Management of Invasive Shot Hole Borers/Fusarium Dieback

[1]Beatriz (Bea) Nobua Behrmann, Ph.D.
[1]John Kabashima, Ph.D.
[2]Shannon Lynch
[3]Akif Eskalen Ph.D.

[1]University of California Cooperative Extension / UC ANR
[2]Dept. of Environmental Studies, University of California, Santa Cruz
[3]Dept. of Microbiology and Plant Pathology, UC Riverside

Invasive Shot-Hole Borers

The Tea, Polyphagous and Kuroshio Shot-Hole Borers

Invasive Shot-Hole Borers / Fusarium Dieback

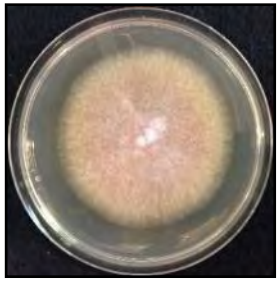
Polyphagous Shot Hole Borer **(PSHB)**

Photos | Akif Eskalen - UCR

Fusarium euwallaceae

Kuroshio Shot Hole Borer **(KSHB)**

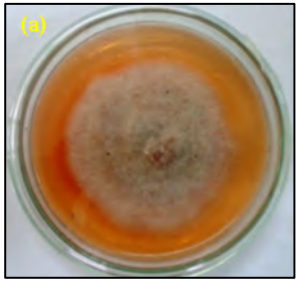
Photos | Akif Eskalen - UCR



Fusarium sp.

Tea Shot Hole Borer **(TSHB)**

Hanna Royals, Museum Collections: Coleoptera, USDA APHIS ITP, Bugwood.org



Cheka Kehelpannala et al. 2018 Journal of Chemical Ecology

Morphologically indistinguishable

- DNA analysis
- ID the associated fungus

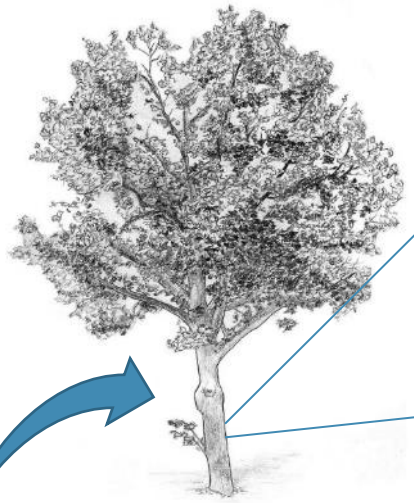


Photo:: Akif Eskalen/UC Riverside

Mated female (carrying fungus spores)

Brothers and sisters mate inside galleries

Photo: Mike Lewis/UC Riverside

Photos | Beatriz Nobua-Behrmann UCCE Orange

- Typically build up the population in one tree (amplifier trees) before invading the rest of the area

Invasive Shot-Hole Borer / Fusarium Dieback

Photos | Akif Eskalen - UCR

PSHB effects on tree trunk and branches

24”
60cm

Infestation in
main trunk

7”
18cm

Infestation in
branches

Invasive Shot-Hole Borers ISHB

Have reached epidemic levels in southern California

- Affects urban trees, as well as riparian, and other natural forests
- May eventually affect agriculture
- More than 137 tree species are at risk of attack (63 confirmed as reproductive hosts, and counting…)

Photo | Beatriz Nobua-Benhrmann – UCCE Orange

Reproductive Host Species (March 2018)

NOT A "DO NOT PLANT" LIST!!!

1. **Box Elder (*Acer negundo*)**
2. Big leaf maple (*Acer macrophyllum*)*
3. Evergreen Maple (*Acer paxii*)
4. Trident maple (*Acer buergerianum*)
5. Japanese maple *(Acer palmatum)*
6. Castorbean (*Ricinus communis*)
7. **California Sycamore (*Platanus racemosa)*****
8. Mexican sycamore *(Platanus mexicana)*
9. **Red Willow (*Salix laevigata*)***
10. **Arroyo willow *(Salix lasolepis)*****
11. **Avocado (*Persea americana*)**
12. Mimosa (*Albizia julibrissin*)
13. English Oak (*Quercus robur*)
14. Coast live oak (*Quercus agrifolia*)*
15. London plane (*Platanus x acerifolia*)
16. **Cottonwood (*Populus fremontii*)***
17. **Black cottonwood (*Populus trichocarpa*)***
18. **White Alder (*Alnus rhombifolia*)***
19. Titoki (*Alectryon excelsus*)
20. Engelmann Oak (*Quercus engelmannii*)*
21. Cork Oak (*Quercus suber*)
22. Valley oak (*Quercus lobata*)*
23. Coral tree (*Erythrina corallodendon*)
24. Blue palo verde (*Cercidium floridum*)*
25. Palo verde (*Parkinsonia aculeata*)
26. Moreton Bay Chestnut (*Castanospermum australe*)
27. Brea (*Cercidium sonorae*)
28. Mesquite (*Prosopis articulata)**
29. **Weeping willow (*Salix babylonica*)**
30. Chinese holly *(Ilex cornuta*)
31. Camelia (*Camellia semiserrata*)
32. Acacia (*Acacia* spp.)
33. Japanese wisteria (*Wisteria floribunda*)
34. **Black willow (*Salix gooddingii*)***
35. Tree of heaven (*Ailanthus altissima*)
36. Kurrajong (*Brachychiton populneus*)
37. Black mission fig (*Ficus carica*)**
38. Japanese beech (*Fagus crenata*)
39. Dense logwood (*Xylosma avilae*)
40. Mule Fat (*Baccharis salicina*)*
41. Black Poplar (Populus nigra)*
42. Carrotwood (*Cupaniopsis anacardioides*)
43. California buckeye (*Aesculus californica*)*
44. Canyon Live oak (*Quercus chrysolepis*)*
45. Kentia Palm (*Howea forsteriana*)
46. King Palm (*Archontophoenix cunninghamiana*)
47. Tamarix (*Tamarix ramosissima*
48. Red Flowering Gum (*Eucalyptus ficifolia*)*
49. American Sweetgum (*Liquidambar styraciflua*)
50. Honey Locust (*Gleditsia triacanthos*)
51. Brazilian Coral Tree (*Erythrina falcata*)
52. Purple Orchid Tree (*Bauhinia variegata*)*
53. Council Tree (*Ficus* altissima)*
54. Tulip Wood (*Harpulia pendula*)
55. Chinese Flame Tree (*Koelreuteria bipinnata*)*
56. Laurel-leaf Snailseed tree (Cocculus laurifolius)
57. Southern Magnolia (*Magnolia grandiflora*)
58. Jacaranda (*Jacaranca mimosifolia*)**
59. Coast coral tree (*Erythrina caffra*)**
60. Australian blackwood (*Acacia melanoxylon*) **
61. Sweet Bay (*Magnolia virginiana*)**
62. African Tulip Tree (*Spathodea campanulata*)**
63. Strawberry snowball tree (*Dombeye cacuminum*)**
64. Chinese Wingnut (*Pterocarya stenoptera*)**

