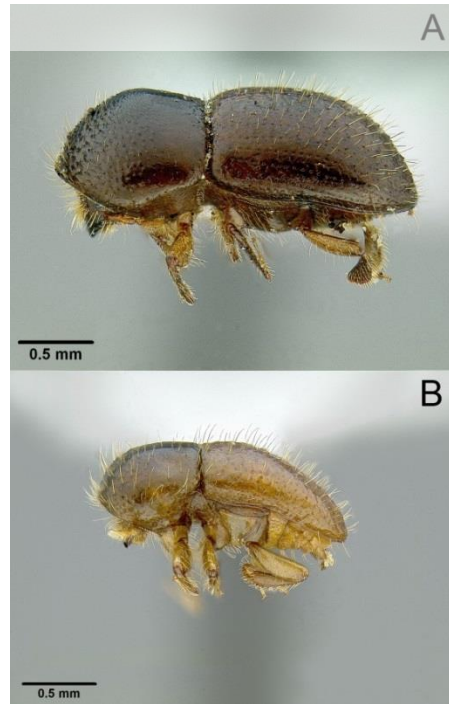


Tales of Two Hardwood Borers:

Polyphagous Shot Hole Borer and Goldspotted Oak Borer



National Plant Diagnostic Network, 4th National Meeting

Advancing Diagnostics for Emerging Pathogens and Pests Affected by Global Trade and Climate Change

March 9, 2016



Steven J. Seybold, Research Entomologist

USDA Forest Service

Pacific Southwest Research Station

Davis, California



Polyphagous Shot Hole Borer/Goldspotted Oak Borer Contrasts and Overview

- I) Pathogenic fungi: PSHB-obligatory/GSOB-no role for fungi.**

Polyphagous Shot Hole Borer/Goldspotted Oak Borer Contrasts and Overview

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Polyphagous Shot Hole Borer/Goldspotted Oak Borer

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Polyphagous Shot Hole Borer/Goldspotted Oak Borer

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- III) **Host range**: PSHB-many hosts-all size classes/GSOB focused on large diameter red oaks.
- IV) **Spread/dispersal**: PSHB-rapid innate spread/GSOB slower innate spread. The key to limiting future expansion of the invaded ranges of both species is preventing the movement of infested firewood.

Ecological and Economic Impacts of Scolytids

Urban Tree Mortality



Shade, aesthetic,
property values

Forest Tree Mortality



Agents of ecosystem disturbance

Impacts on values: wildlife habitat, watershed
quality, recreation, and wood production

How are Big Trees Killed by Small Beetles?



Aggregation Behavior in Bark/Ambrosia Beetles

Dendroctonus



Female colonizes first
Female- and male-produced pheromone
Monogynous mating system

Ips



Male colonizes first
Male-produced pheromone
Polygynous mating system



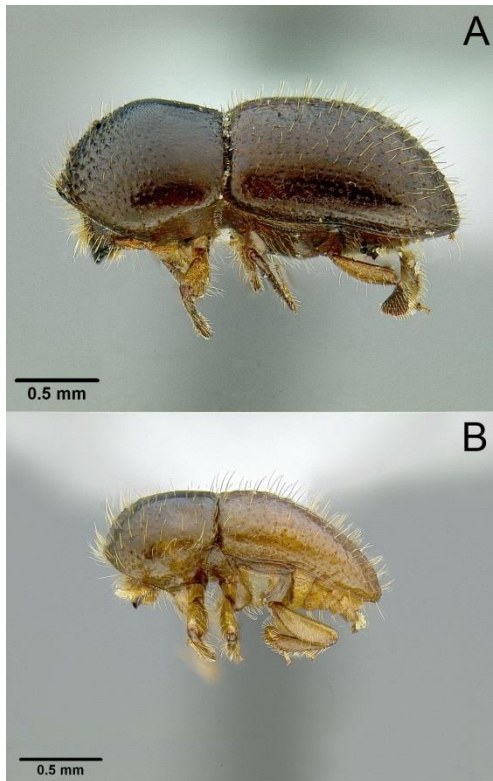
Stem of a boxelder tree mass attacked by PSHB near the point of original discovery, Whittier Narrows Recreation Area, LA Co.



**Stem of a sycamore tree mass attacked by KSHB at the Sycuan Resort, San Diego Co.
(T.W. Coleman, photos).**

A New Ambrosia Beetle Complex: Polyphagous Shot Hole Borer and Kuroshio Shot Hole Borer in California

Shot Hole Borer/*Fusarium* Wilt of Hardwoods



**An ambrosia beetle (woodborer) that is well adapted to invade new habitats
Haplodiploidy, parthenogenesis, many hosts, etc.**

**Polyphagous shot hole borer (PSHB),
Euwallacea sp.: An ambrosia beetle**



- First detected in California in 2003
 - Whittier Narrows Recreation Area (LA Co.). This insect/pathogen complex was not linked to tree injury and mortality until 2012 in LA Co.

Polyphagous shot hole borer (PSHB), *Euwallacea* sp.: An ambrosia beetle



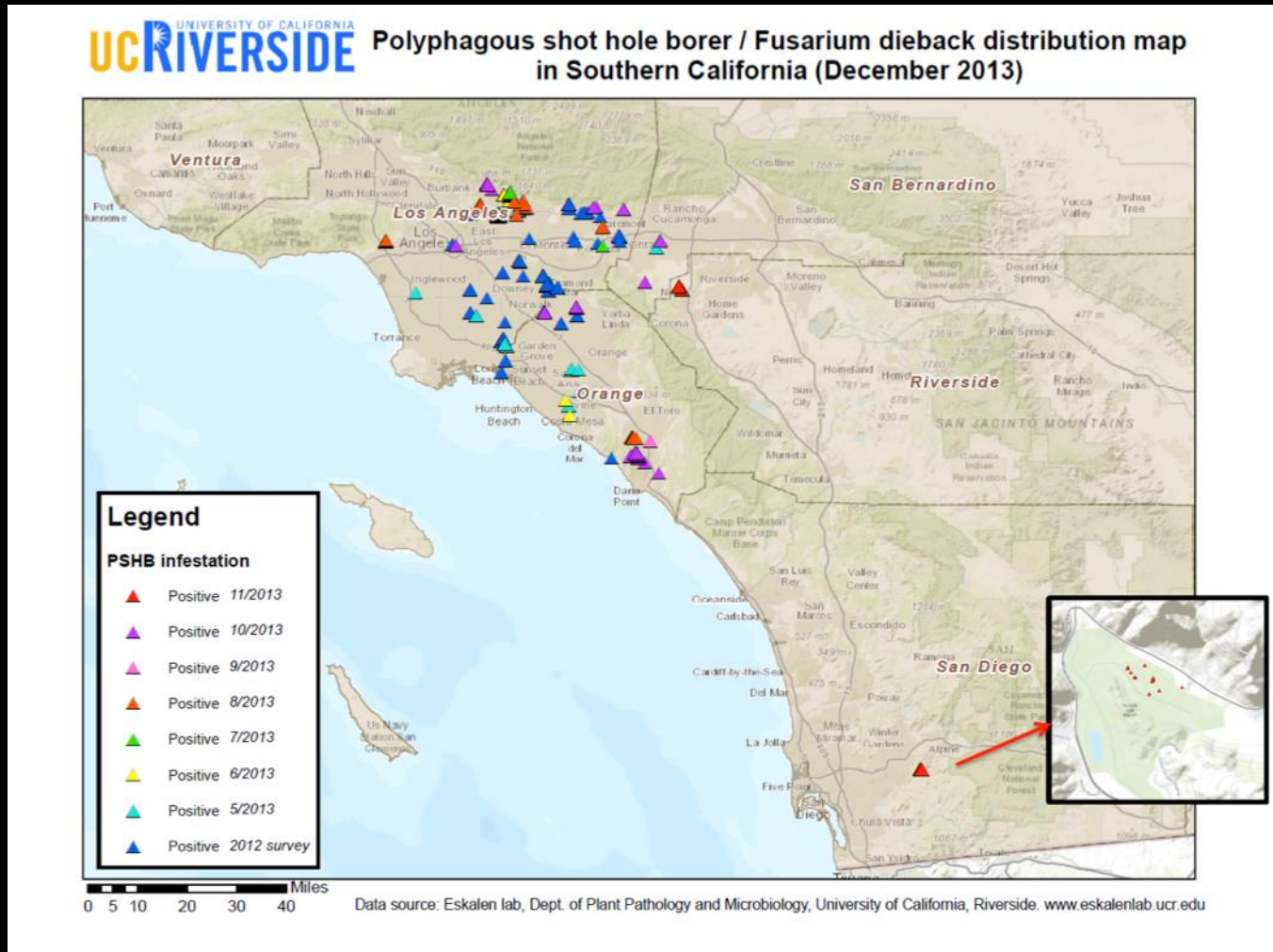
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Polyphagous shot hole borer (PSHB), *Euwallacea* sp.: An ambrosia beetle



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- PSHB in California was believed initially to be the tea shot hole borer, *Euwallacea fornicatus*, which had been introduced into Florida
- Recent molecular analyses suggest that the CA species of *Euwallacea* is likely a new species (R. Stouthamer Laboratory, UCR)
 - The same species attacks hardwood trees and shrubs in Israel

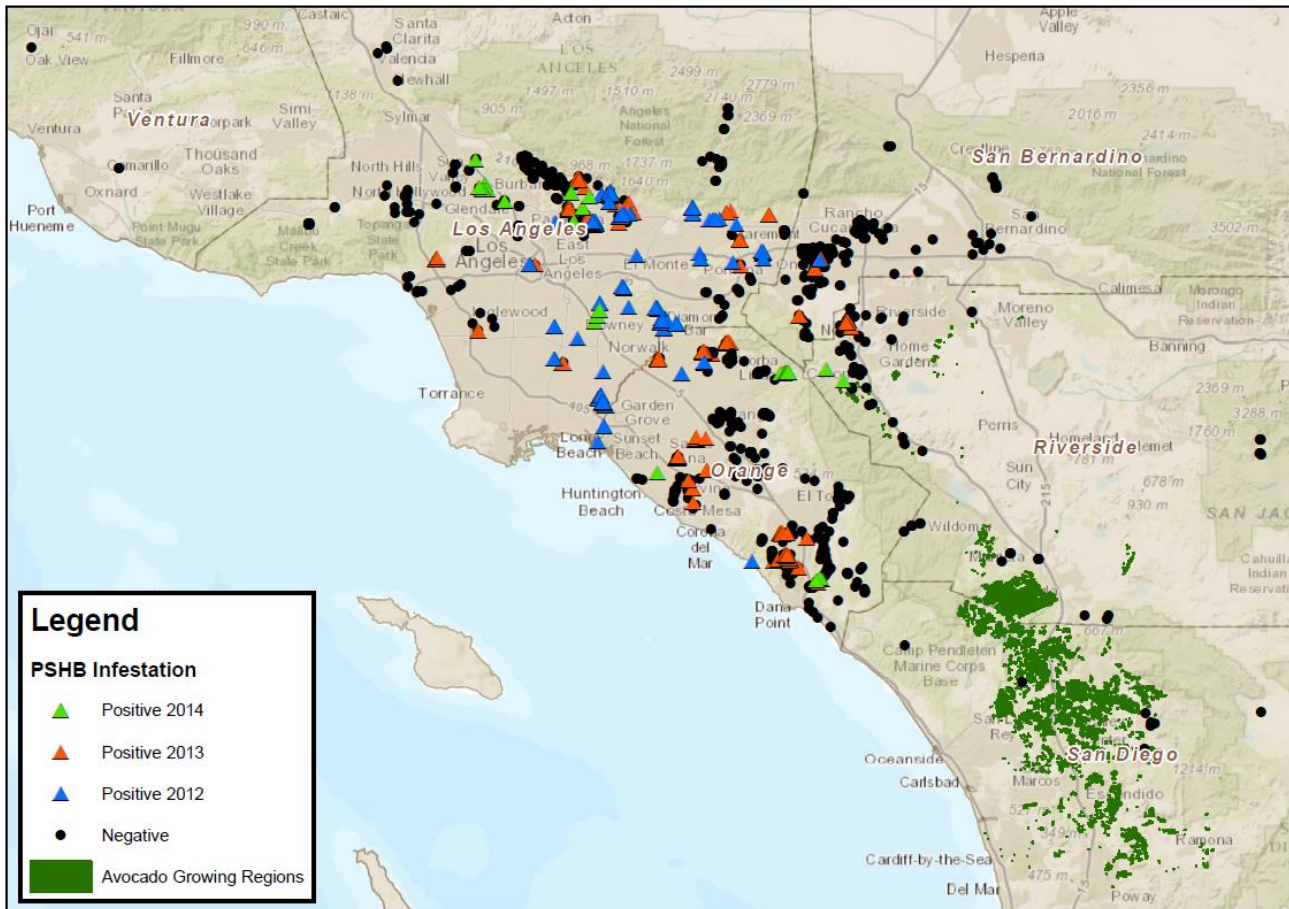
Distribution of PSHB in CA as of 2013



El Cajon (San Diego Co.): Recent detection of PSHB

– Population may be from Taiwan

Distribution of PSHB in CA as of 2014



Miles
0 4.258.5 17 25.5 34

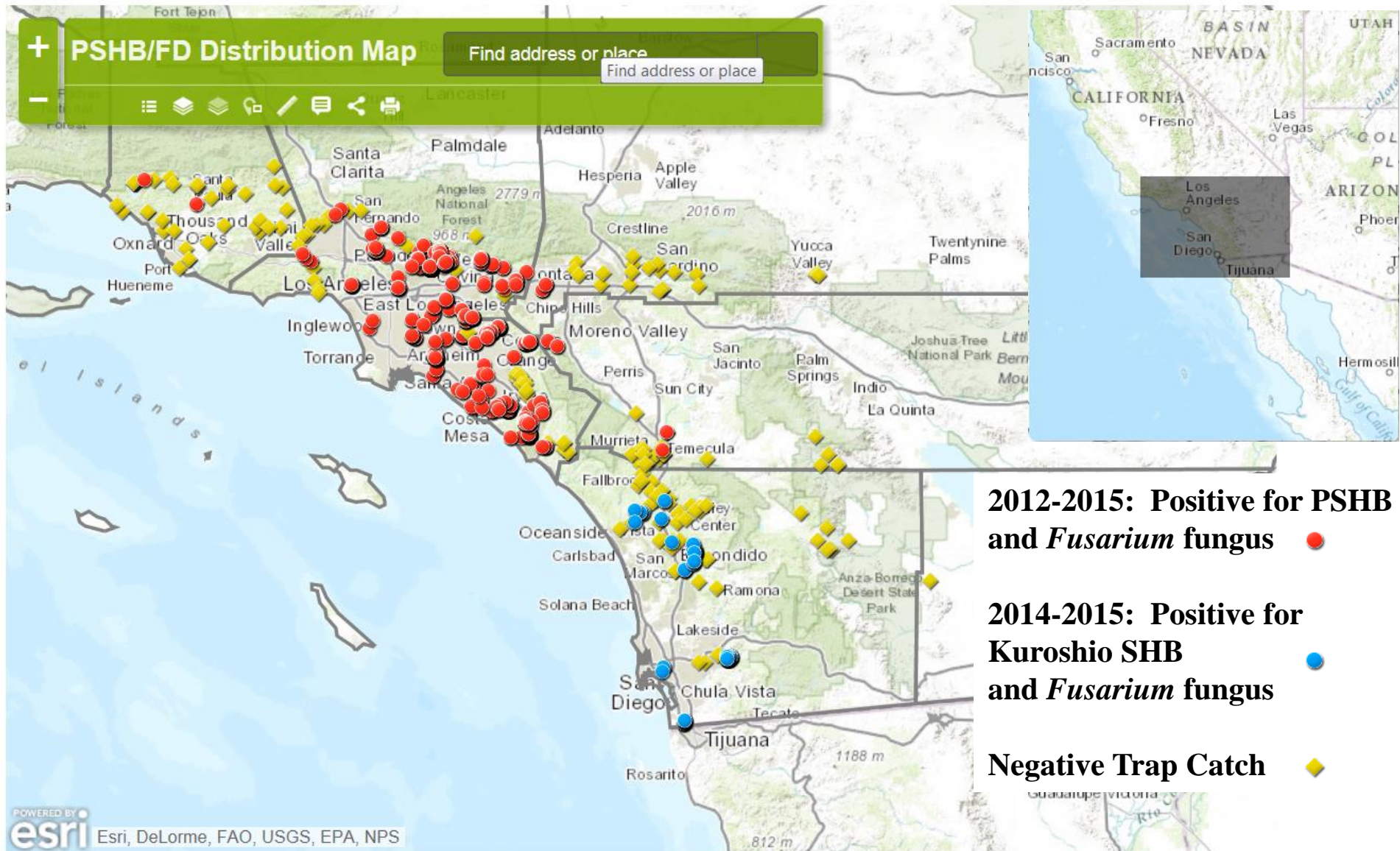
Data source: Eskalen lab, Dept. of Plant Pathology and Microbiology, University of California, Riverside. www.eskalenlab.ucr.edu

