California Black Oak Forest Health Challenges

CA Black Oak and OR White Oak Woodland Ecology and Management Symposium
November 12, 2015

Steven J. Seybold
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Pacific Southwest Research Station
Davis, CA

Figure 83. Anthracnose symptoms on California black oak.

Photo: Bruce Hagen, CDF.

Forest Insects on California Black Oak?

WESTERN FOREST INSECTS

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and
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U.S. Department of Agriculture Forest Service

Quercus kelloggii (California black oak):
Twigs and small branches, on
Scale
Asterolecanium minus, 112
Quercus lobata (California white oak):
Foliage, on
Caterpillar
Phryganidia californica, 220
Twigs and small branches, on
Scales
Asterolecanium minus, 112
Kermes cockerelli, 120

FAMILY ASTEROLECANIIDAE—PIT SCALES

The body covering of the **pit scales** is membranous. Adult females have no legs. Some species feed in pits formed by swelling of plant tissue around them, hence their common name.

Asterolecanium contains about 150 species in the world (Russell 1941). Three species attacking oak have been introduced into California from Europe. The most abundant and damaging of these is *A. minus* Lindinger which attacks *Quercus lobata*, *Q. douglasii*, *Q. agrifolia*, and *Q. kelloggi* (Pritchard and Beer 1950). It can seriously weaken a tree by killing twigs and branches. Such killing shows up in late summer.

There is one generation a year. Emergence of the crawlers begins in late April and continues until late September. Pits are formed where they settle and feed. Males are unknown. Chemical control is effective from late April until early June (Koehler 1964).

A bit of a "backwater"

Forest Pathogens on California Black Oak?

DISEASES
OF FOREST AND
SHADE TREES OF
THE UNITED STATES

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE · AGRICULTURE
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386

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July 1971

In California the foliage of *Quercus kelloggii* and some other oaks is occasionally very severely attacked by *Septoria quercicola*. It produces small, angular, dead spots visible on both sides of a leaf. Branches may be bare of leaves by the end of August.

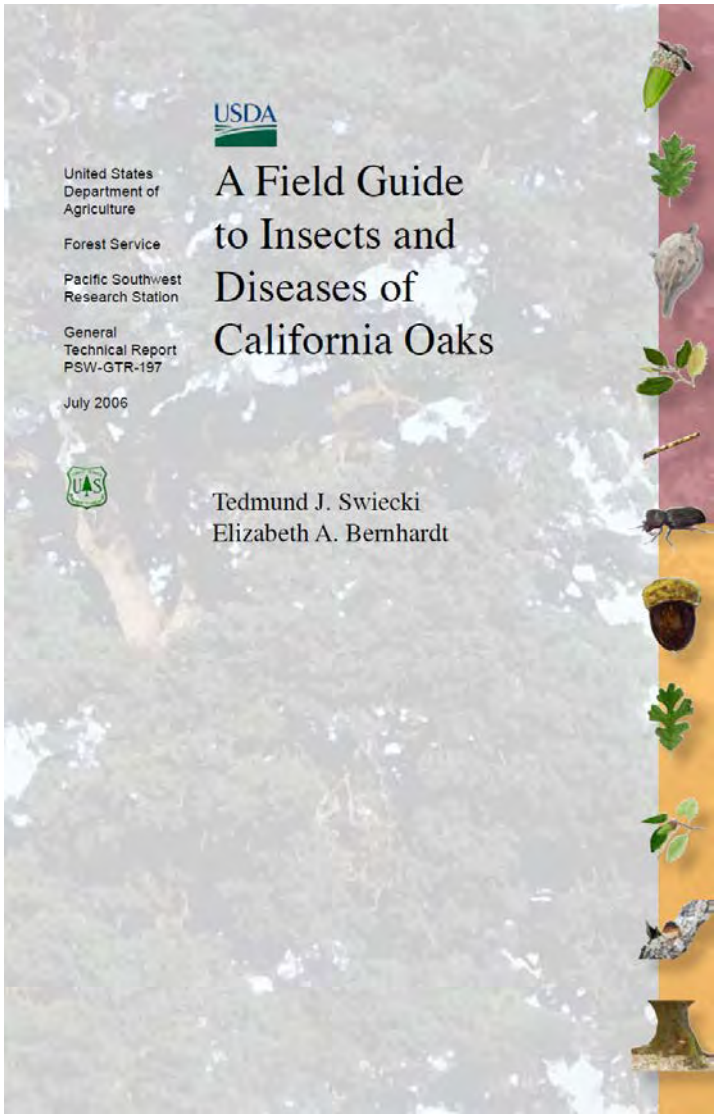
Late in the growing season oak foliage may be spotted by many fungi. Thus, discrete spots have been attributed to several species of *Phyllosticta*, and dead leaves on the ground in the spring often bear perithecia of *Mycosphaerella* spp., notably *M. maculiformis* but others also. It is likely that some of the *Phyllosticta* spp. are spermatial stages of the *Mycosphaerella* spp.