*18 species native to California

** Canker associated

Source: www.eskalenlab.ucr.edu
www.pshb.org

Origin and history

Believed to be introduced via wood products and/or shipping material from southeast Asia.

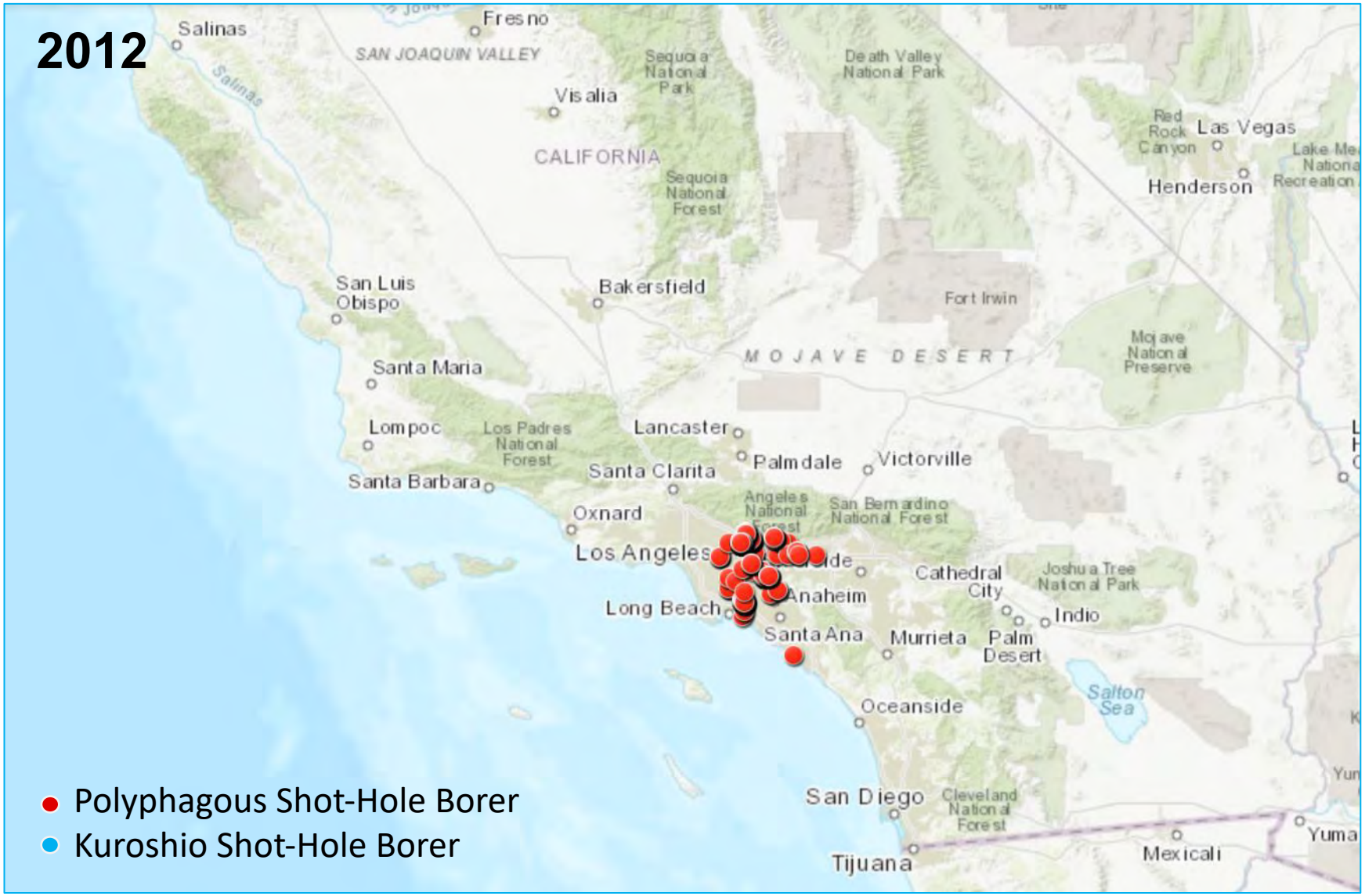
- **2003**
  First found at Whittier Narrows, Los Angeles County
  (but mistaken for Tea Shot-Hole borer, a pest of low concern)