- Infested counties:
 - Los Angeles
 - Orange
 - Riverside
 - San Bernardino
 - San Diego

Distribution of PSHB in CA as of 2015

Polyphagous shot hole borer vs. Kuroshio shot hole borer

<http://ucanr.maps.arcgis.com/apps/Viewer/index.html?appid=3446e311c5bd434eabae98937f085c80>, accessed 11/9/2015



GC-MS Analysis of Cuticular Hydrocarbon Profiles

Provides species-level diagnosis of bark/ambrosia beetles



Insect Cuticular Hydrocarbon Analysis Methods

Sample
(25-300 dry
adult insects)



Surface Extraction
(10 ml hexane)

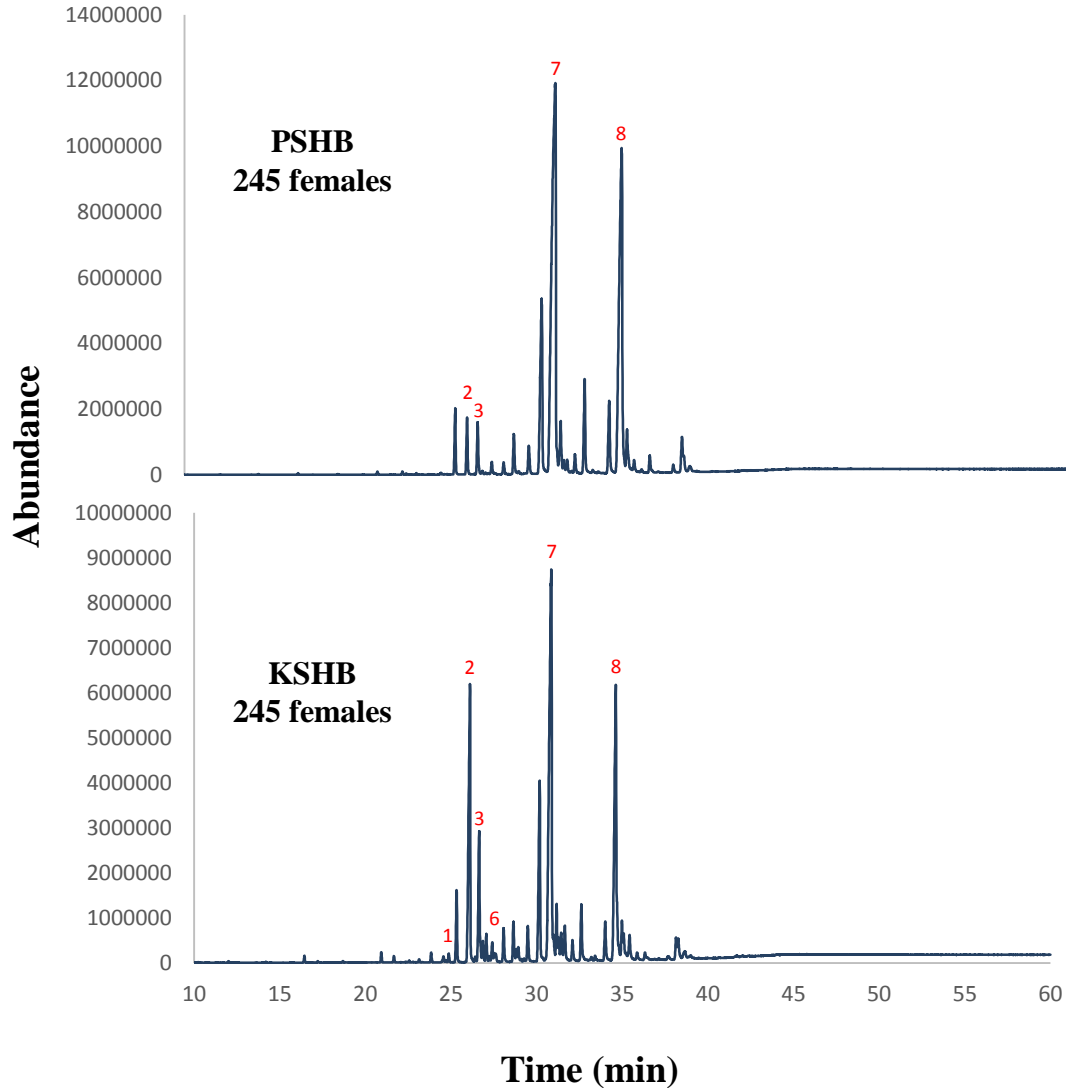


Filtration
(silica gel)

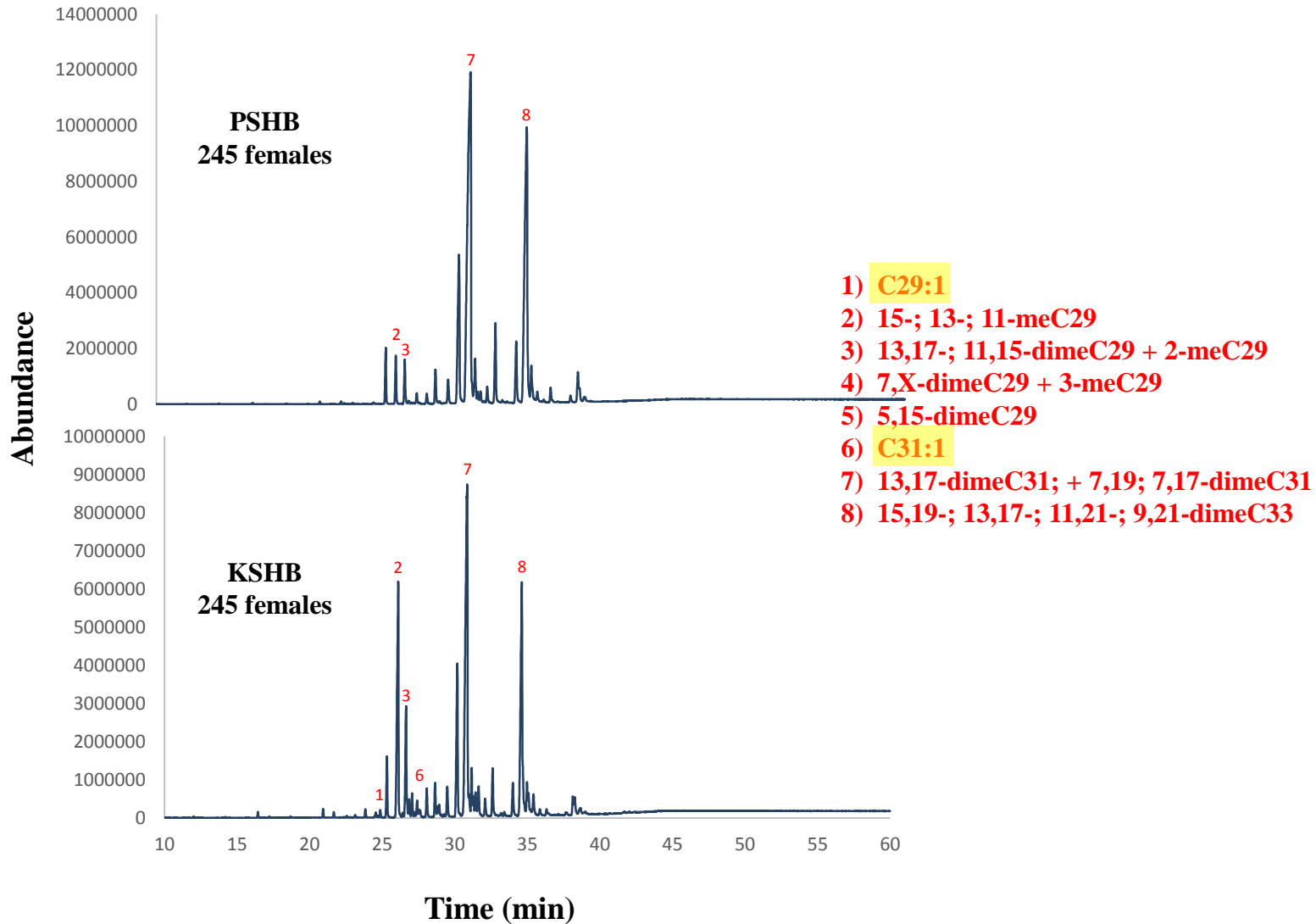


GC-MS Analysis
(non-polar
fraction)

Comparative GC-MS Analysis of Cuticular Hydrocarbon Profiles of Polyphagous and Kuroshio Shot Hole Borers

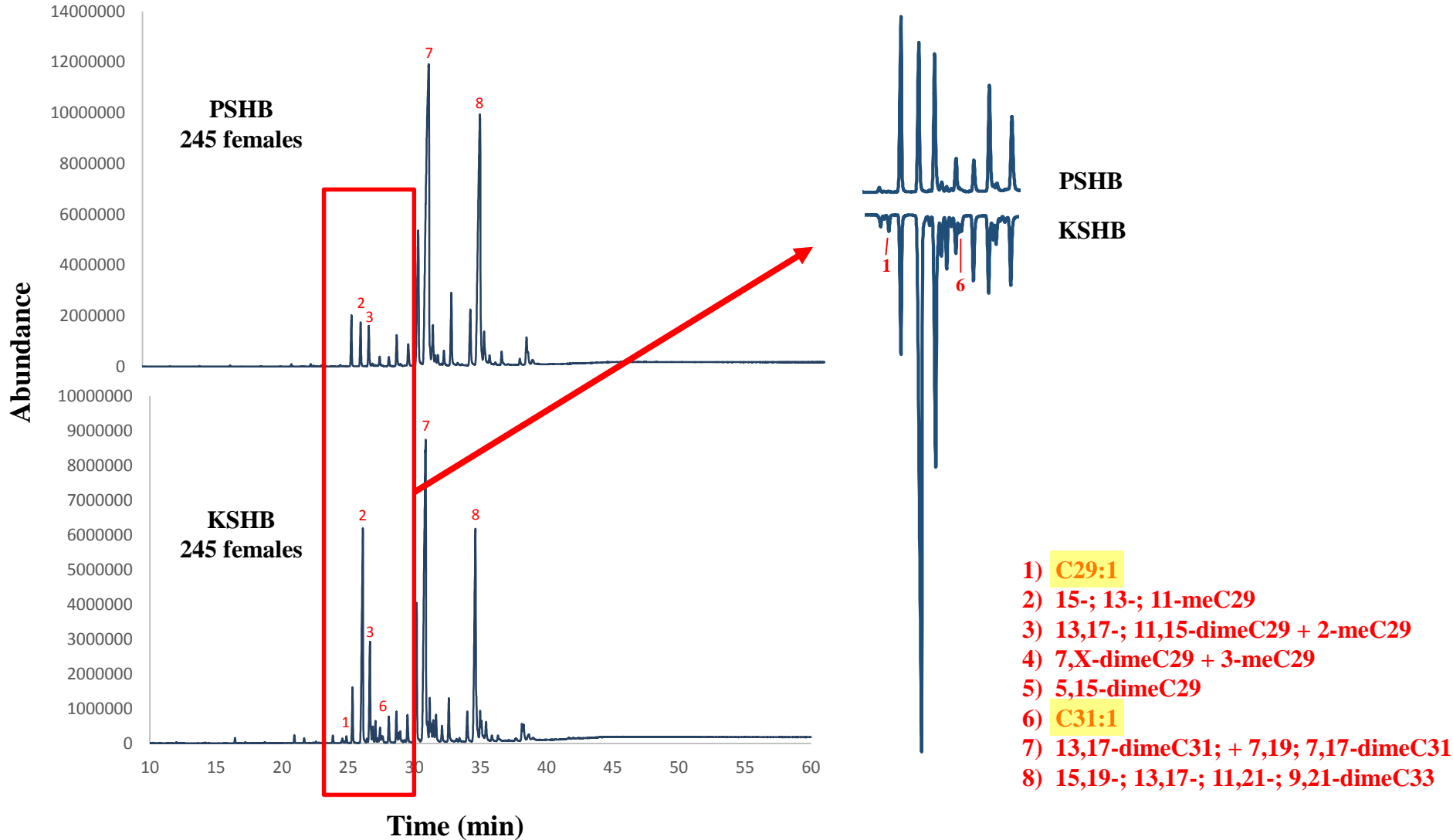


Comparative GC-MS Analysis of Cuticular Hydrocarbon Profiles of Polyphagous and Kuroshio Shot Hole Borers



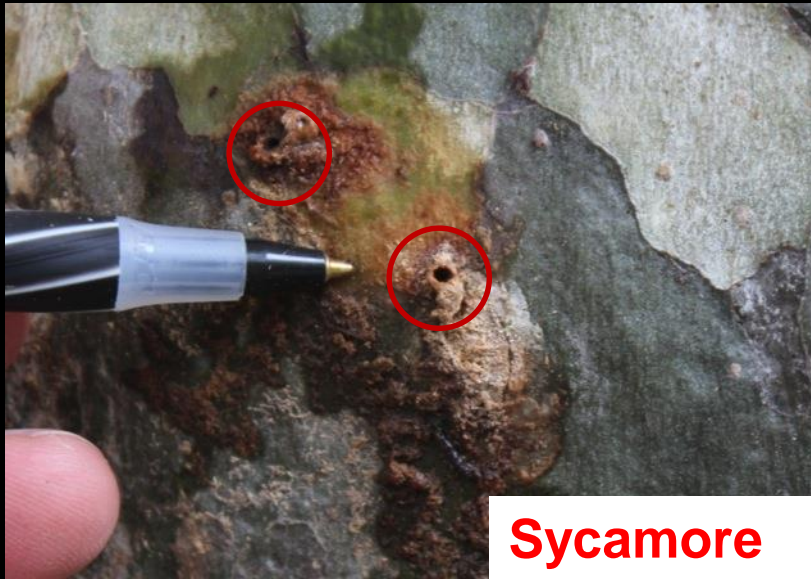
Comparative GC-MS Analysis of Cuticular Hydrocarbon Profiles of Polyphagous and Kuroshio Shot Hole Borers

[Portrait](#)