Figure 83. Anthracnose symptoms on California black oak.

Photo: Bruce Hagen, CDF.

Also, a bit of a "backwater"

How Times Have Changed



Sudden Oak Death

Goldspotted oak borer

Forest Health Challenges to California Black Oak

I) Insects

A) Phloem feeders: Oak bark (and ambrosia) beetles

B) Phloem feeders: Goldspotted oak borer

C) Defoliators: Fruit tree leafroller

II) Pathogens

A) Stem cankers: *Phytophthora ramorum* and sudden oak death

B) Root diseases: *Armillaria mellea/gallica-Armillaria* root rot

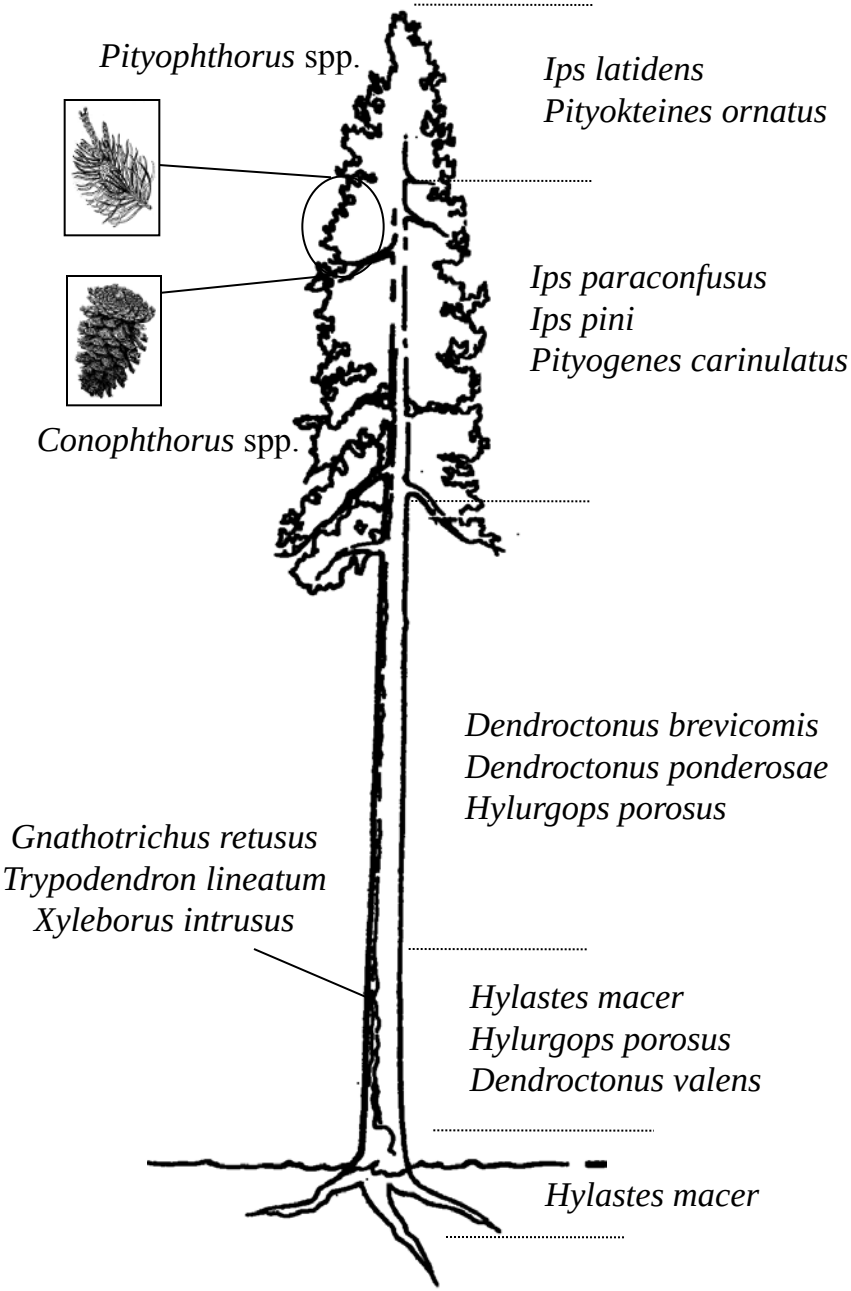
C) Foliage (twig) diseases: *Apiognomonia errabunda* and oak anthracnose