  Found on a few trees **(2003 – 2010)**

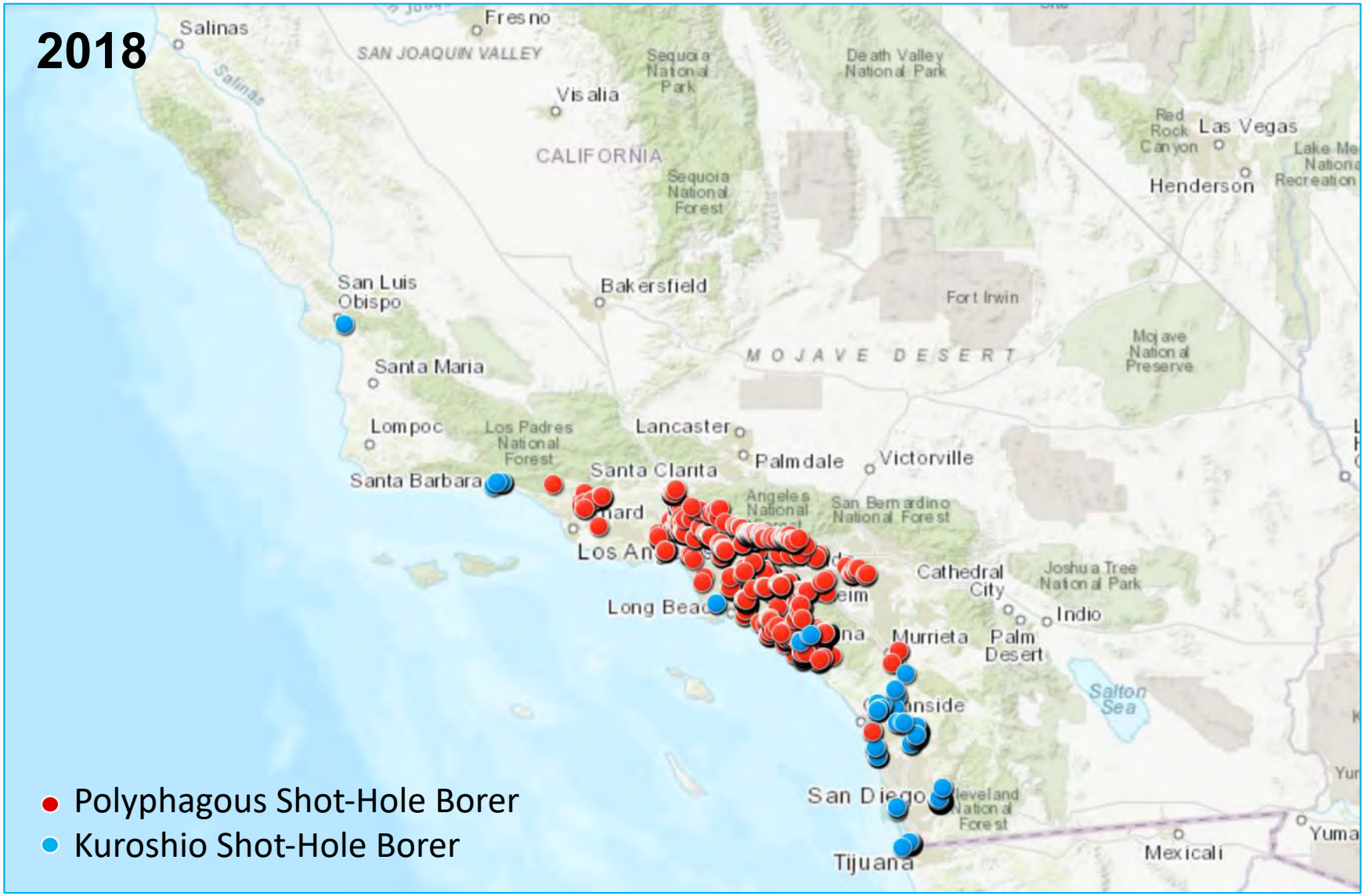
- **2010**
  Presumed cause of death of large number of Box Elder street trees in Long Beach (but no one knew at the time)

- **2012**
  PSHB first identified by Dr. Eskalen in Los Angeles

Historic distribution of ISHB infestation



Historic distribution of ISHB infestation



The Tijuana River Valley

Kuroshio Shot-Hole Borer/Fusarium Dieback impact on riparian habitat

The riparian forest at Dairy Mart Bridge before the beetle attack (May 2015).

Photos: John Boland, PhD/Southwest Wetlands Interpretive Association

The Tijuana River Valley

Kuroshio Shot-Hole Borer/Fusarium Dieback impact on riparian habitat

The forest at Dairy Mart Bridge after the beetle attack (February 2016).

140,000 willow trees severely damaged; loss of ecological services such as endangered species habitat; fire and flood Hazard

Photos: John Boland, PhD/Southwest Wetlands Interpretive Association

Laguna Niguel Regional Park

2016

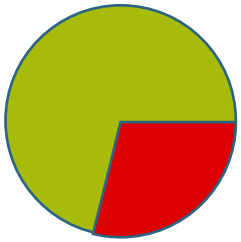
2017

What could happen if ISHB is not controlled?