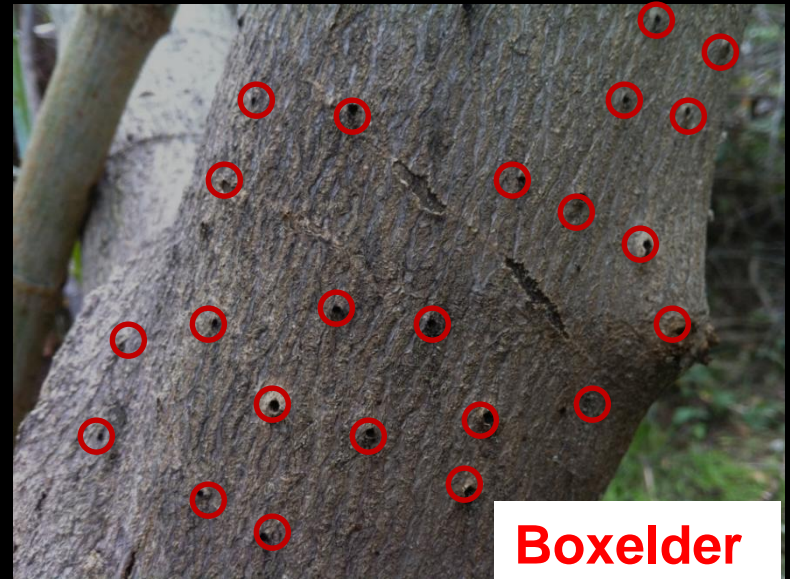


PSHB colonizes the main stem from the root collar to the smaller branches

Note the density of entrance holes



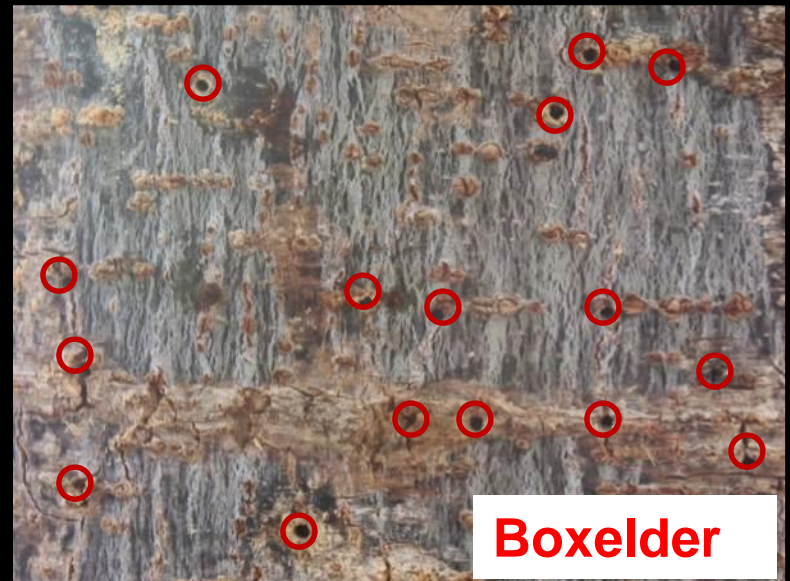
Sycamore



Boxelder



Coast live oak



Boxelder

**Polyphagous Shot Hole Borer Galleries
Cross Section of Sycamore Stem,
Glendora, CA**



Fusarium wilt: Fungi associated with PSHB



- New species of *Fusarium* and *Graphium* are associated with PSHB
 - Eskalen (UCR) is conducting virulence tests with each fungus
- The same *Fusarium euwallaceae* is found in CA and Israel

PSHB-Impacts and Potential Impacts

- I) **Urban forest-Street trees, parks/arboreta, golf courses**
- II) **Wildland forest-Riparian zones**
- III) **Agriculture?**



Preliminary Survey Data for PSHB: ~800 trees surveyed across four LA County sites

(Arcadia Wilderness Park, Glendora, Pasadena Glen, Whittier Narrows Park)

(TW Coleman, USDA FS FHP, San Bernardino, CA, unpublished data)

Tree Species	% Infested	% Severely Injured	%Dead with PSHB
Boxelder (<i>N</i> =84)	89%	83%	30%
Gooding's black willow (<i>N</i> =27)	88%	0%	7%
Red willow (<i>N</i> =103)	83%	49%	17%
California sycamore (<i>N</i> =149)	77%	25%	5%
White alder (<i>N</i> =54)	74%	18%	2%
Castorbean (<i>N</i> =25)	68%	71%	16%
Fremont's cottonwood (<i>N</i> =52)	60%	61%	4%
Ash spp. (<i>N</i> =66)	32%	8%	0%
Coast live oak (<i>N</i> =92)	23%	0%	0%
Southern California black walnut (<i>N</i> =14)	23%	0%	0%

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Native hardwood stands in southern California riparian areas



PSHB attacks and kills native riparian trees

Angeles National Forest

Potential impacts on 1) threatened/endangered species; 2) water quality; and 3) structure/composition of fuel load.



Red willow



White alder



California sycamore

Willow flycatcher, least Bell's vireo, arroyo toad, yellow-legged frog, western yellow-billed cuckoo, gray vireo, 3 bat species, and 6 snake species

Kuroshio Shot Hole Borer: San Diego County



Damage to arroyo willow in the Tijuana River Delta, San Diego Co.

John Boland, photo
Adrian Poloni, photo

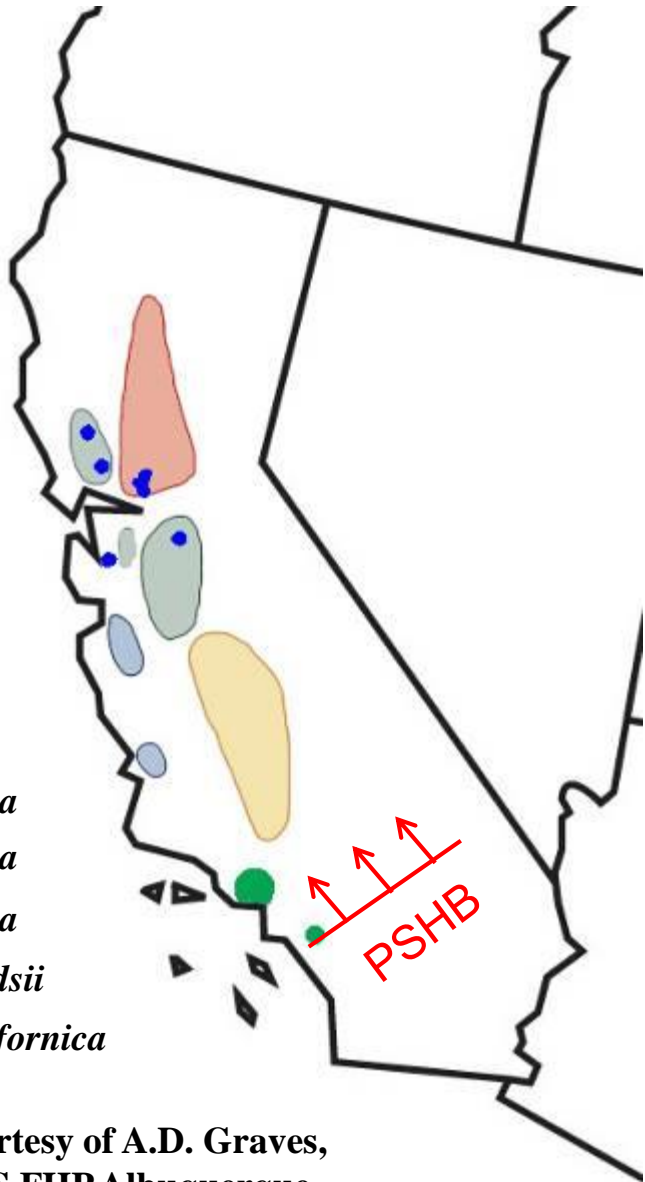
What about interactions of PSHB Impact and Agriculture?





- PSHB attacks avocados
- California produces 90% of the nation's avocado crop
- ~21,000 ha of avocados planted from San Luis Obispo to San Diego
- Crop valued at \$382,000,000/yr



What about the Central Valley?

Distribution of Walnuts in California



-  *J. regia*
-  *J. regia*
-  *J. regia*
-  *J. hindsii*
-  *J. californica*

Slide Courtesy of A.D. Graves,
USDA FS FHP Albuquerque

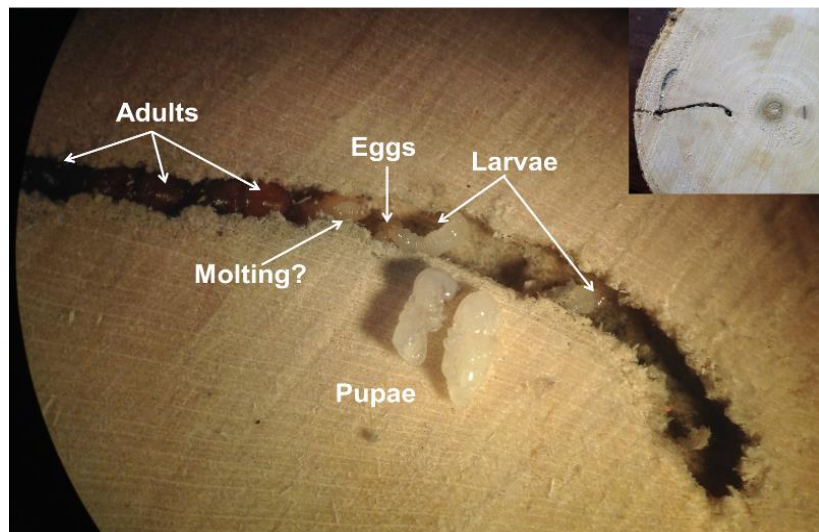
California

Annual Value of *J. regia* Nut Crop:
\$500 Million to \$1 Billion

Central Valley

A “carpet” of walnut,
almond, and pistachio trees

PSHB: 2014 and 2015 No-choice Host Range Tests



A PSHB gallery showing all life stages



PSHB: 2014 No-choice Host Range Tests

Based on the presence of male or pupal PSHB in a gallery

CA (9 spp.)

Boxelder

California ash*

California bay laurel*

California sycamore

Castor bean

English walnut*

Fremont's cottonwood

Interior live oak*

Red willow

LA (3 spp.)

Black willow*

Red maple*

Southern red oak*

NM (4 spp.)

Boxelder*

Quaking aspen*

Narrow-leaf cottonwood*

Salix sp. *



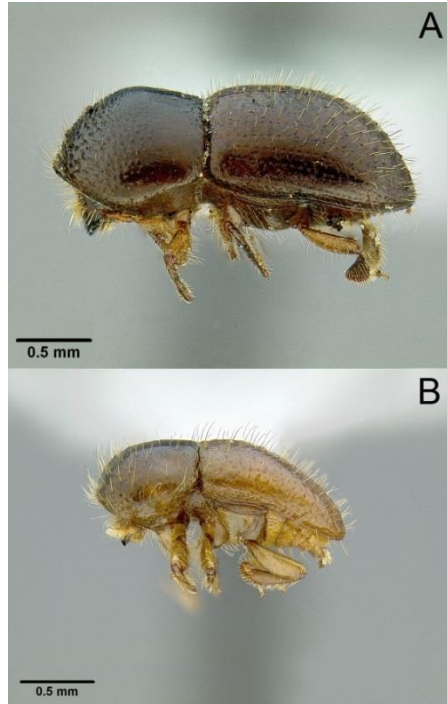
* = Newly found host plants

PSHB: 2015 Laboratory No-choice Host Range Tests

- July 2015: Removed green branch sections (2-3” dia. x 24”long) from five English walnut cultivars from the Wolfskill UCD Stuke Collection (Chandler, Chico, Payne, Serr, and Tulare);**
- Removed ends of branch sections (cut to 18 inch lengths), added 2-3 branch sections to 19 liter containers and added 40 to 60 female PSHB;**
- “Incubated” females with potential host branch sections for at least 2 months;**
- Split logs and looked for presence of new adult males or pupae = positive host;**
- Lab Results: Chandler, Chico, and Payne were positive; Serr and Tulare yielded PSHB larvae, which suggests at least partial reproduction in the latter hosts.**

Tales of Two Hardwood Borers:

Polyphagous Shot Hole Borer and Goldspotted Oak Borer



USDA FS Resources



United States Department of Agriculture
Forest Service
Pacific Southwest Region
State and Private Forestry
R5-RP-022
October 28, 2008

New Pest in California:

The Goldspotted Oak Borer, *Agrilus coxalis* Waterhouse

The goldspotted oak borer (GSOB) was first detected in 2004 in San Diego Co., California by the California Department of Food and Agriculture during a survey for exotic woodborers. In 2008, it was found in the same county attacking coast live oak, *Quercus agrifolia*, canyon live oak, *Q. chrysolepis*, and California black oak, *Q. kelloggii*, on the Cleveland National Forest. GSOB is playing a major role in on-going oak mortality on federal, state, private, and Native American lands in southern California. GSOB larvae feed under the bark primarily at the interface of the sapwood and phloem on the main stem and larger branches. Larvae kill patches and strips of phloem and cambium, resulting in limb and branch die back and, eventually, tree death. Although the exact origin of the California population is unknown, GSOB has been previously collected in Arizona, Mexico, and Guatemala. Because of host distribution, GSOB has the potential to spread further north in California and cause similar tree mortality. Since very little published information is available on this insect, additional research is needed to determine the life cycle, behavior, and management strategies. The movement of infested firewood likely represents a significant pathway for introducing GSOB into non-infested areas.

Identification

Adults are about 10 mm long and 2 mm wide (Fig. 1). They are bullet-shaped and can be identified by the six golden-yellow spots on the dark green forewings. Mature larvae are about 18 mm long and 3 mm wide. They are legless, white, and have a long slender appearance (Fig. 2). The larvae possess two pincher-like spines at the tip of the abdomen. Pupae are found in the outer bark and resemble adults, but are commonly white in color. Eggs are probably laid in bark crevices like other *Agrilus* spp., but have not been observed by the authors.

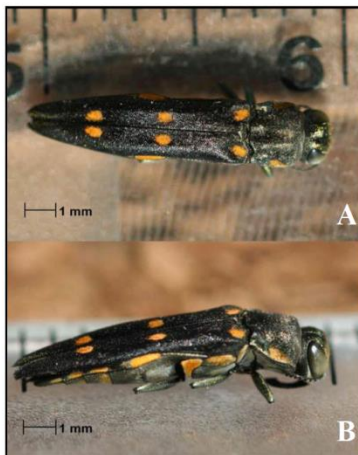


Figure 1. Dorsal (A) and lateral (B) views of the GSOB adult. The six gold spots on the forewings (elytra) are diagnostic for this species.



Figure 2. White, legless larvae of GSOB

1

Coleman, T.W. and Seybold, S.J. (2008) New Pest in California: The Goldspotted Oak Borer. Pest Alert

http://www.fs.usda.gov/detail/r5/forest-grasslandhealth/?cid=fsbdev3_046707 or <http://www.nps.gov/yose/learn/nature/upload/pest-oak-borer-alert.pdf>



Goldspotted Oak Borer

T.W. Coleman¹, M.I. Jones², S.L. Smith³, R.C. Venette⁴, M.L. Flint⁵, and S.J. Seybold⁶

The goldspotted oak borer (GSOB), *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae) (Figure 1), is a flatheaded phloem- and wood borer that infests and kills several species of oak (Fagaceae: *Quercus*) in California. One or more populations of GSOB were likely introduced via infested firewood into San Diego County, California from the native range in southeastern Arizona. Since its introduction to California, GSOB has expanded its range and has killed red oaks (*Quercus* Section *Lobatae*) nearly continuously across public and private lands (Figure 2).

New Mexico, and southwestern Texas. Specimens of GSOB have only been collected from Arizona, California, and Mexico. In southeastern Arizona, GSOB feeds primarily on *Q. emoryi*, and silverleaf oak, *Q. hypoleucoides* A. Camus (both Section *Lobatae*). Larval feeding injures the phloem and outer xylem of these red oak species, with most feeding activity and occasional cases of tree mortality noted in large-



Figure 1. Adult goldspotted oak borer, *Agrilus auroguttatus*, an exotic insect threatening red oaks in California (Adults are approximately 0.35 inches long by 0.08 inches wide).