Impacts of Feeding Groups of Forest Insects

Table 2. Ranking insect feeding guilds (with select examples) according to their potential impact on host plant fitness.

Herbivore guild	Potential impact on host growth and reproduction
Gall formers: leaves Cynipidae, Cecidomyidae, Psyllidae	Least
Gall formers: twigs/stems Adelgidae, Cynipidae	
Folivores: end of season or prior-year's leaves Diprionidae	
Folivores: beginning of season/current year leaves Geometridae, Lasiocampidae, Lymantriidae, Tortricidae	
Sap feeders: leaves/twigs/branches Aphididae, Coccidae, Diaspididae	
Phloem/sapwood/pith borers: twigs/branches/shoots Buprestidae, Cerambycidae, Curculionidae, Olethreutidae	
Root sap feeders Cicadidae	
Root free feeders Curculionidae, Scarabacidae	
Folivores: middle-late season Arctiidae, Lymantriidae, Notodontidae, Saturniidae	
Folivores: both current and prior year's leaves Diprionidae, Lymantriidae	
Sap feeders: stem phloem/xylem Aphididae, Coccidae, Diaspididae	
Phloem/cambium/sapwood borers: root and root crown Buprestidae, Curculionidae, Scolytidae	
Phloem/cambium/sapwood borers: main stem Buprestidae, Cerambycidae, Sesiidae, Scolytidae	Most

From: Mattson, W.J. *et al.* (1988) Defensive strategies of woody plants against different insect feeding guilds in relation to plant ecological strategies and intimacy of association with insects, *In*: W.J. Mattson, J. Levieux, and C. Bernard-Dagan, eds., *Mechanisms of Woody Plant Defenses Against Insects, Search for Pattern*, pp. 1-38, Springer-Verlag, New York.



GSOB: The Entomological Context in California
Bark and Woodboring Insects Associated with Declining Oaks

Species	Feeding Group	Significance (Early vs. Late in Decline Cycle)
Agrilus auroguttatus	Goldspotted oak borer, phloem and outer xylem of stems and branches	**Highly significant, early**
Pseudopityophthorus pubipennis/ agrifoliae	Oak bark beetles, phloem of stems and branches	Moderately significant, can be early on seriously weakened trees
Monarthrum dentiger/scutellare	Oak ambrosia beetle, xylem of stems and branches	Moderately significant, late—stem breakage of SOD infected trees
Gnathotrichus pilosus	Oak ambrosia beetle, xylem of stems and branches	Moderately significant, late—stem breakage of SOD infected trees
Chrysobothris femorata/mali	Flatheaded borers, bark and outer xylem of stems and branches	Not significant, late, important for wood decomposition
Agrilus angelicus	Pacific oak twig girdler, xylem of small branches and twigs	Not significant, early, but attacks peripheral portions of tree
Scobicia declivis	Lead cable borer, xylem of stems and branches	Not significant, late, important for wood decomposition
Xylotrechus nauticus	Oak cordwood borer, phloem and xylem of stems and branches	Not significant, late, important for wood decomposition
Phymatodes lecontei/decussatus	Roundheaded borers, phloem and xylem of dying branches/stem	Not significant, late, important for wood decomposition