Impact of Invasive Shot-Hole Borers

Credit: Luana Vargas – Forestry Images.org

- US Forest Service researcher* estimations:



70.8 Million total urban trees

23.2 Million especially at risk

Losing 50% of them will result in:

- Removal and replacement cost: ~ **$15.9 billion**
- Lost ecosystem services: **$616.8 million** annually or **$12 billion** over a 20-year life span.
- Health implications

Losing 80% of them will result in:

- Removal and replacement cost: aprox. $25.4 billion
- Lost ecosystem services valued at:

$987 million annually or
$20 billion over a 20-year life span.

- 100 Million trees at risk if moves into northern California
- Lack of Funding for a Coordinated Response because it is a “B” rated pest

*E. Gregory McPherson,USDA Forest Service

Identification of external signs & symptoms

Staining

Frass (sawdust)

Gumming

Sugary exudate

Photos | Monica Dimson/UCCE Orange County & Akif Eskalen/UCR

Beetle entry holes

Photos | Monica Dimson/UCCE Orange County

Symptoms in California Sycamore, *Platanus racemosa*

Photos | Monica Dimson/UCCE Orange County

Red Willow, *Salix laevigata*

Photo | left: Akif Eskalen/UC Riverside; right: Monica Dimson/UCCE Orange County

Coast Live Oak, *Quercus agrifolia*

Photo Monica Dimson/UCCE Orange County

White alder, *Alnus rhombifolia*

Photo : Monica Dimson/UCCE Orange County

Be careful with the lookalikes!

Bigger holes

Fruit tree shot-Hole Borer, *Scolytus rugulosus*

Smaller holes

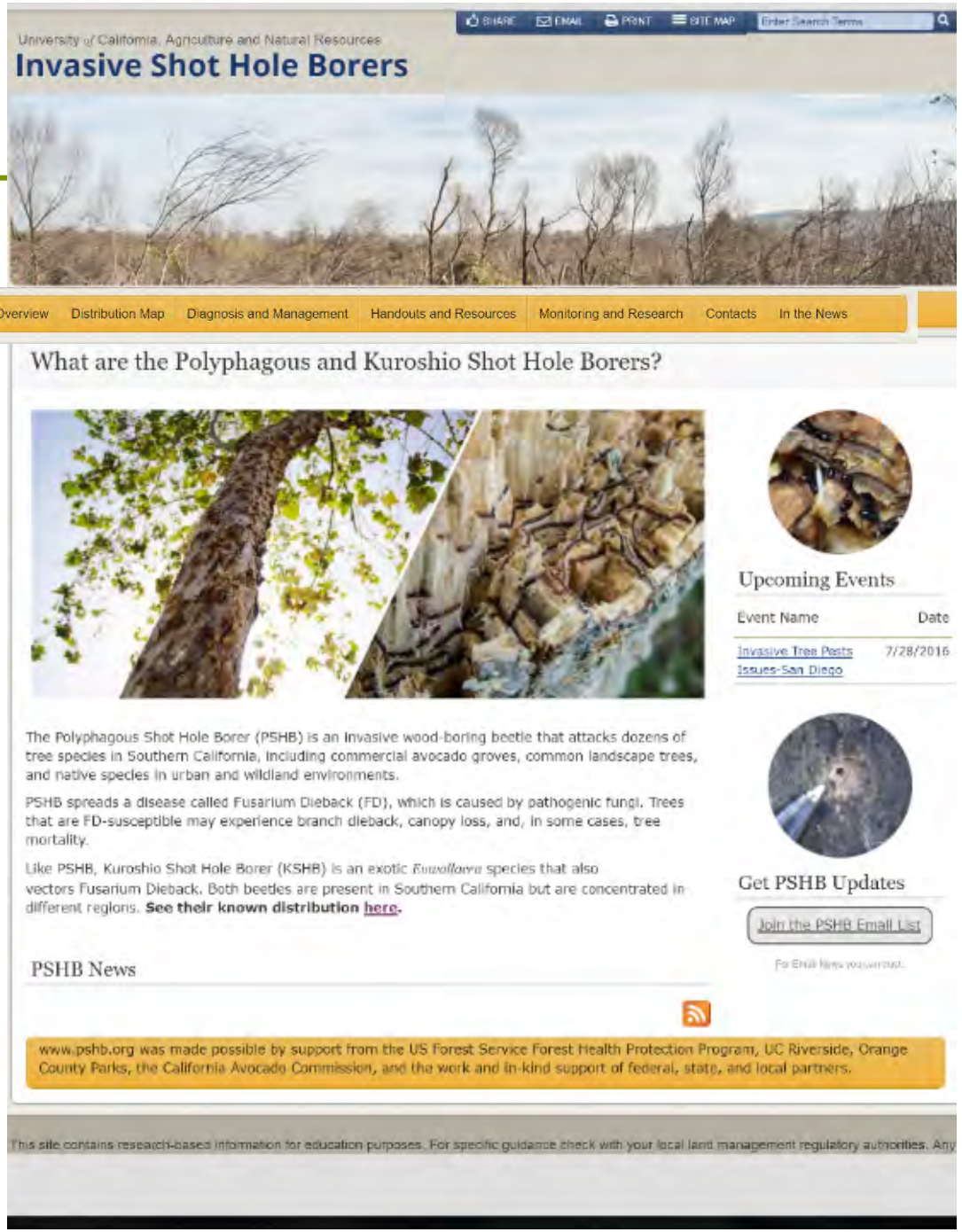
Western Oak Bark Beetle + Foamy Bark Canker

Photos : Monica Dimson/UCCE Orange County, Jack Kelly Clark/UC IPM, Beatriz Nobua-Behrmann/UCCE Orange County

This information and MORE!