Distribution and Hosts

The native distribution of GSOB likely coincides with that of Emory oak, *Q. emoryi* Torrey, including the Coronado National Forest in southeastern Arizona and floristically related regions in northern Mexico, southern

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²Entomologist, Dept. of Environmental Science and Forestry, Syracuse University, Syracuse, NY; ³Entomologist, USDA Forest Service, Forest Health Protection, Susanville, CA; ⁴Research Biologist, USDA Forest Service, Northern Research Station, St. Paul, MN; ⁵Entomologist, Dept. of Entomology and Nematology and Statewide Integrated Pest Management Program, University of California, Davis, CA; ⁶Research Entomologist, USDA Forest Service, Pacific Southwest Research Station, Davis, CA.

Coleman, T.W. et al. (2015) Goldspotted Oak Borer.

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf

Goldspotted Oak Borer

Take Home Messages

- I) GSOB is not always associated with a pathogenic fungus.**
- II) GSOB appears to have originated from the Southwest (AZ/NM); so far it has only invaded southern California.**
- III) GSOB prefers to attack and kill large diameter red oaks (>18" dbh); it takes a long time (conservatively 3 to 5 yrs) to kill these trees.**
- IV) The key to limiting future expansion of the invaded range of GSOB is preventing the movement of infested firewood.**

Adults feed on foliage; larvae feed on phloem



GSOB life stages



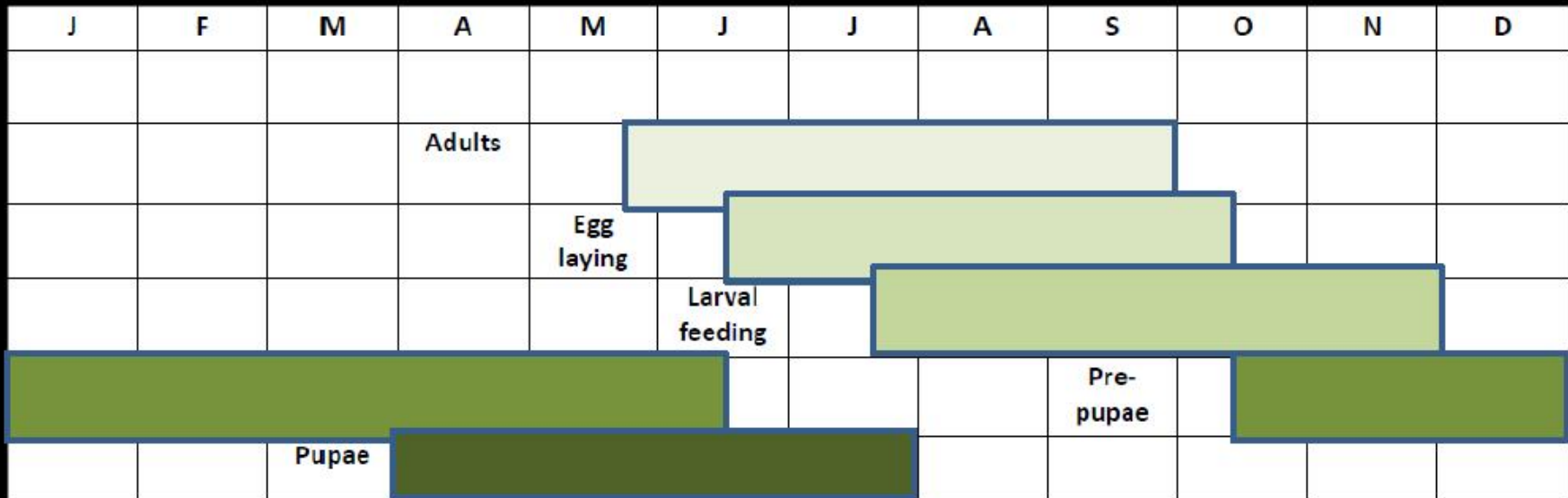
Only life stages causing significant tree injury

2

3

4

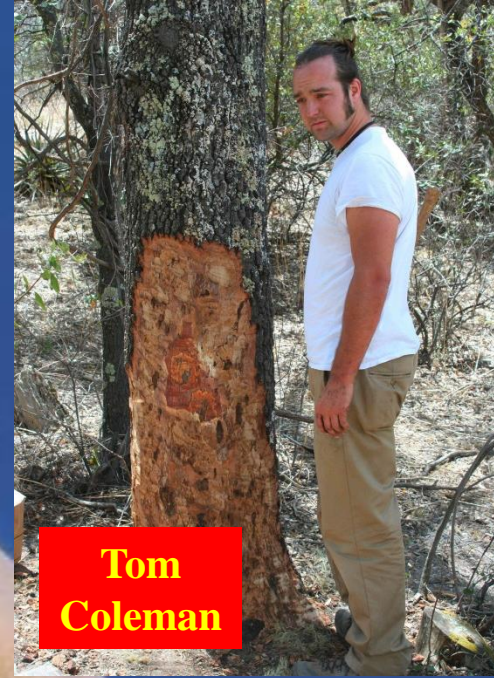
GSOB life cycle



- One generation per year
- Adults fly primarily between May and September
- Pre-pupae found nearly year round



GSOB mature larva



**Tom
Coleman**

May 2008



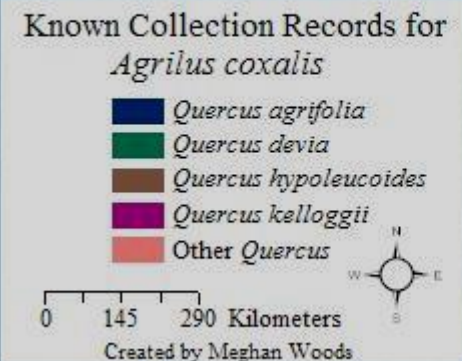
4 mm

GSOB's native and introduced ranges

Agrilus auroguttatus



Coleman and Seybold (2008)
Pan-Pacific Entomologist 84: 288-300



Agrilus coxalis



Historical Collection Records of GSOB in Southeastern AZ

Coleman and Seybold (2011) *Coleopterists Bulletin* 65: 93-108

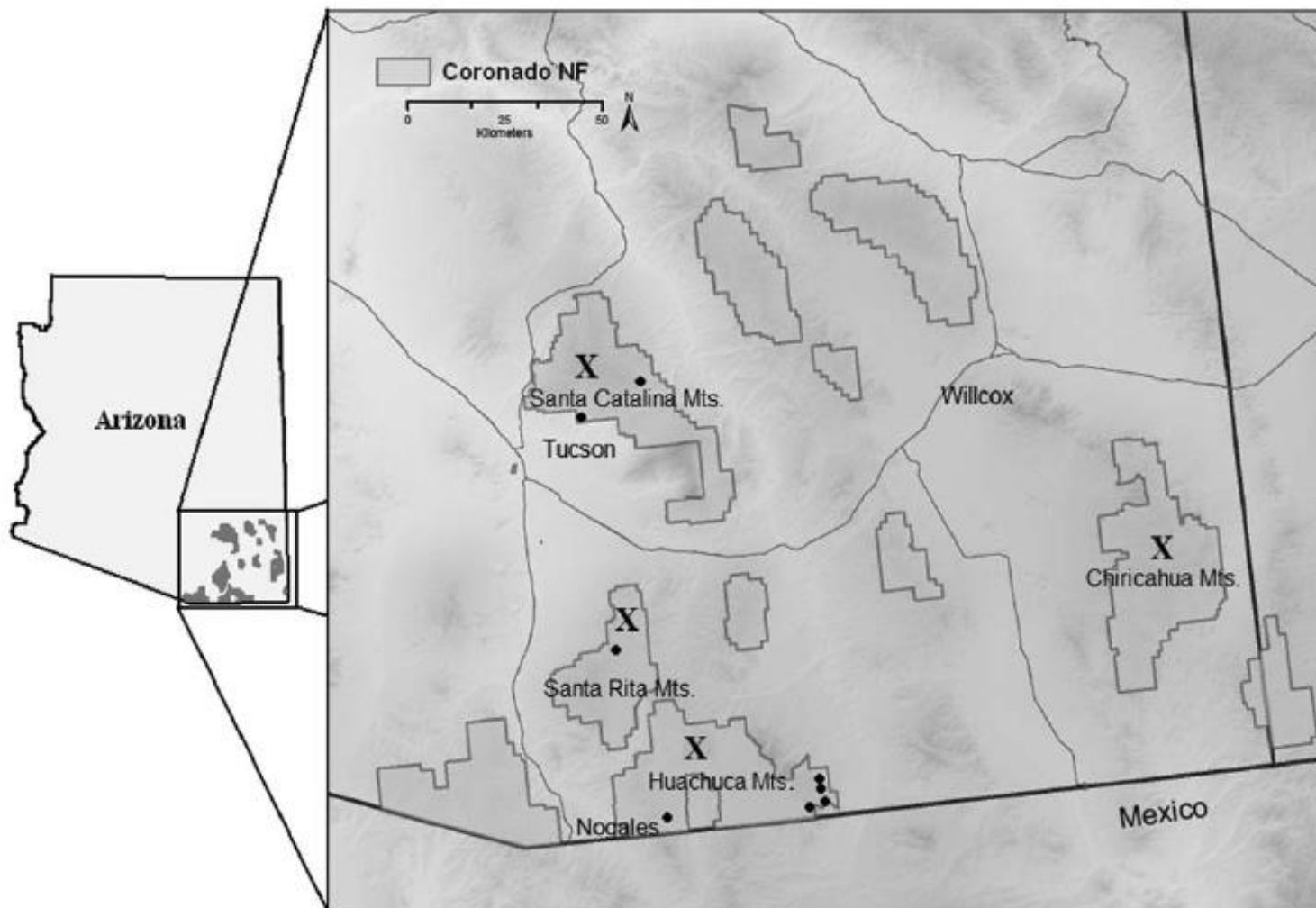


Fig. 2. The four mountain ranges (Santa Catalina, Santa Rita, Huachuca, and Chiricahua) in the Coronado National Forest in southeastern Arizona where historical collections of *Agrilus auroguttatus* were made. General localities (X) are noted on the four mountain ranges, but a few exact localities (●) were available from collection labels.

Historical Collection Records of GSOB in Southeastern AZ

Coleman and Seybold (2011) *Coleopterists Bulletin* 65: 93-108

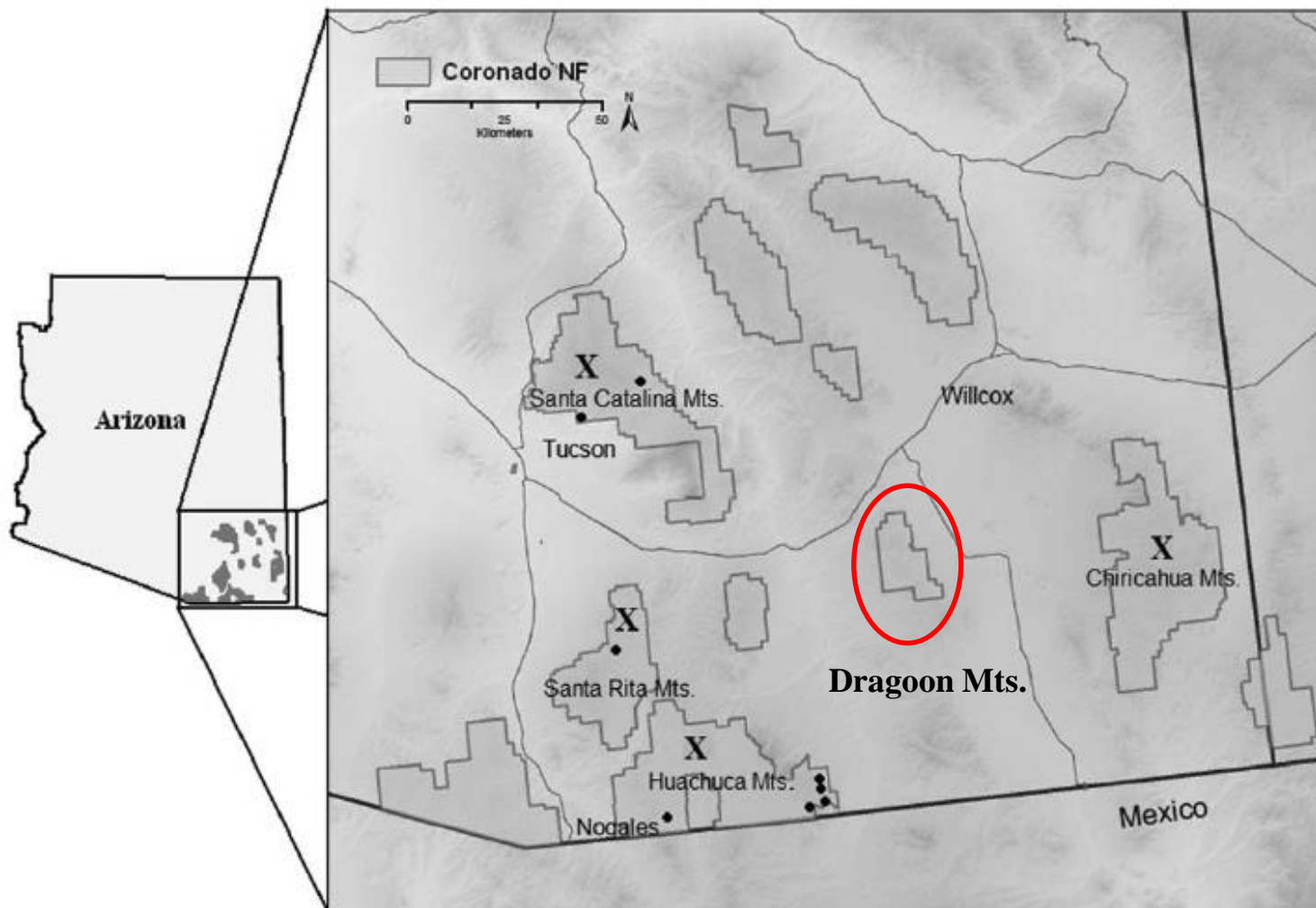


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GSOB Population Genetics and Similarity of AZ and CA Populations Mitochondrial Cytochrome Oxidase I Haplotypes of GSOB

Biol Invasions (2014) 16:2393–2402
DOI 10.1007/s10530-014-0672-7

ORIGINAL PAPER

Population genetics of goldspotted oak borer, *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae): investigating the origin of an invasive pest of native oaks in California

Vanessa M. Lopez · Paul F. Rugman-Jones ·
Tom W. Coleman · Mark S. Hoddle ·
Richard Stouthamer

Received: 14 October 2013 / Accepted: 5 March 2014 / Published online: 13 March 2014
© Springer International Publishing Switzerland 2014

Abstract The goldspotted oak borer, *Agrilus auroguttatus* Schaeffer, is an invasive woodborer in California USA that is native to oak woodlands across southern Arizona USA. Developing a classical biological control program for this pest in southern California is a high priority due to the continuing ecological and economic damage caused by this insect since its recent introduction into the area. In an attempt to determine the area of origin for this invasive beetle, analyses of the mitochondrial cytochrome oxidase and ribosomal nuclear D2 domain of the 28S gene regions were undertaken and provided insight into the phylogeographic relationship between and within populations of *A. auroguttatus* in Arizona and California. The area of origin for the invasive population of goldspotted oak borer in California was not determined conclusively, although our molecular data suggests the Dragoon Mountains in Cochise Co., Arizona as a possible source for the California

population of *A. auroguttatus*. Results also confirmed that individuals collected from populations across southern Arizona and California are all *A. auroguttatus*, and are not part of a cryptic species complex comprised of the morphologically similar *A. coxalis*. Future surveys for natural enemies of *A. auroguttatus* will focus on the Dragoon Mountains as a potential source for co-evolved enemies for use in a classical biological control program against this invasive woodborer in southern California.