Brown and Eads (1965) California Agricultural Experiment Station Bulletin 810;

Furniss and Carolin (1977) USDA FS Misc. Publ. 1339; Coleman and Seybold (2008) *Pan-Pac. Entomol.* 84:288

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Exotic/ Aggressive

Brown and Eads (1965) California Agricultural Experiment Station Bulletin 810;

Furniss and Carolin (1977) USDA FS Misc. Publ. 1339; Coleman and Seybold (2008) *Pan-Pac. Entomol.* 84:288

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Native/Opportunistic

Brown and Eads (1965) California Agricultural Experiment Station Bulletin 810;
Furniss and Carolin (1977) USDA FS Misc. Publ. 1339; Coleman and Seybold (2008) *Pan-Pac. Entomol.* 84:288

Western Oak Bark Beetles

Pseudopityophthorus spp.

Distribution/Hosts

Pseudopityophthorus pubipennis is reported throughout California from the coast to the western slopes of the Sierra Nevada and Cascade Range. It occurs north to southern British Columbia, at least in the coastal zone. It is common on various oaks, including coast live, California black, and Oregon white oak, but has also been reported on tanoak, chestnut, and California buckeye.

P. agrifoliae is reported from at least Marin to Los Angeles County on coast live, California black, and canyon live oak. Both *P. agrifoliae* and *P. pubipennis* are often very abundant in oak firewood.

P. pruinosus (=*P. pulvereus*) is reported as uncommon in southern California, and occurs on various oaks. *P. pruinosus* also occurs in Arizona, Texas, Mexico, and some states in the eastern U.S.

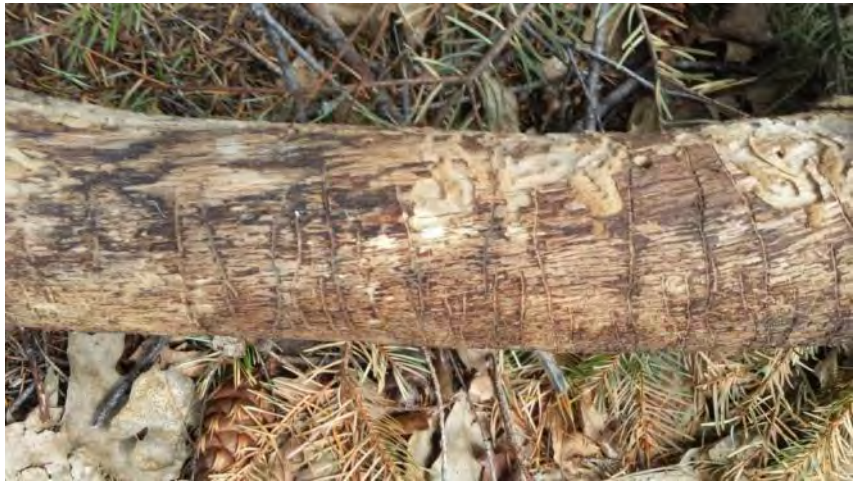

Figure 59 (left). Boring dust on bark of coast live oak resulting from infestation by bark beetles (darker brown dust) and ambrosia beetles (lighter boring dust).

Figure 60 (right). White ooze associated with oak bark beetle attack.

Photo: Don Owen, CDF.

F–523484

FIGURE 235.—Egg galleries of the western oak bark beetle (*Pseudopityophthorus pubipennis*).

Foamy Bark Canker = Mass Attack of Western Oak Bark Beetles + *Geosmithia pallida*

***Geosmithia* has been isolated from:**

—Coast live oak
—Interior live oak

Likely will be isolated from California black oak

Pest Alert

***Geosmithia pallida* and Western Oak Bark Beetle (*Pseudopityophthorus pubipennis*) Causing Foamy Bark Canker Disease on Coast Live Oak (*Quercus agrifolia*) in California**

Shannon Lynch, Paul Rugman-Jones, Richard Stouthamer, and Akif Eskalen
Departments of Plant Pathology and Microbiology and Entomology, University of California, Riverside

Declining coast live oak (*Quercus agrifolia*) trees have recently been found throughout urban landscapes in Los Angeles, Orange, Riverside, Santa Barbara, Ventura and Monterey counties. The fungal species *Geosmithia pallida* was recovered from symptomatic plant tissues in association with the western oak bark beetle *Pseudopityophthorus pubipennis* (Coleoptera: Curculionidae: Scolytinae). Pathogenicity tests on detached shoots showed that *G. pallida* is pathogenic to coast live oak seedlings and produced symptoms of foamy canker.

