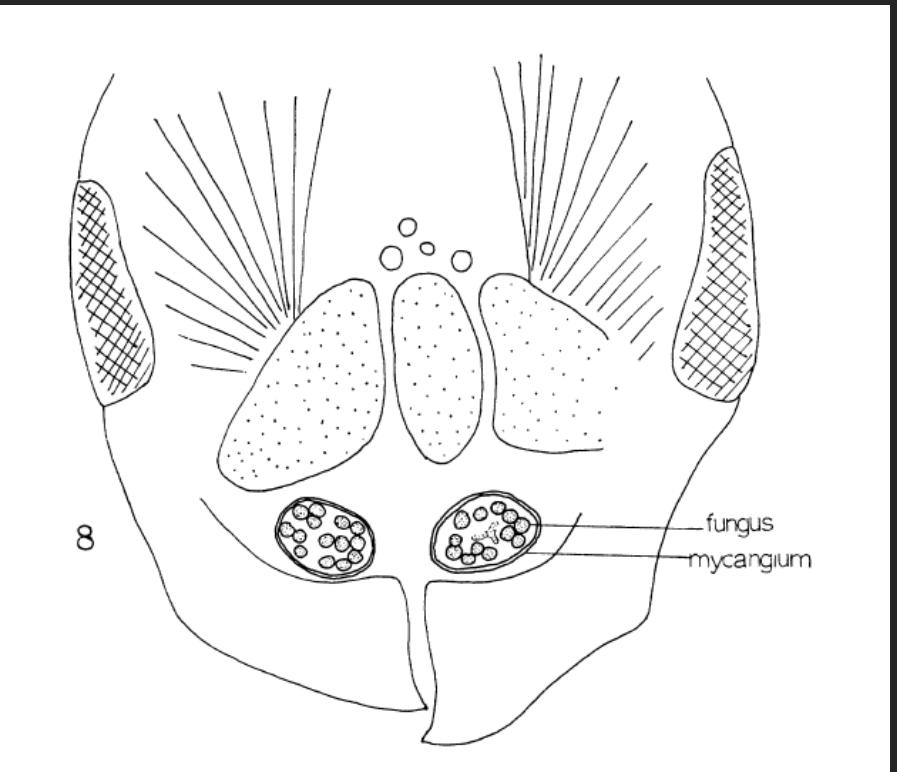


Plate 2 Distribution of *Xyleborus fornicatus* Eichh. (Coleoptera: Scolytidae) in the world (source. CABI CPC 2004) (Yellow dot indicates at least one positive record from the country).

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

Plate 5c Isolated eggs of the beetle

Plate 5d Isolated pupae of the beetle

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.

Castor (year plant)	No. of holes/30 cm from ground level						
	30	60	90	120	150	180	210
One	18	3	—	—	—	—	—
Two	67	33	15	3	3	—	—
Two	75	12	5	—	—	—	—

From: Mote and Tambe 1989, J. Mahrashtra 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

Degree day model

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

Temperature dependent development rate

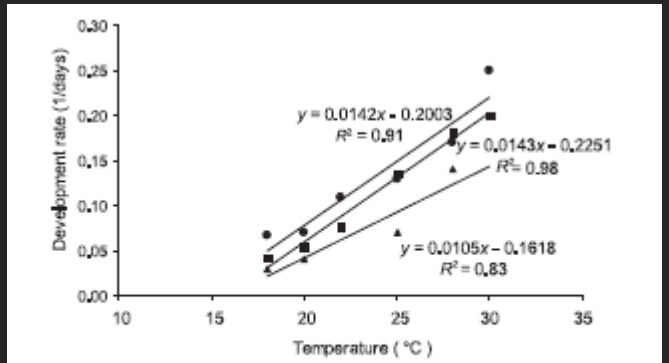


Fig. 1 Linear regression of the development rates of egg (■), larvae(▲)and pupae(●)of *Xyleborus fornicatus*.