Keywords *Agrilus auroguttatus* · Biological control · Cytochrome oxidase I · Phylogeography · Wood-borer

Introduction

The goldspotted oak borer, *Agrilus auroguttatus* Schaeffer, (Coleoptera: Buprestidae) is an invasive wood-boring beetle that aggressively attacks native oak trees in southern California, USA. Native to Arizona, this beetle was initially detected in the Descanso Ranger District, Cleveland National Forest (DRD-CNF), San Diego County, California, in 2004, but was likely introduced accidentally several years earlier through movement of infested oak firewood (Coleman and Seybold 2008a; Coleman et al. 2012a). Infestation of *A. auroguttatus* in southern California currently covers approximately 213,000 ha across San Diego, and Riverside Counties (Jones et al. 2013), and

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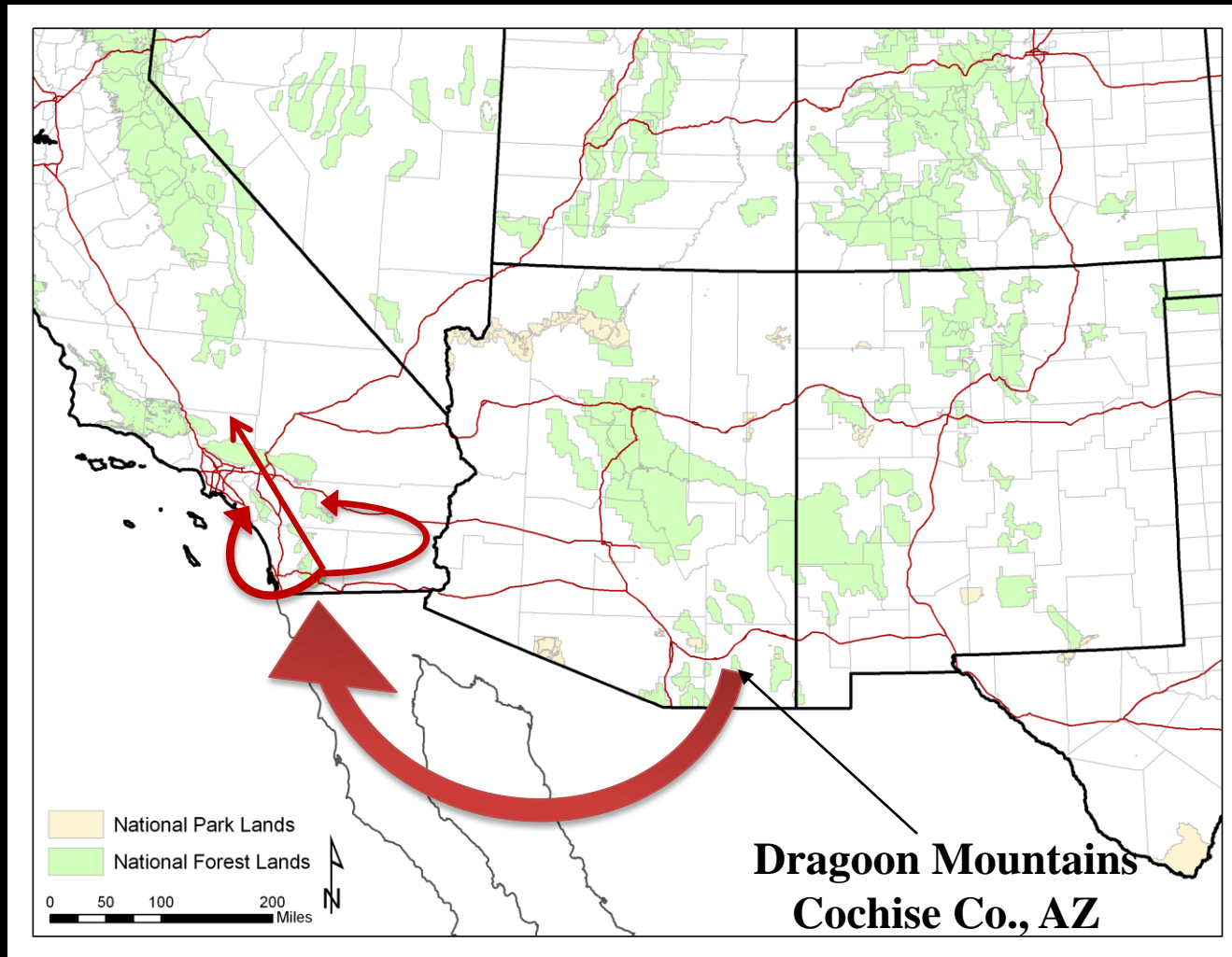
Vanessa Lopez



Richard Stouthamer

Analysis by P. Rugman-Jones,
Vanessa Lopez,
and R. Stouthamer,
Dept. Entomology,
UC-Riverside

GSOB: Source of Introduced Population



- mtDNA and nuclear DNA analyses suggest that the CA population is most similar to populations in southeastern AZ
- Likely transported to CA on firewood

GSOB larval hosts

California



Arizona



Mexico

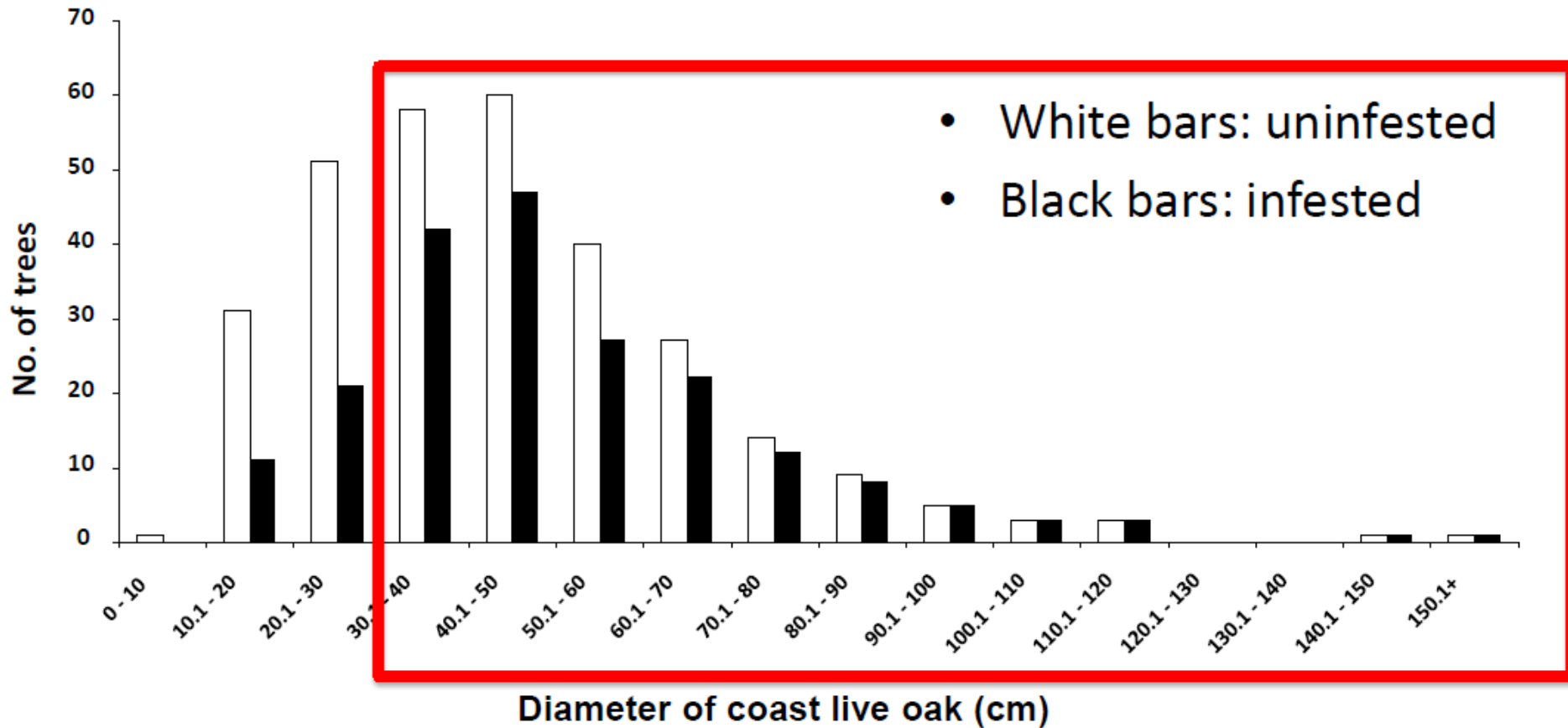


Q. peduncularis

Q. conzatti

(*A. coxalis*)

Host size preference



- Larger size-classes preferred by GSOB

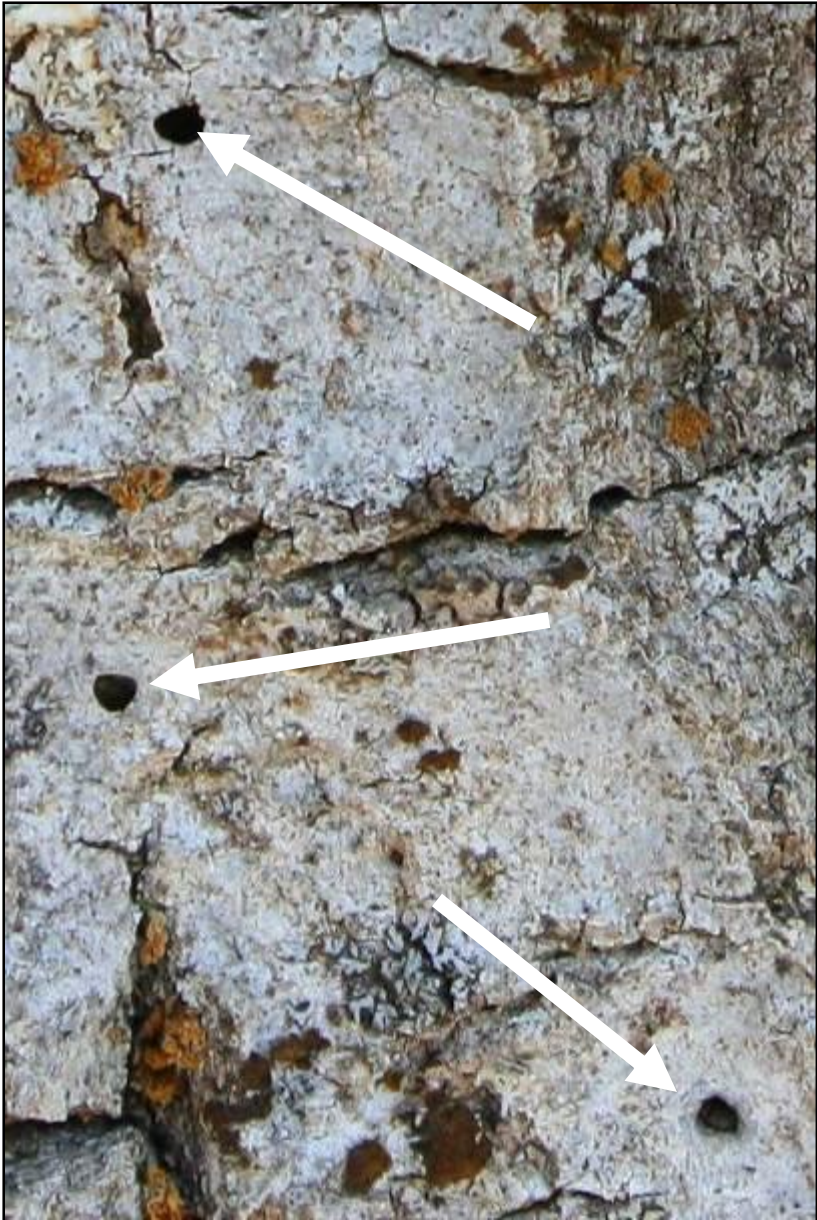
Sap stain on outer bark of several oak species



Signs/Symptoms: Woodpeckering and Bleeding Wounds



D-Shaped Emergence Holes and Galleries Beneath the Bark



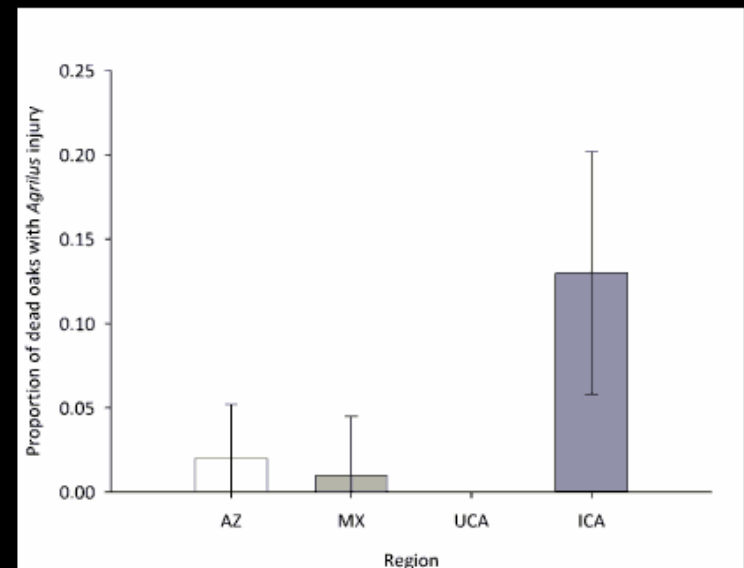
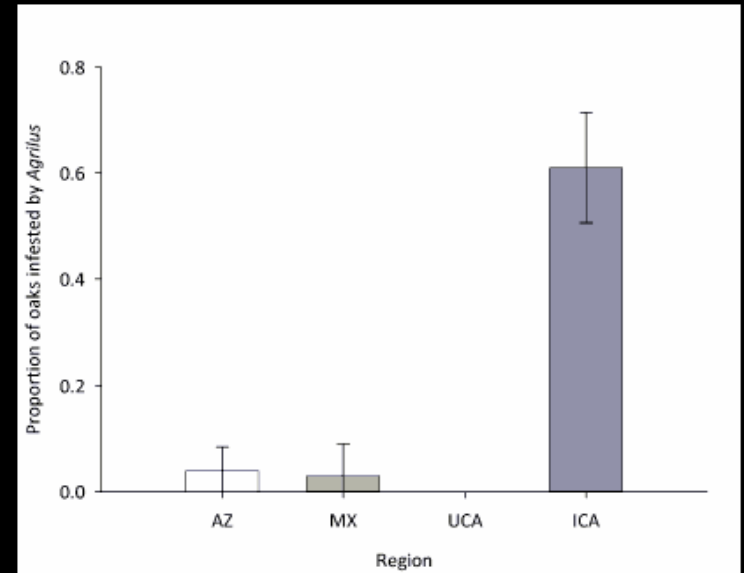
High density larval mining by GSOB in oak phloem





GSOB's impact in California

- Mean infestation rate
 - 61% in San Diego Co
 - <4% in AZ and MX
 - In CA, 90% infestation in areas with tree mortality for about a decade
- Mean oak mortality with GSOB injury
 - 13% in San Diego Co
 - <2% in AZ and MX
 - In CA, 50% in areas with tree mortality for about a decade



Southern California Oak Mortality





Aerial Detection of Southern California Oak Mortality



Distribution of Southern California Oak Mortality Documented Annually through Aerial Sketch Mapping (USDA Forest Service FHM, 2014)