PSHB.ORG

Eskalenlab.ucr.edu



Using IPM to manage Shot-Hole Borer/Fusarium Dieback

1. Pest Identification
2. Monitoring and assessing pest numbers and damage
3. Preventing pest problems
4. Guidelines for when management action is needed
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools
6. After action is taken, assessing the effect of pest management

Using IPM to manage Shot-Hole Borer/Fusarium Dieback

1. Pest Identification
2. Monitoring and assessing pest numbers and damage
3. Preventing pest problems
4. Guidelines for when management action is needed
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools
6. After action is taken, assessing the effect of pest management

Diagnosing a suspect tree

- tree species
- location (and/or GPS coordinates)
- symptoms

1. The trunk or symptomatic branches
2. The symptoms (close-up)
3. The entry/exit hole, if visible, with a ballpoint pen for scale (remove gumming or exudate if necessary)

Field Monitoring – Visual Survey

Top 3 Infested Species at OC Parks

California Sycamore
55% of OCP infestation

Willows
18% of OCP infestation

Cottonwood
12% of OCP infestation

Trapping to monitor flight activity

Lindgren Funnel Trap

Elm leaf beetle panel trap

- Lure: Querciverol (weak)
  - Traps should be 10-50 yards apart
  - # of traps may be dependent on $$ and manpower

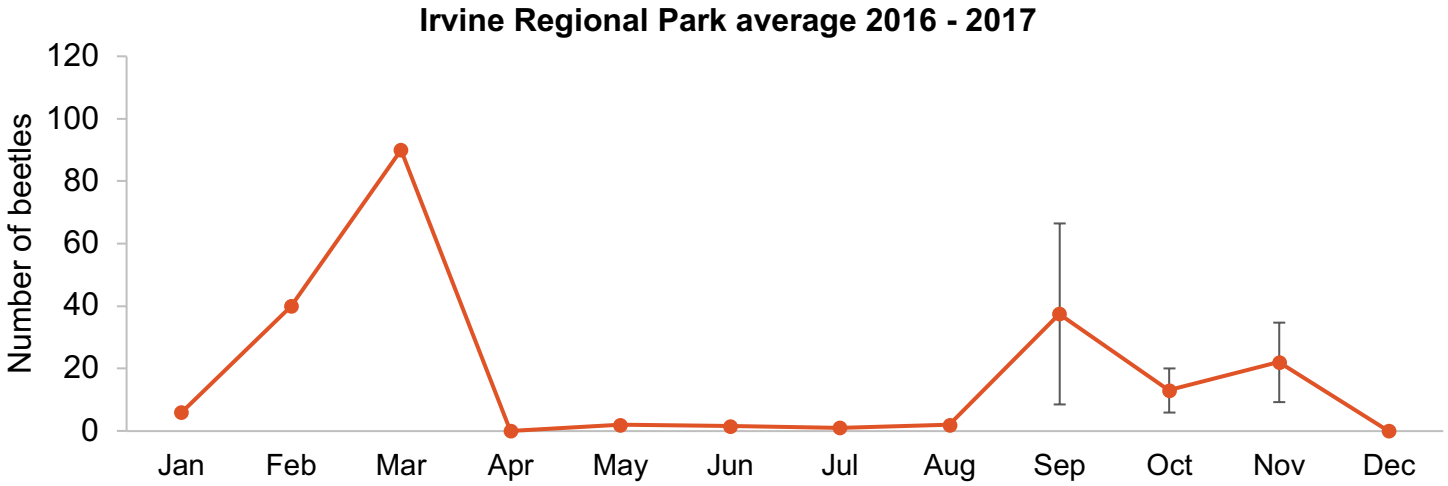
- Potential trapping locations: Areas containing host species

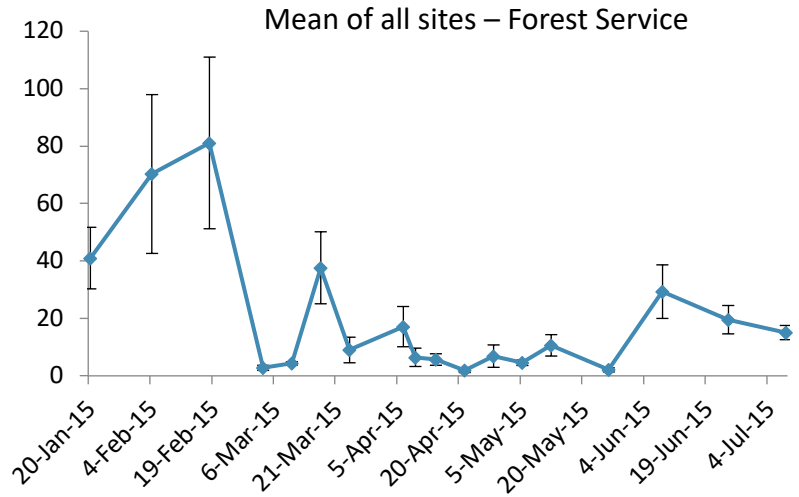
Photo | Richard Stouthamer, UC Riverside

Integrated Pest Management Program
Trapping, Repellents & Deterrents

- Traps w/ Querciverol lure
  - Cost range $26 (Vane/Short Funnel)
    - Lindgren Funnel Trap $60.00 - 71.55 per trap
    - Non-toxic (Sierra) antifreeze $12.99/gal
  - Querciverol lure
    - ChemTica is $6.90 and lasts 60 days
    - Synergy is $9 & lasts 60-120? days
  - Bottle traps may be a cheaper option
    - 40% as effective as the Lindgren Funnel Trap
  - Elm leaf beetle panel trap (18” X 25”) is $3.60 each
- Repellents - Verbenone
- Deterrents – in the testing phase

Trapping: Flight period





Two peaks:

- Early February to mid-April
- Fall: September - November

Compartmentalized beetle galleries

Eskalen et al. Unpublished data

Using IPM to manage Shot-Hole Borer/Fusarium Dieback

1. Pest Identification
2. Monitoring and assessing pest numbers and damage
3. Preventing pest problems
4. Guidelines for when management action is needed
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools
6. After action is taken, assessing the effect of pest management

Preventing Pest Problems:

- Good cultural practices
  - Soil prep
  - Fertilization
  - Irrigation (trees in turf = not good)
  - Clean cutting tools
  - Don’t move pests around
- Plant selection
- Avoid monocultures

Using IPM to manage Shot-Hole Borer/Fusarium Dieback

1. Pest Identification
2. Monitoring and assessing pest numbers and damage
3. Preventing pest problems
4. Guidelines for when management action is needed
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools
6. After action is taken, assessing the effect of pest management

ISHB Management: Factors to Consider

- **Host Species**

  Is the tree a reproductive host?

- **Infestation Level**

  How advanced is the infestation?

- **Host Value**

  Is the host of high economic or cultural value?

- **Hazard Level**

  Does the infested tree pose a safety risk to people or property?

Infestation Level

Level of Infestation	# Entry/Exit Holes	Dieback Observed
Low	< 50	No
Moderate	50-150	No
Heavy	>150	No
Severe	≥ 150	Yes

Photo | Monica Dimson, UC Cooperative Extension

			ISHB Infestation Level				
	Host Species	Hazard Level	No infestation	Low	Moderate	Heavy	Severe
HIGH VALUE HOSTS	Reproductive	Low	Preventative treatment	Treat/prune infested branches	Treat/prune infested branches	Treat/prune infested branches	Remove tree or infested branches
		High	Preventative treatment	Treat/prune infested branches	Treat/prune infested branches	Remove tree or infested branches	Remove tree or infested branches
	Non-Reproductive	Low	Monitor	Monitor	Notify UC ANR; reclassify species as reproductive host in consultation with ISHB/FD experts		
		High	Monitor	Monitor			

			ISHB Infestation Level				
	Host Species	Hazard Level	No infestation	Low	Moderate	Heavy	Severe
LOW VALUE HOSTS	Reproductive	Low	Monitor	Monitor	Remove tree or infested branches	Remove tree or infested branches	Remove tree or infested branches
		High	Monitor	Treat/prune infested branches	Remove tree or infested branches	Remove tree or infested branches	Remove tree or infested branches
	Non-Reproductive	Low	Monitor	Monitor	Notify UC ANR; reclassify species as reproductive host in consultation with ISHB/FD experts		
		High	Monitor	Monitor			

Using IPM to manage Shot-Hole Borer/Fusarium Dieback

1. Pest Identification
2. Monitoring and assessing pest numbers and damage
3. Preventing pest problems
4. Guidelines for when management action is needed
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools
6. After action is taken, assessing the effect of pest management

Integrated Pest Management Control Options

Cultural, physical/mechanical

- **Tree and stump removal**
- **Pruning infested branches (and protect wounds with Bifenthrin + *Bacillus subtilis* & Pentra Bark)**
- **Restrict firewood and green waste movement**
- **Correct disposal of infested greenwaste**

Chemical

- Trunk sprays : **Bifenthrin + *Bacillus subtilis***
- Systemic soil injection/drench: **Imidacloprid**
- Trunk injection: **Emamectin Benzoate + Tebuconazole or Propiconazole**
- Repellents: **(Verbenone) and Deterrents**

Biological

Long Term Strategy

- **Natural enemies**
- **Entomopathogenic fungi**
- **Endophytic bacteria or fungi**

Integrated Pest Management Control Options

Cultural, physical/mechanical

- **Tree and stump removal**
- **Pruning infested branches (and protect wounds with Bifenthrin + *Bacillus subtilis & Pentra Bark)***
- **Restrict firewood and green waste movement**
- **Correct disposal of infested greenwaste**

Chemical

- Trunk sprays
  - **Bifenthrin + *Bacillus subtilis***
- Systemic soil injection/drench
  - **Imidacloprid**
- Trunk injection
  - **Emamectin Benzoate + Tebuconazole or Propiconazole**
- Repellents **(Verbenone) and Deterrents**

Biological

Long Term Strategy

- **Natural enemies**
- **Entomopathogenic fungi**
- **Endophytic bacteria or fungi**

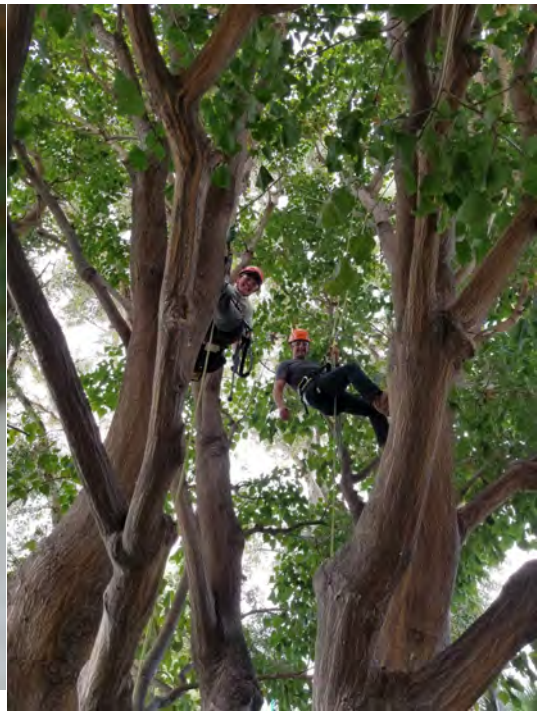
Handling infested plant material

- Chipping (less than 1”) +
  - Compost
  - Solarize
  - Deliver to landfill for use as Alternative Daily Coverage