Emergence from stems

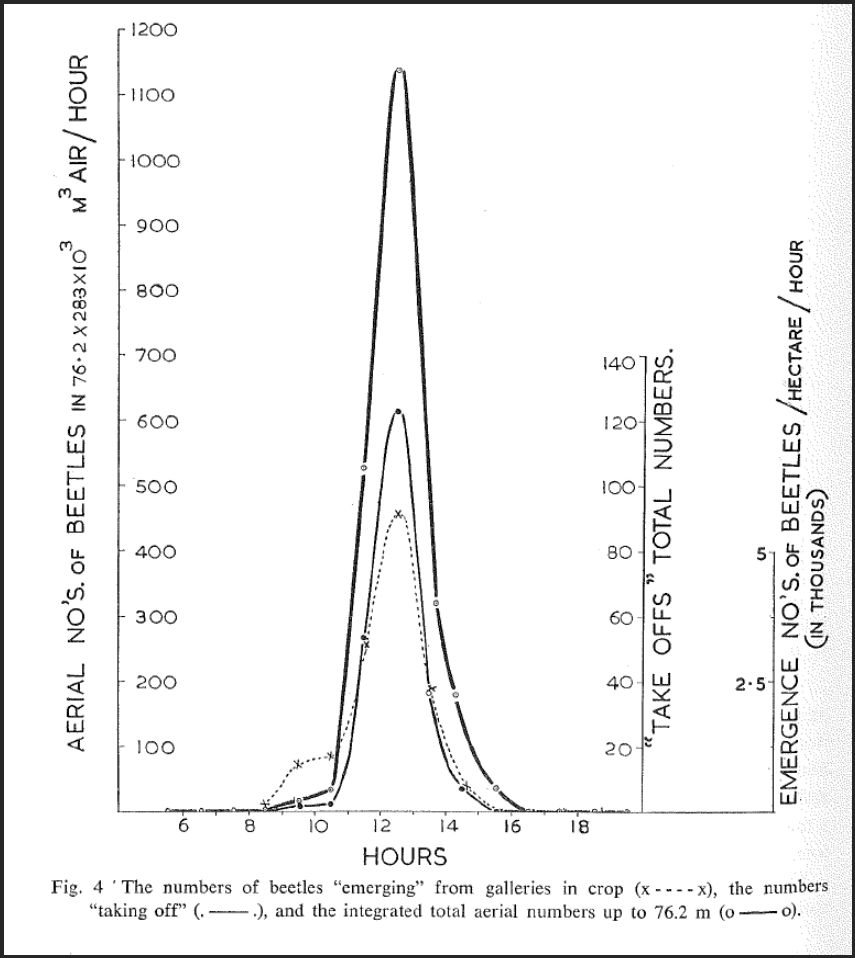


Fig. 4 ' The numbers of beetles "emerging" from galleries in crop (x - - - - x), the numbers "taking off" (. —— .), and the integrated total aerial numbers up to 76.2 m (o —— o).