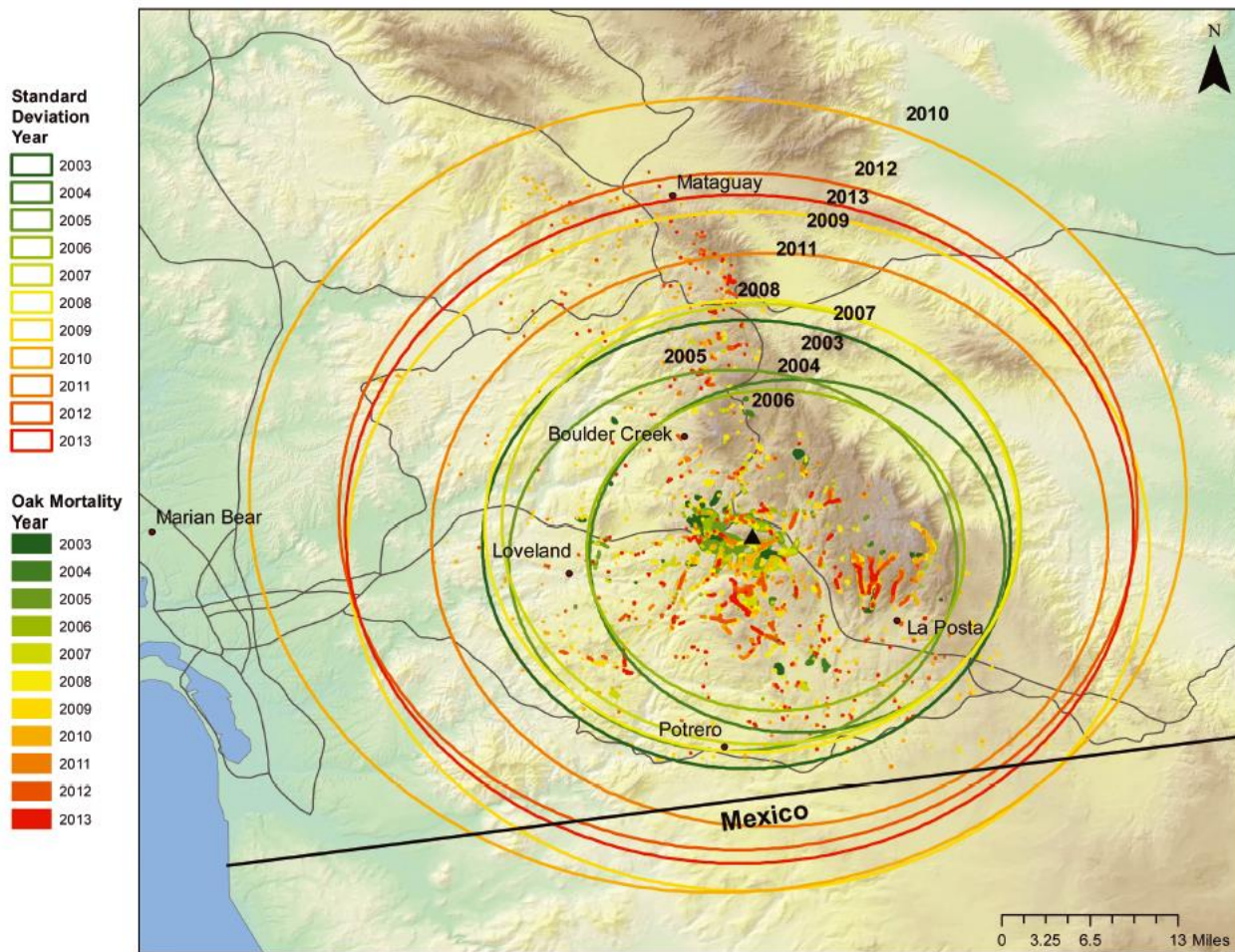


Figure 1 Location of research sites in southern California relative to the distribution of oak mortality documented annually by aerial sketch mapping (USDA Forest Service FHM, 2014) and modified from Coleman *et al.* (2012a). Large circles represent the standard distance, a measure of the degree that oak mortality was concentrated or dispersed around its geometric mean centre (i.e. the black triangle), and characterize the area potentially affected by *Agrilus auroguttatus* by year.



Laurel Haavik

Agricultural and Forest Entomology

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Goldspotted oak borer effects on tree health and colonization patterns at six newly-established sites

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- Abstract**
- 1 Newly-established populations of invasive wood-inhabiting insects provide an opportunity for the study of invasion dynamics and for collecting information to improve management options for these exotic species.
 - 2 From 2011 to 2013, we studied the dynamics of the goldspotted oak borer *Agrilus auripunctatus* Schaeffer (Coleoptera: Buprestidae), a new pest of oaks in southern California, at six sites that had been colonized recently.
 - 3 At all sites, the percentage of coast live oak *Quercus agrifolia* Née, colonized by *A. auripunctatus* increased between 2011 (6–35%) and 2013 (23–40%), although beetle densities did not grow rapidly at most sites.
 - 4 From 2011 to 2013, there were minor changes in signs and symptoms of *A. auripunctatus* infestation (adult emergence holes, bark staining, and evidence of woodpecker foraging), except at one site where an outbreak occurred. At some sites, noticeable negative changes in oak crown health occurred 1 year prior to positive *A. auripunctatus* population growth.
 - 5 Among sites, most of the *A. auripunctatus* population density (66–93%) was produced by a small number of heavily-infested trees (or brood trees). Early identification and removal of brood trees in newly-invaded areas could slow the growth of *A. auripunctatus* populations.

Keywords *Agrilus auripunctatus*, brood trees, insect population dynamics, invasion dynamics, newly-established invasive species, oak pest, per capita rate of increase.

Introduction

As the number of invasive alien species that are moving about the globe continues to increase, so does the number of invasive alien insects that feed beneath the bark of woody plants (Autena *et al.*, 2010). These insects are often moved inter- and intra-continents via wood-packing material or firewood (Hacker, 2006; Haavik *et al.*, 2010; Hertz & McCullough, 2010). Opportunities for studying invasive subterranean insects since they have caused extensive and noticeable damage to their new habitat are more frequent than opportunities for studying newly-established populations. Invasive borers may not be noticed for several years, possibly because founder populations are small, borers have cryptic habits and detection tends to be poor, or some combination of these factors. Nonetheless, researchers

have taken advantage of opportunities to study new populations of invasive borers (Mrosovsky *et al.*, 2009; Stegen *et al.*, 2010; Danks & Orwig, 2011; Fierke *et al.*, 2013), often using external symptoms on recently colonized trees to detect nascent infestations (Colley *et al.*, 2007; Danks *et al.*, 2010). Such studies enhance our understanding of the biology and ecology of invasive borers in their new habitats and can lead to the development of effective management strategies.

Goldspotted oak borer *Agrilus auripunctatus* Schaeffer (Coleoptera: Buprestidae), is a new invasive phloem- and wood-boring beetle in southern California (Coleman & Seybold, 2008, 2011). To date, *A. auripunctatus* has killed more than 25 000 oaks (mostly coast live oak *Quercus agrifolia* Née; California black oak *Quercus kelloggii* Newberry; and some canyon live oak *Quercus chrysolepis* (Lobman) in eastern San Diego County (Coleman *et al.*, 2012a; USDA Forest Service FHM, 2014). *Agrilus auripunctatus* is native to southeastern Arizona, where it feeds on Emory oak *Quercus emoryi* Torrey and silverleaf oak *Quercus hypoleucoides* A. Camus; and is likely

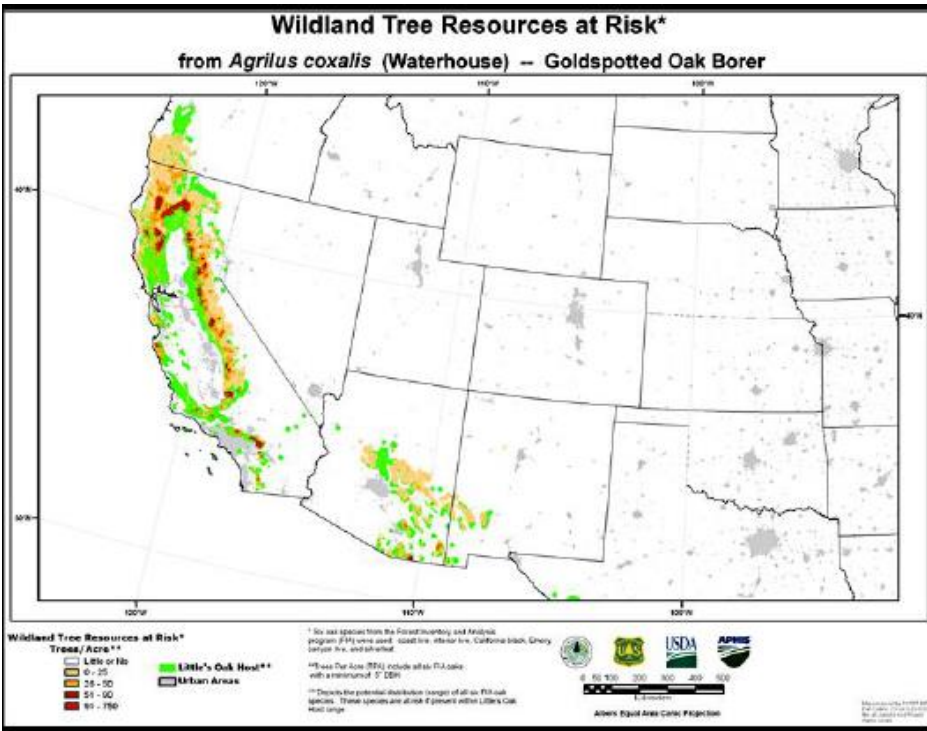
*Correspondence: Laurel J. Haavik. Tel.: +1 705 541 5636; fax: +1 705 541 5700; e-mail: lhaavik@ucdavis.edu
[†]Present address: Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario P6A 2E5, Canada.

GSOB Risk Assessment

Initial Risk Assessment, 2008/2009

Based on:

Range of Potential Hosts



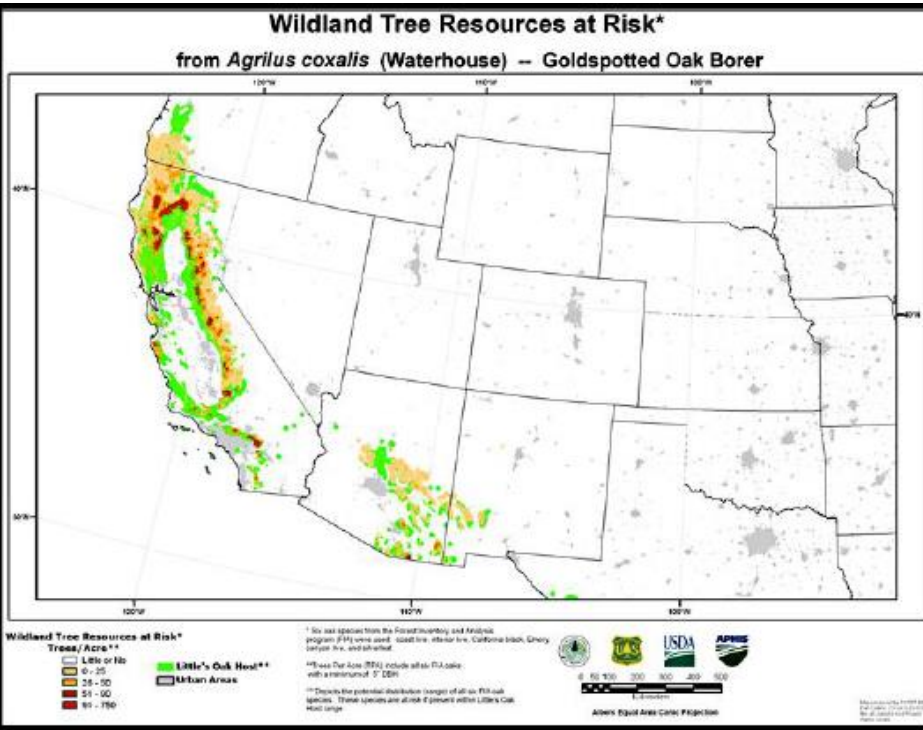
GSOB Risk Assessment

Initial Risk Assessment, 2008/2009



Rob Venette
USDA FS
Northern Res. Station
St. Paul, MN

Rob Venette



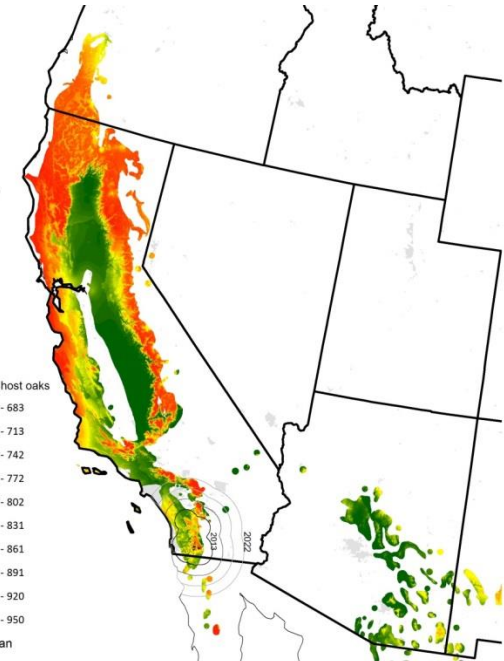
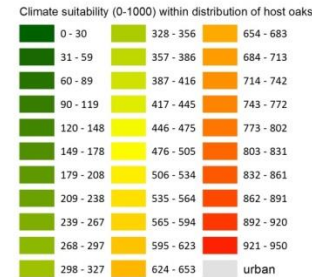
Advanced Risk Assessment, 2015

Based on:

- Temperature/Precipitation
- Freeze Tolerance
- Host Susceptibility
- Dispersal Capacity

Venette, R.C., Coleman, T.W., and Seybold, S.J. 2015. Assessing the risks posed by goldspotted oak borer to California and beyond, pp. 317-329, in R.B. Standiford and K.L. Purcell (tech. coords.). Proceedings of the Seventh California Oak Symposium: Managing Oak Woodlands in a Dynamic World. November 3-6, 2014, Visalia, California, USDA Forest Service General Technical Report, PSW-GTR-251, 579 pp.

Resources at Risk:
 Potential Spread of
 Goldspotted Oak Borer
 into Suitable Habitat



Resources at Risk:
Potential Spread of
Goldspotted Oak Borer
into Suitable Habitat

Climate suitability (0-1000) within distribution of host oaks

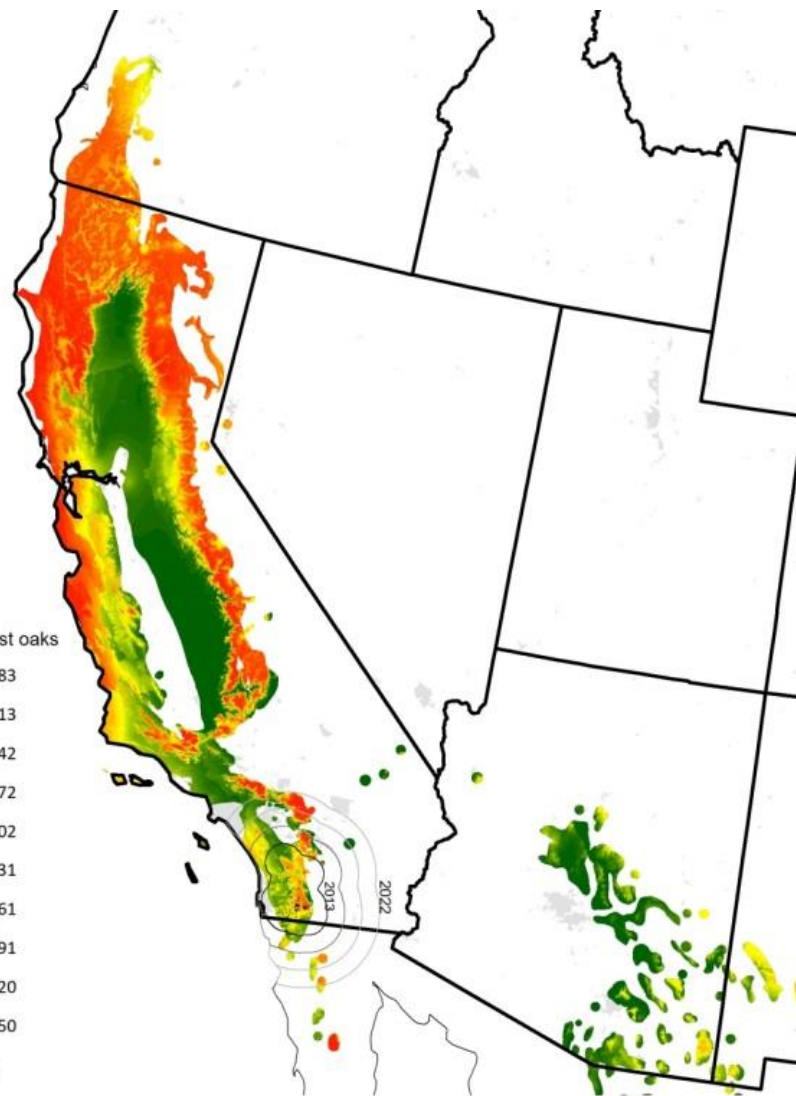


Figure 1—Composite risk map for *Agrilus auroguttatus* depicting the degree of climate suitability and potential extent of natural spread from 2013 – 2022 within the range of confirmed and suspected hosts. United States states outside New Mexico, Arizona, California, and Oregon are presumed to have little to no risk based the current understanding of host and climate requirements for this insect.