- Cut logs +
  - Kiln-dry
  - Solarize

If relocating infested material, cover in-transit to prevent beetles from escaping

Beetle colonization on the smaller branches of coral tree



Eskalen et al. Unpublished data

Integrated Pest Management Control Options

Cultural, physical/mechanical

- Tree and stump removal
- Pruning infested branches (and protect wounds with Bifenthrin + *Bacillus subtilis* & Pentra Bark)
- Restrict firewood and green waste movement
- Correct disposal of infested greenwaste

Chemical

- Trunk sprays: **Bifenthrin + *Bacillus subtilis* or Tebuconazole (+ Pentra Bark or equivalent)**
- Systemic soil injection/drench: **Imidacloprid**
- Basal Trunk Spray: **Dinotefuran? (+ Pentra Bark or equivalent)**
- Trunk injection: **Emamectin Benzoate + Tebuconazole or Propiconazole**
- Repellents **(Verbenone) and Deterrents**

Biological

Long Term Strategy

- Natural enemies
- Entomopathogenic fungi
- Endophytic bacteria or fungi

Field Pesticides Trials on Sycamore in UCI and OC Parks

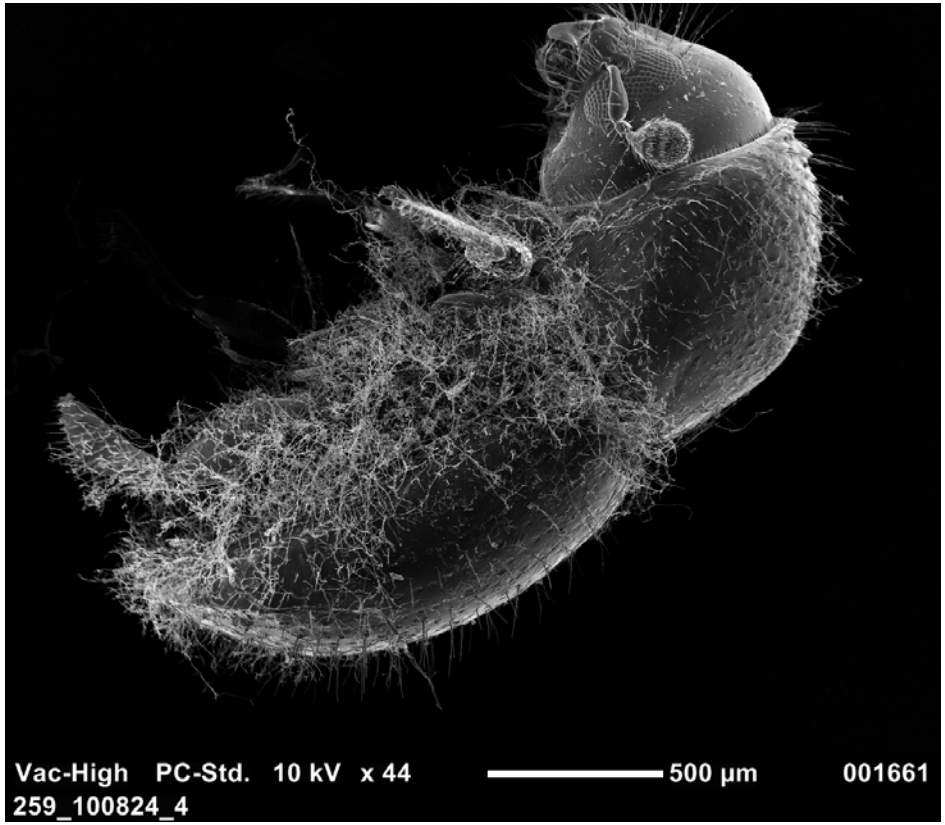
Tree IV injection system

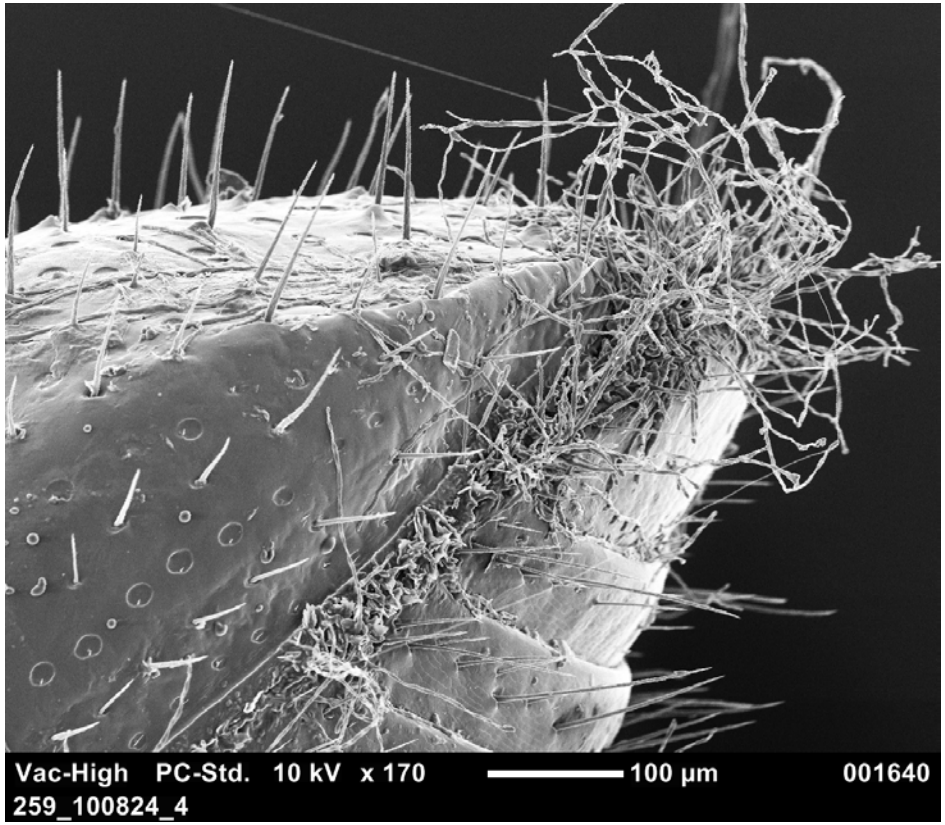
Quick-Jet Air injection system

Collaborators : Tim Paine, Michele-Eatough Jones, Chris Hanlon, Joey Mayorquin (UCR), John Kabashima, Monica Dimson (UCCE), Don Grosmas (Arborjet), Ann Hope (Mauget), Paul Webb, Kevin Holman (RPW Services) Richard Demerjian, Matt Deines, K.M Yoshino (UCI).

Secondary fungal infection on pesticides treated trees

Fungal contamination on the beetle surface





Picture Credit: Matt Kasson

Beetle transfers secondary pathogenic fungi by contamination on their surface

Secondary fungus infestation on SHB infested California Sycamore (*Platanus rasemosa*)

Integrated Pest Management Control Options