Symptoms: Symptoms occurring on the trunk and primary branches include wet discoloration seeping through entry holes caused by the western oak bark beetle (*Pseudopityophthorus pubipennis*). Peeling back of the outer bark reveals phloem necrosis surrounding the entry hole, and multiple entry holes may be observed on each tree. As the disease advances, a reddish sap may ooze from the entry hole, followed by a prolific foamy liquid. This foamy liquid may run as far as 2 feet down the trunk.

The beetle: Western oak bark beetle is a small beetle that burrows through the bark, excavating shallow tunnels under the bark across the grain of the wood. Female beetles lay their eggs in the tunnels; the developing larvae tunnel at right angels to these, but mostly within the phloem (inner bark) close to the surface (Costello et al 2012).

***Note:* Symptoms may be confused with those caused by Fusarium Dieback/Polyphagous Shot Hole Borer (PSHB).**

The size of the entry hole associated with foamy canker is smaller than that made by the PSHB.

Who to contact if you find the problem:

If you suspect that you have found these symptoms of the foamy canker on your tree please contact either your local farm advisor, pest control advisor, county Ag Commissioner office or Dr. Akif Eskalen akif.eskalen@ucr.edu. For more information visit www.eskalenlab.ucr.edu.

Fig. 1. Branch die back symptoms of foamy canker disease

Fig. 2. A Cinnamon colored gum, followed by a creamy, foamy sap, running down the bark.

Fig. 3. Brown discolored canker caused by the fungus on the bark.

Fig. 4. Brown canker caused by the fungus in the bark.

http://ucanr.edu/sites/socaloakpests/files/189274.pdf

Oak Ambrosia Beetles

Monarthrum spp., *Xyleborinus* spp., *Xyleborus* spp., *Gnathotrichus* spp.

Figure 56. Detail showing ambrosia beetle larval tunnels branching from the end of the main entrance tunnel excavated by the adult male.

Figure 57. *Monarthrum scutellare* adult beetle.

Photo: Jack Kelly Clark, courtesy UC Statewide IPM Program

Oak Ambrosia Beetles

Monarthrum spp., *Xyleborinus* spp., *Xyleborus* spp., *Gnathotrichus* spp.

Figure 54. White boring dust produced by ambrosia beetles on the surface of a tanoak infected with *Phytophthora ramorum*.

Figure 55. Broken trunk of a failed coast live oak that was killed by *Phytophora ramorum* (sudden oak death) shows a very high density of ambrosia beetle galleries. Although ambrosia beetle galleries are common in trees with this disease, only some trees show such high gallery densities.

Goldspotted Oak Borer, *Agrilus auroguttatus*

An Invasive Pest of Coast Live Oak, California Black Oak, and Canyon Live Oak in Southern California

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.**

UC-IPM Resources

Goldspotted Oak Borer

Field Identification Guide

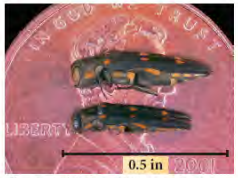

Figure 1. Adult goldspotted borer. Photo by Stacy Blomquist, USDA Forest Service, Southern Research Station.

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.

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Agriculture and Natural Resources
Statewide Integrated Pest Management Program

UC IPM

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

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

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.

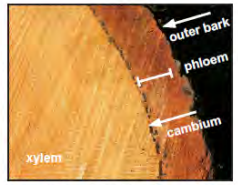

Figure 4. A cross-section of a coast live oak trunk. Goldspotted oak borer larvae feed primarily at the interface of the xylem and phloem. Pupae can be found in the outer bark and at the interface of the outer bark and the phloem.

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

University of California
Agriculture and Natural Resources
Statewide Integrated Pest Management Program

January 2013

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

USDA FS Resources

Pest Alert

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.