This flies faster than GSOB...



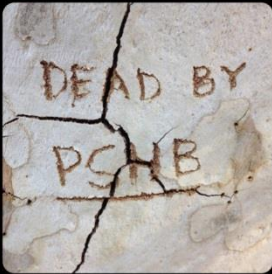
This flies faster than GSOB...
.....and further than GSOB!



Polyphagous Shot Hole Borer/Goldspotted Oak Borer Contrasting Overview

- I) Pathogenic fungi: PSHB-obligatory/GSOB-no role for fungi.**
- II) Source of invasion: PSHB-non-native invasive (Asia)/GSOB-native invasive (Southwest, AZ/NM).**
- III) Host range: PSHB-many hosts-all size classes/GSOB focused on large diameter red oaks.**
- IV) Spread/dispersal: PSHB-rapid innate spread/GSOB slower innate spread. The key to limiting future expansion of the invaded ranges of both species is preventing the movement of infested firewood.**

PSHB Management: Don't Move Infested Wood; Chip in Place



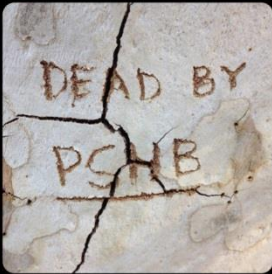
Sycamore, red willow, coast live oak, and boxelder were chipped into ~1 inch pieces

PSHB Management: Don't Move Infested Wood; Chip in Place



Sycamore, red willow, coast live oak, and boxelder were chipped into ~1 inch pieces

Chipping wood was >99% effective at killing PSHB



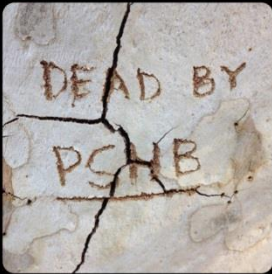
PSHB Management: Don't Move Infested Wood; Chip in Place



Sycamore, red willow, coast live oak, and boxelder were chipped into ~1 inch pieces



Chipping wood was >99% effective at killing PSHB



Beetles emerged from control wood pieces for 4 to 6 mo. after trees were cut and experiment was initiated



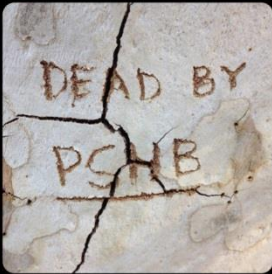
PSHB Management: Don't Move Infested Wood; Chip in Place



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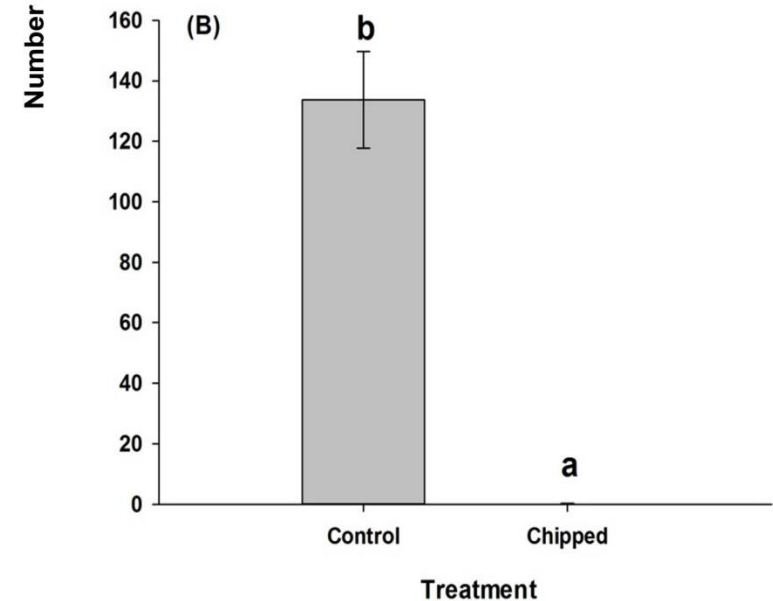
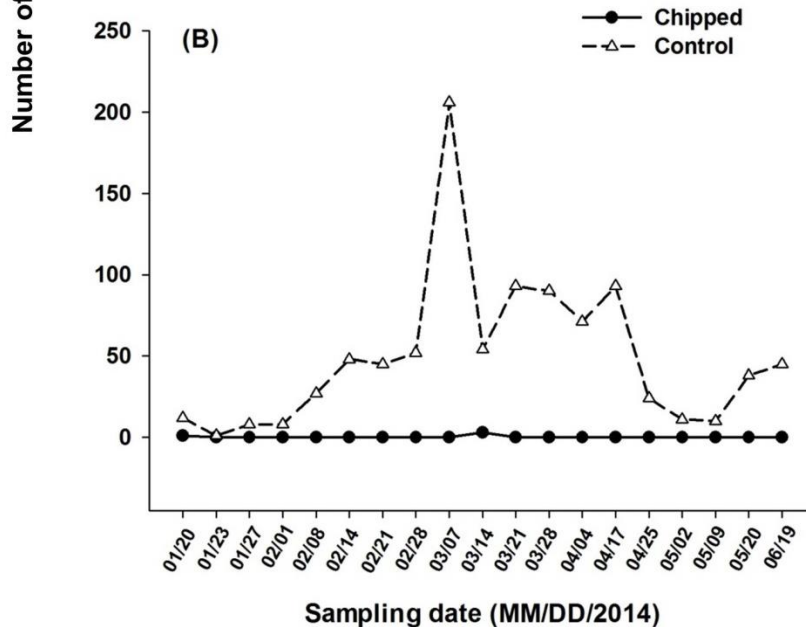
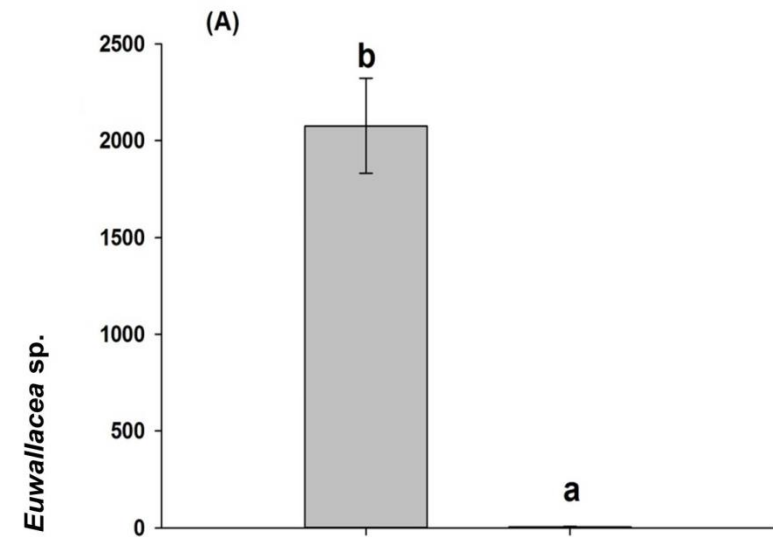
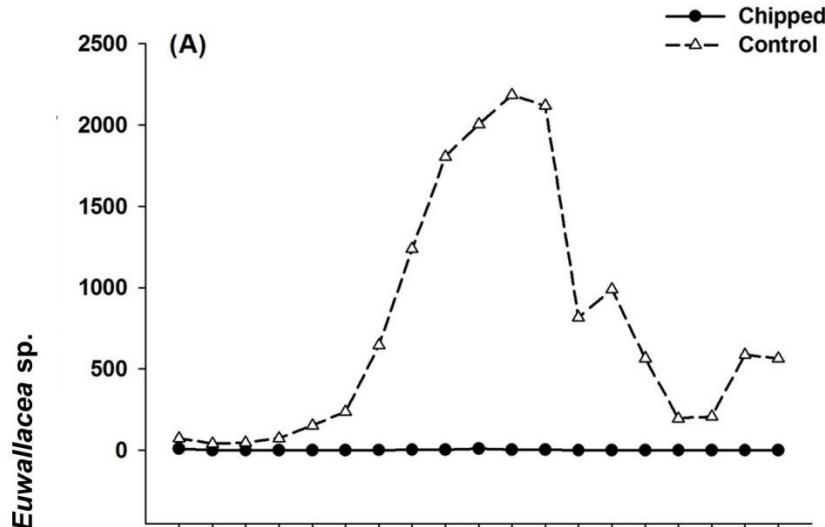


Female:male sex ratio was 90%

2014 : Effective Sanitation through Chipping

California sycamore, *Platanus racemosa*

Female

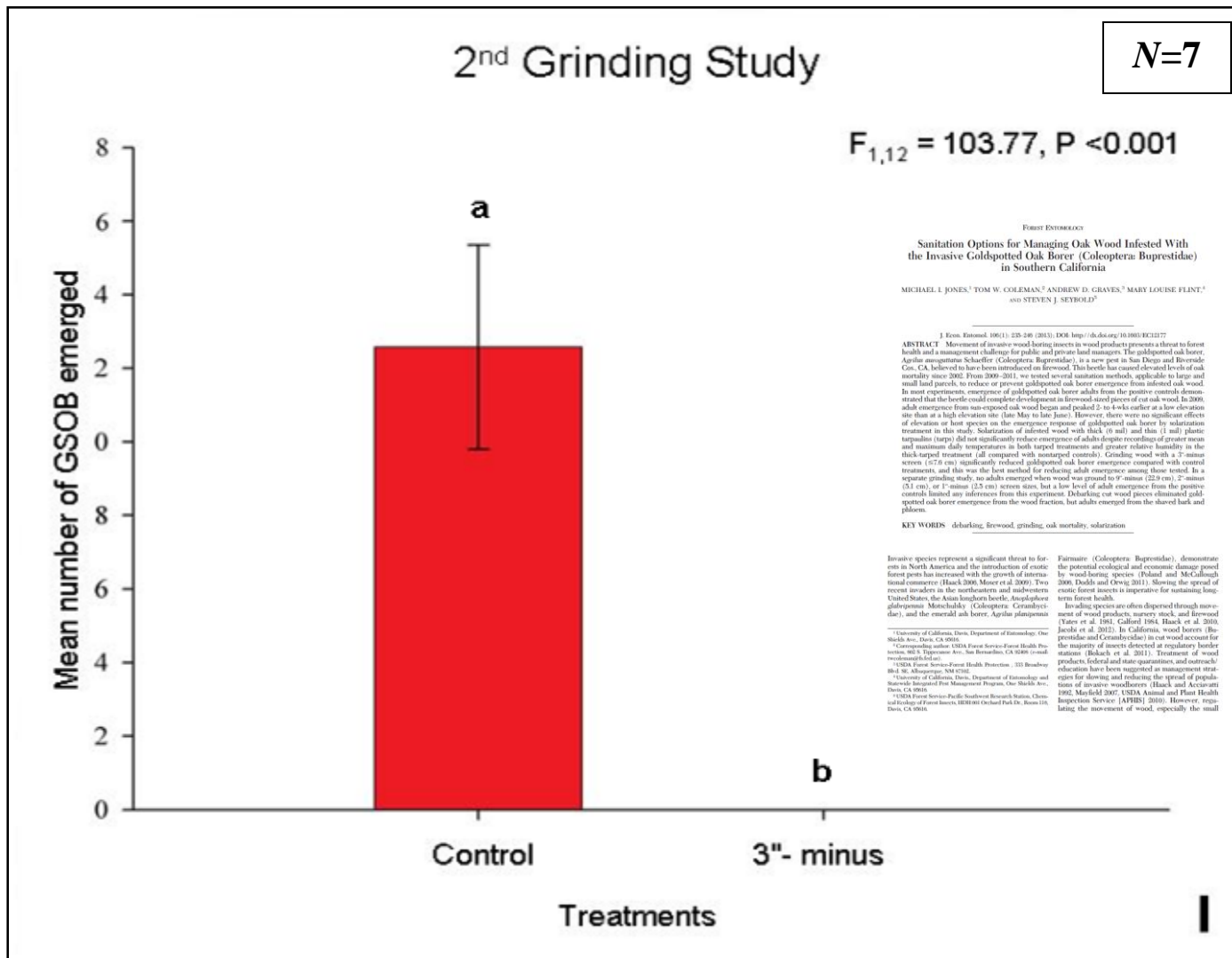


Male

Treatments: Management of Wood from Infested Areas

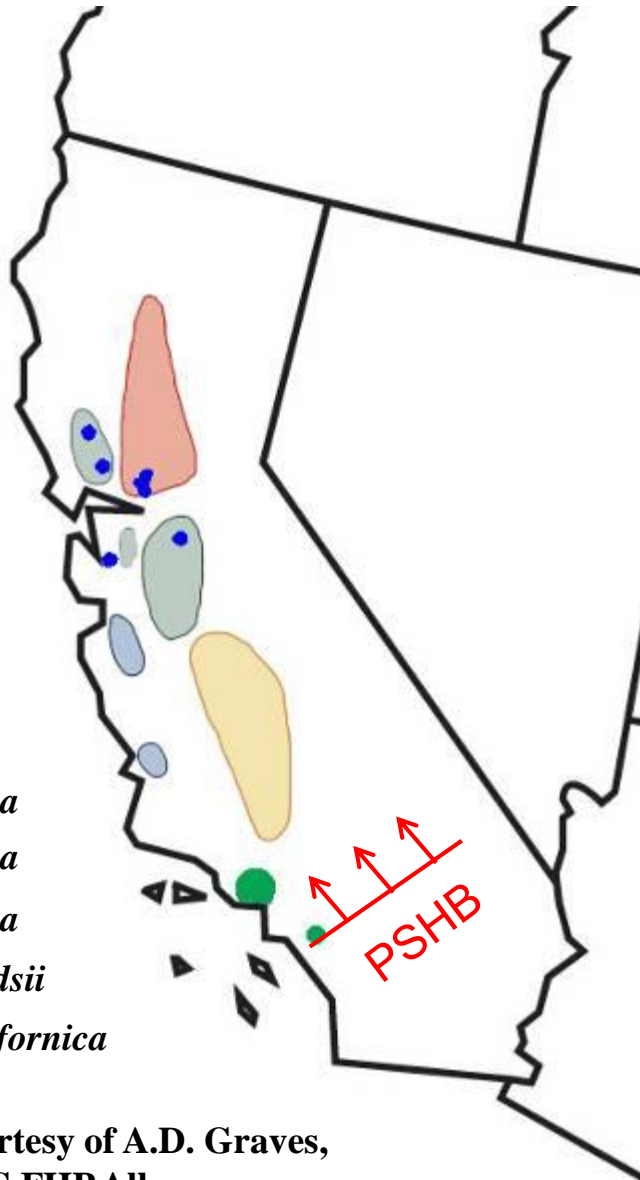







2011: Survival and Management of GSOB in Firewood (Grinding, 3" Pieces)



PSHB: What about the Central Valley?