- 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

Fight activity

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

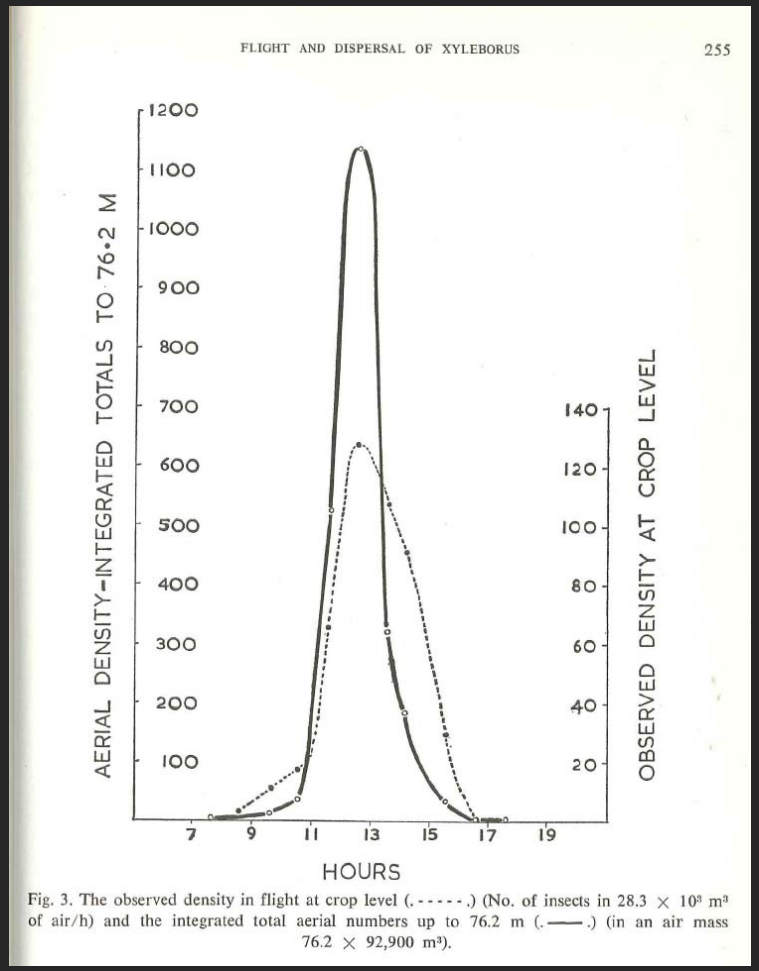


Fig. 3. The observed density in flight at crop level (. - - - - - .) (No. of insects in 28.3 × 10^3 m^3 of air/h) and the integrated total aerial numbers up to 76.2 m (. —— .) (in an air mass 76.2 × 92,900 m^3).

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

Emergence pattern of males and females

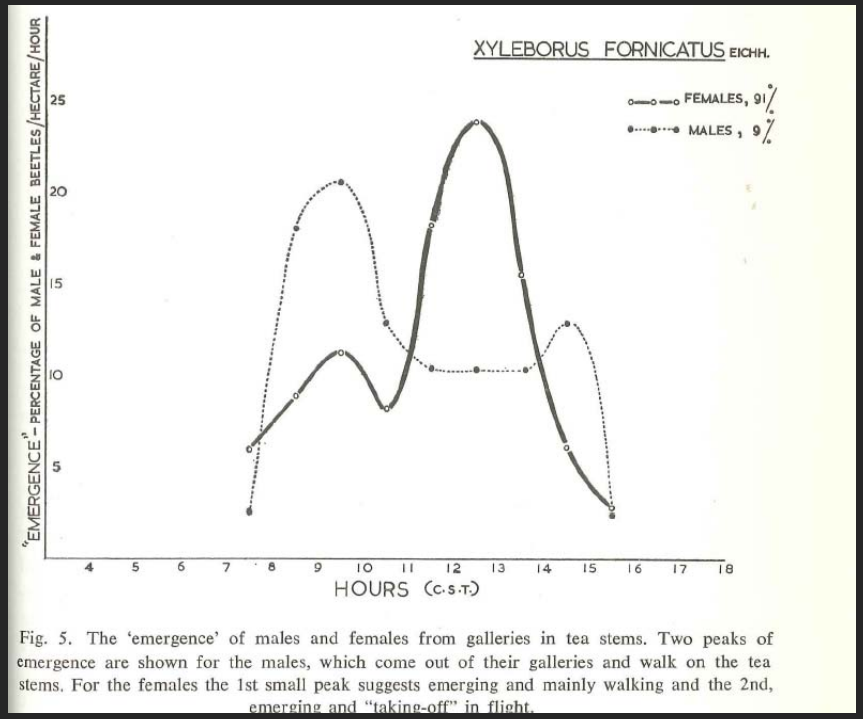


Fig. 5. The 'emergence' of males and females from galleries in tea stems. Two peaks of emergence are shown for the males, which come out of their galleries and walk on the tea stems. For the females the 1st small peak suggests emerging and mainly walking and the 2nd, emerging and "taking-off" in flight.

- 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.