Cultural, physical/mechanical

- **Tree and stump removal**
- **Pruning infested branches**
- **Pruning wound protection (Bifenthrin + *Bacillus subtilis*)**
- **Chipping, Composting, Solarization, Burning/Biogeneration**
- **Restrict firewood and green waste movement**

Chemical

- Trunk sprays
  - **Bifenthrin + *Bacillus subtilis***
- Systemic soil injection/drench
  - **Imidacloprid**
- Trunk injection
  - **Emamectin Benzoate + Tebuconazole or Propiconazole**
- Repellents **(Verbenone) and Deterrents**

Biological

Long Term Strategy

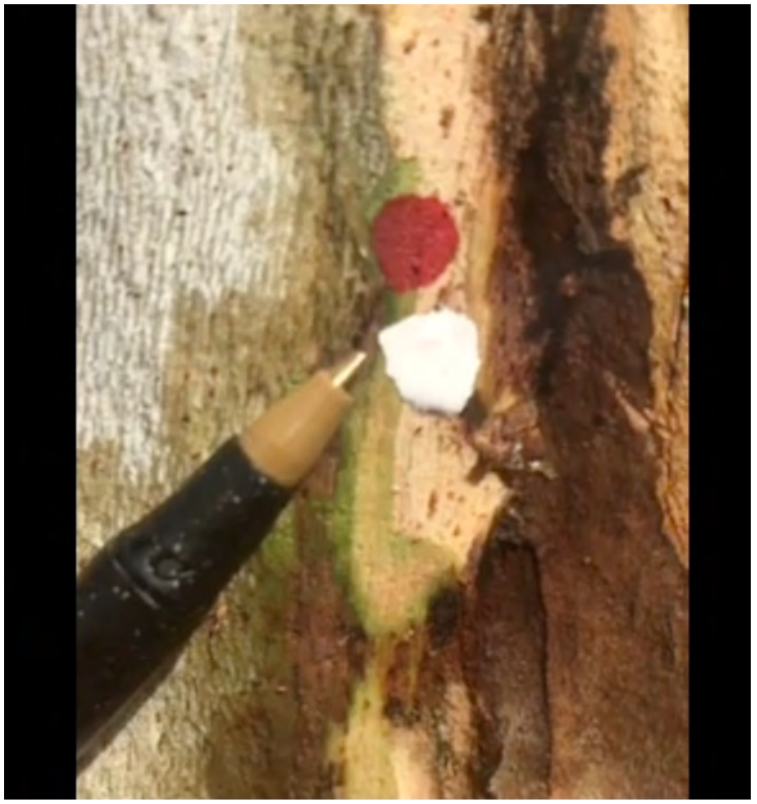
Current Research

- **Natural enemies**
- **Entomopathogenic fungi**
- **Endophytic bacteria or fungi**
- **Nematodes**

Using IPM to manage Shot-Hole Borer/Fusarium Dieback

1. Pest Identification
2. Monitoring and assessing pest numbers and damage
3. Preventing pest problems
4. Guidelines for when management action is needed
5. Using a combination of biological, cultural, physical/mechanical and chemical management tools
6. After action is taken, assessing the effect of pest management

Using water based paint to determine beetle activity



Credit: Madeline Rauhe

Acknowledgements

Photo | Monica Dimson, UC Cooperative Extension

Akif Eskalen, Ph.D., UC Riverside

Tim Paine, Ph.D., UC Riverside

Richard Stouthamer, Ph.D., UC Riverside

Michele Eatough-Jones, Ph.D., UC Riverside

Monica Dimson – OC UCCE

Hannah Vasilis – OC UCCE

Matt Dimson – OC UCCE

Richard Demerjian, UC Irvine

Matt Deines, UC Irvine

OC Parks

California Avocado Commission

California Association of Nurseries and Garden Centers

Cal Fire

Great Scott Tree Services

RPW Services Inc.

US Forest Service

USDA Farm Bill and Specialty Crop Grants

West Coast Arborists