Distribution of Walnuts in California



-  *J. regia*
-  *J. regia*
-  *J. regia*
-  *J. hindsii*
-  *J. californica*

Slide Courtesy of A.D. Graves,
USDA FS FHP Albuquerque

California

Annual Value of *J. regia* Nut Crop:
\$500 Million to \$1 Billion

Central Valley

A “carpet” of walnut,
almond, and pistachio trees

Doomsday Scenario?

We would rather not see what will happen to oaks if GSOB and SOD join forces



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USDA FS Forest Health Protection; WO, Forest Health Monitoring, and STDP Programs
USDA APHIS CPHST, Otis Lab
University of California ANR Grants Program
USDA NIFA SCRI Program



UC-IPM Resources

Goldspotted Oak Borer Field Identification Guide



Figure 1. Adult goldspotted borer. Photo by Stacy Blomquist, USDA Forest Service, Southern Research Station.



Figure 2. GSOB larva with close up of spiracles and spines. Photo by Stacy Blomquist, USDA Forest Service, Southern Research Station.



Figure 3. Mature larva in hairpin configuration. Photo by Tom W. Coleman.



Figure 4. Pupa in outer bark. Photo by Tom W. Coleman.

The goldspotted oak borer (GSOB), *Agrilus auroguttatus* (Coleoptera: Buprestidae), is a flatheaded borer new to California that poses a significant threat to oak trees. The pest is native to southeastern Arizona, although a related species occurs in southern Mexico and northern Guatemala. GSOB was first collected and identified in California in 2004 in San Diego County but was not linked to extensive oak mortality until 2008. As of 2010, GSOB has killed an estimated 21,500 trees covering 1,893 square miles in San Diego County in forests, parks, and residential landscapes.

GSOB larvae feed beneath the bark of certain oaks near the interface of the phloem and xylem, the nutrient and water conducting tissues of plants. The larvae damage both of these tissues as well as the cambium, a unicellular layer between the phloem and xylem that is responsible for the radial growth of the tree. Trees die after several years of injury inflicted by multiple generations of the beetle. Currently there are no effective tools for protecting trees once infestation occurs.

IDENTIFICATION

Capture of adult GSOB on sticky traps in infested areas of San Diego County and observations of immature life stages suggest that this pest completes one generation each year. Adults are about 0.4 inch long and 0.08 inch wide with a slender, bullet-shaped body (Figure 1) and are agile flyers. They are primarily black with an iridescent green sheen and have six gold-colored spots on their forewings, hence the common name.

Eggs are extremely small (0.01 inch), dull colored, and rarely observed on trees. They likely are laid singly or in clusters in bark cracks on the main stem and larger branches of oaks.

Larvae are white, legless, and about 0.8 inch long when mature (Figure 2). GSOB larvae can be distinguished from those of other wood boring beetles by C-shaped spiracles and two pincherlike spines on the end of their abdomen. Mature larvae can be found in a hairpin configuration in the outer bark (Figure 3) from early fall until early summer.

Pupae also are found in the outer bark from late spring to early summer; they resemble the adults in size and shape but are primarily white and soft bodied (Figure 4). When adult beetles emerge from the pupal cell in the bark, they make a diagnostic D-shaped emergence hole; see External Symptoms below. Adult GSOB feed on oak foliage and make notches along leaf margins (Figure 5), but tree mortality results from larval feeding. This pest is known to kill three species of native oaks in California; for more information, see the sidebar Which Oak Species Are Attacked? on Page 3.

University of California
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Statewide Integrated Pest Management Program



GOLDSPOTTED OAK BORER

Integrated Pest Management for Land Managers and Landscape Professionals

The goldspotted oak borer (GSOB), *Agrilus auroguttatus* (Coleoptera: Buprestidae), is a flatheaded borer introduced to San Diego County, California, in the late 1990s or early 2000s and also detected at one site in Riverside County in 2012. It was likely brought into the state on oak firewood collected and transported from the insect's native range in southeastern Arizona or northern Mexico. Although currently confined to San Diego and Riverside counties, this pest will likely invade other areas of California.

Since at least 2000, GSOB has caused extensive injury and mortality to oaks in woodlands and mixed-conifer forests in San Diego County. GSOB prefers mature oak trees but occasionally attacks smaller oaks with a diameter at breast height (dbh) of about 10 inches. It has rarely been recorded in oaks with a dbh of less than 5 inches. Trees with a dbh of 18 inches or greater are the most likely to be killed.

GSOB attacks only oaks and prefers those in the red oak group including coast live oak, *Quercus agrifolia*, and California black oak, *Q. kelloggii*. GSOB also infests canyon live oak, *Q. chrysolepis*, and on very rare occasions Engelmann oak, *Q. engelmannii*. Red oaks are a common component of forests throughout California, and species in this group are at risk throughout the state if GSOB spreads by adult flight dispersal or via human-assisted transport (e.g., in firewood) from its current locations.

Typical damage associated with GSOB-infested trees includes crown thinning and dieback, bark staining on the main stem, bark injury from woodpecker foraging, and D-shaped emergence holes on the main stem and larger branches of the tree. Following several years of extensive and repeated bouts of injury from larval feeding, tree health declines, and trees eventually die.



Figure 1. Dorsal and ventral views of the goldspotted oak borer. The slightly larger adult on the left is a female, whereas the adult on the right is a male, as identified by the groove located on the underside in the first segment of the abdomen and indicated by an arrow.



Figure 2. Tiny (less than 0.25 mm) eggs of the goldspotted oak borer laid in a crevice on the surface of coast live oak bark.

IDENTIFICATION

Adults are about 10 millimeters long and 2 millimeters wide with a bullet-shaped body typical of beetles in the Buprestid family. They are black or iridescent green with six gold-colored pubescent spots on the forewings and two gold-colored spots on the edge of the thorax. Females and males appear nearly identical, but females are generally larger (Figure 1). Adults are rarely observed on trees.

Eggs are very small (less than 0.25 mm in diameter), brown, oval, and are laid singly or in clusters on the bark surface or in



Figure 3. Life stages of the goldspotted oak borer. From left: fourth-instar larva, fourth-instar larva in a hairpin configuration and in a constricted form (both prepupal stages), pupa, and adult.

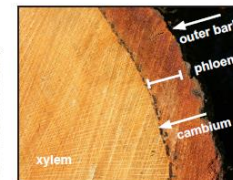


Figure 4. A cross-section of a coast live oak trunk. Goldspotted oak borer larvae feed primarily at the interface of the xylem and phloem. Pupae can be found in the outer bark and at the interface of the outer bark and the phloem.

fissures of the outer bark (Figure 2). Eggs are extremely difficult to locate on a tree.

Larvae are white, legless, and identifiable by C-shaped spiracles (breathing holes) along the side of the body wall and two pincherlike spines at the tip of the abdomen (Figure 3). When first hatched, larvae are about 2 millimeters long but grow to about 20 millimeters before maturing. Developing larvae feed under the bark and primarily at the interface of the xylem and phloem, girdling the cambium (Figure 4). Larvae are visible only if

PEST NOTES Publication 74163

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Agriculture and Natural Resources
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January 2013

Hishinuma, S. *et al.* (2011) Goldspotted Oak Borer: Field Identification Guide.
http://www.ipm.ucdavis.edu/PDF/MISC/GSOB_field-identification-guide.pdf

Flint, M.L. *et al.* (2013) Goldspotted Oak Borer Pest Note.
<http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74163.html>

Distribution of Oak Hosts for Goldspotted Oak Borer

Coast live oaks and California black oaks are naïve hosts for this pest



Coast live oak, Cleveland National Forest
San Diego Co.

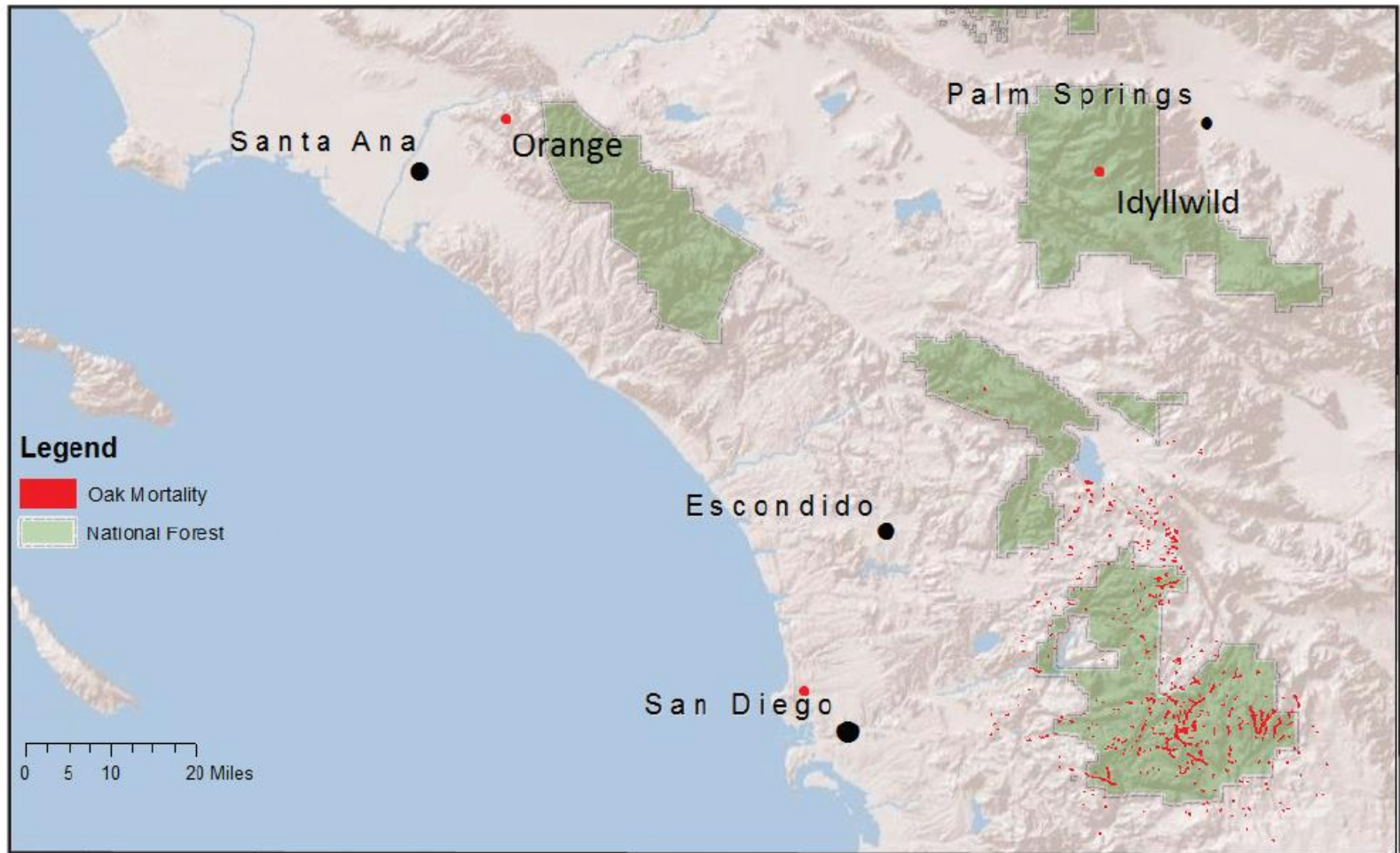
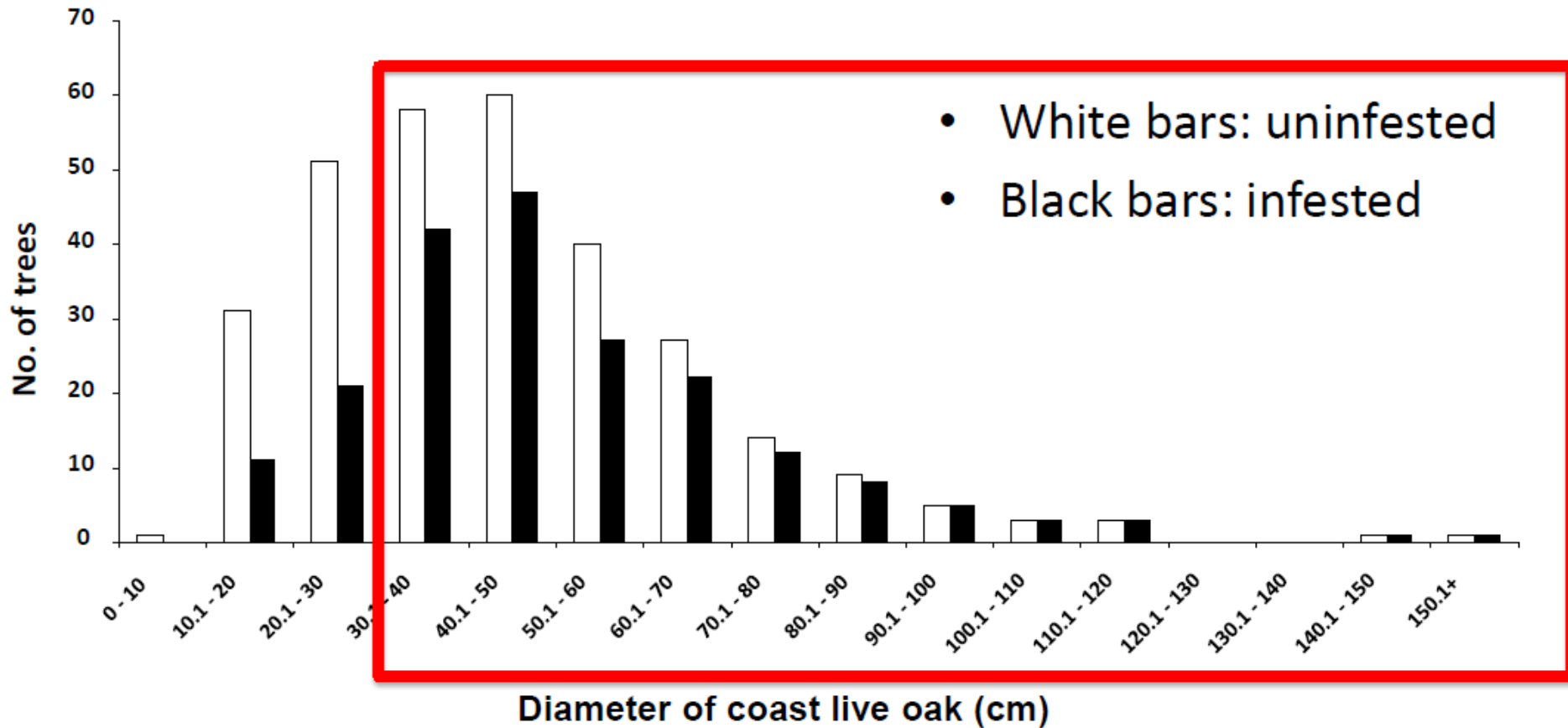


Figure 2. Aerially mapped oak mortality (red stippling) associated with the goldspotted oak borer in San Diego County in southern California (2002-2013). Disjunct infested areas (satellite populations indicated by ●) occur in San Diego County (San Diego); Riverside County (Idyllwild) and Orange County (Orange).

Coleman, T.W. et al. (2015) Goldspotted Oak Borer.

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf

Host size preference



- Larger size-classes preferred by GSOB

GSOB timeline in CA