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

From A. Eskalen, R. Stouthamer, S.C. Lynch, P. Rugman-Jones, M. Twizeyimana, A. Gonzalez, T. Thibault (submitted). Host Range of fusarium dieback and its ambrosia beetle (Coleoptera: Scolytinae) vector in southern California.

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

	Trees species	% of all tree specimens
Total number	103	
Attacked by PSHB	53	56
Host for fungus	36	48
Reproductive host	6	26

From A. Eskalen, R. Stouthamer, S.C. Lynch, P. Rugman-Jones, M. Twizeyimana, A. Gonzalez, T. Thibault (submitted). Host Range of fusarium dieback and its ambrosia beetle (Coleoptera: Scolytinae) vector in southern California.

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

Fig. 3 Galleries constructed by adult female beetles at a typical breaking point of an avocado branch

From Mendel et al 2012. An Asian ambrosia beetle *Euwallacea fornicatus* and its novel symbiotic fungus *Fusarium* sp. pose a serious threat to the Israeli avocado industry. *Phytoparasitica* :DOI 10.1007/s12600-012-0223-7

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 is 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

Richard Stouthamer - Outl | UCR eskalenlab.ucr.edu/handou

eskalenlab.ucr.edu/handouts/specimenform.pdf

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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.

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University of California, Riverside
Department of Plant Pathology and Microbiology

Permit: CDFA 2749

Plant Disease Diagnostic Form

Fill and submit original copy with specimen

CONTACT INFORMATION – Please Print Clearly

Date: | GPS Coordinate: N W

Submitted by: | Company/Grower:

Address: | City/Zip:

County: | Email:

Phone: | Fax:

Check one of the following:

☐ Commercial grower ☐ Farm advisor ☐ Consultant ☐ Researcher ☐ Home grower

Other:

HOST PLANT AND SYMPTOM INFORMATION – Please Print Clearly

Cultivar: | Rootstock:

Symptoms: ☐ wilted ☐ spotted ☐ yellowed ☐ abnormal growth ☐ stunted ☐ mosaic ☐ other

Part(s) of Plant Affected and Symptom(s) Expressed

Roots	Trunk	Branch	Leaves	Flower	Fruit
☐ poor growth ☐ discolored ☐ rotted ☐ stubby ☐ galls/swelling ☐ other:	☐ galls/swelling ☐ cankers ☐ gummosis ☐ discolored int. ☐ rotted ☐ other:	☐ galls/swelling ☐ cankers ☐ discolored int. ☐ dieback ☐ wilted ☐ other:	☐ spotted ☐ blighted ☐ yellowed ☐ mosaic ☐ wilted ☐ other:	☐ spotted ☐ blighted ☐ discolored ☐ yellowed ☐ mosaic ☐ other:	☐ spotted ☐ discolored ☐ rotted ☐ mosaic ☐ distorted ☐ other:

PLANT PRODUCTION AND HISTORY OF PROBLEM – Please Print Clearly

Type of Planting: ☐ Grove/Orchard ☐ Nursery ☐ Landscape ☐ Greenhouse ☐ Forest

Symptom(s) Prevalence: ☐ Entire Plant ☐ Localized area ☐ Scattered area

Symptom(s) Appeared (In Past): ☐ Days ☐ Weeks ☐ Months

Recently Applied Chemicals: Fertilizer: Pesticide:

Lab:951-827-3499 www.eskalenlab.ucr.edu e-mail.: eskalenlab@gmail.com

Address: Eskalen Lab. 3401 Watkins Dr. Fawcett Lab. (#232), Dept. of Plant Pathology and Microbiology. University of California, Riverside, CA, 92521

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
Akif Eskalen, Plant Pathology, UC Riverside
Reuben Hofshi, Hofshi Foundation
Mary Lu Arpaia, UC Riverside
Tim Thibault, Huntington Botanical Garden
Frank McDonough, LA Arboretum
Gevork Arakelian, County Ag. Commissioner in LA
Tom Coleman, Forest Service, Southern California
John Kabashima, UC-CE Orange County
Andrew Trotter, West Coast Arborists