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

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.

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

FID

Forest Insect & Disease Leaflet 183

March 2015

U.S. Department of Agriculture • Forest Service

Goldspotted Oak Borer

T.W. Coleman[1], M.I. Jones[2], S.L. Smith[3], R.C. Venette[4], M.L. Flint[5], and S.J. Seybold[6]

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).

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 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).

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Coleman, T.W. *et al.* (2015) Goldspotted Oak Borer.
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf

GSOB: Awareness Began in May/June 2008

THE PAN-PACIFIC ENTOMOLOGIST
84(4):288–300, (2008)

Previously unrecorded damage to oak, *Quercus* spp., in southern California by the goldspotted oak borer, *Agrilus coxalis* Waterhouse (Coleoptera: Buprestidae)

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Abstract. A new and potentially devastating pest of oaks, *Quercus* spp., has been discovered in southern California. The goldspotted oak borer, *Agrilus coxalis* Waterhouse (Coleoptera: Buprestidae), colonizes the sapwood surface and phloem of the main stem and larger branches of at least three species of *Quercus* in San Diego Co., California. Larval feeding kills patches and strips of the phloem and cambium resulting in crown die back followed by mortality. In a survey of forest stand conditions at three sites in this area, 67% of the *Quercus* trees were found with external or internal evidence of *A. coxalis* attack. The literature and known distribution of *A. coxalis* are reviewed, and similarities in the behavior and impact of this species with other tree-killing *Agrilus* spp. are discussed.

Key Words. *Agrilus coxalis*, California, flatheaded borer, introduced species, oak mortality, *Quercus agrifolia*, *Quercus chrysolepis*, *Quercus kelloggii*, range expansion.

INTRODUCTION

Extensive mortality of coast live oak, *Quercus agrifolia* Née (Fagaceae), Engelmann oak, *Quercus engelmannii* Greene, and California black oak, *Q. kelloggii* Newb., has occurred since 2002 on the Cleveland National Forest (CNF) in San Diego Co., California. Hardwood (primarily oak) mortality was aerially mapped across 6447 ha and has impacted an estimated 17000 trees on the Descanso Ranger District of the CNF (USDA Forest Service, Pacific Southwest Region (R5), Forest Health Monitoring 2009). *Quercus* spp. mortality has also been evident on state, private, and Native American lands adjacent to the CNF. Without a clear causal agent (Bohne and Rios 2006—2008), this phenomenon of oak mortality has been known among forest health specialists and local residents as "oak croak."

Several evergreen and deciduous oaks are dominant or co-dominant canopy species in southern oak woodlands of California. *Quercus agrifolia* is commonly found below 1200 m in coastal foothills, valleys, and canyons. *Quercus engelmannii* is found inland in foothills below 1200 m. Canyon live oak, *Quercus chrysolepis* Liebm., is widely distributed in canyons, moist slopes, and flats below 2000 m. On the CNF, *Quercus kelloggii* is found further upslope (1219–1828 m) in co-dominant canopy positions with Jeffrey pine, *Pinus jeffreyi* Grev. & Balf. (Pinaceae).

Initial attempts to explain the causes of mortality among southern California oaks focused on *Phytophthora ramorum* S. Werres, A.W.A.M. de Cock & W.A. Man In't Veld, 2001, the causal agent of sudden oak death and significant tree mortality in coastal areas of northern and central California. However, no evidence of *P. ramorum* was detected at these sites (P.A. Nolan, County of San Diego, personal

Pest Alert

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.

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

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.

GSOB timeline in CA

GSOB found in Green Valley (Los Angeles Co.) **Aug. 2015**

GSOB found in Orange/Weir Cyn (Orange Co.) **2015**

GSOB research: insecticides, fuel impacts

2014

GSOB research: insecticides, trap development, risk assessment, fuel impacts

GSOB found in Idyllwild (Riverside Co.) **2013**

2012 “ “

2011 “ “

2010 GSOB research: biology, managing infested wood, insecticides, trap development, biocontrol, risk assessment

2009 Research on GSOB biology and detection efforts begin

2008 Tree mortality linked to GSOB and nothing known about the species

2002 Tree mortality begins-dismissed as drought

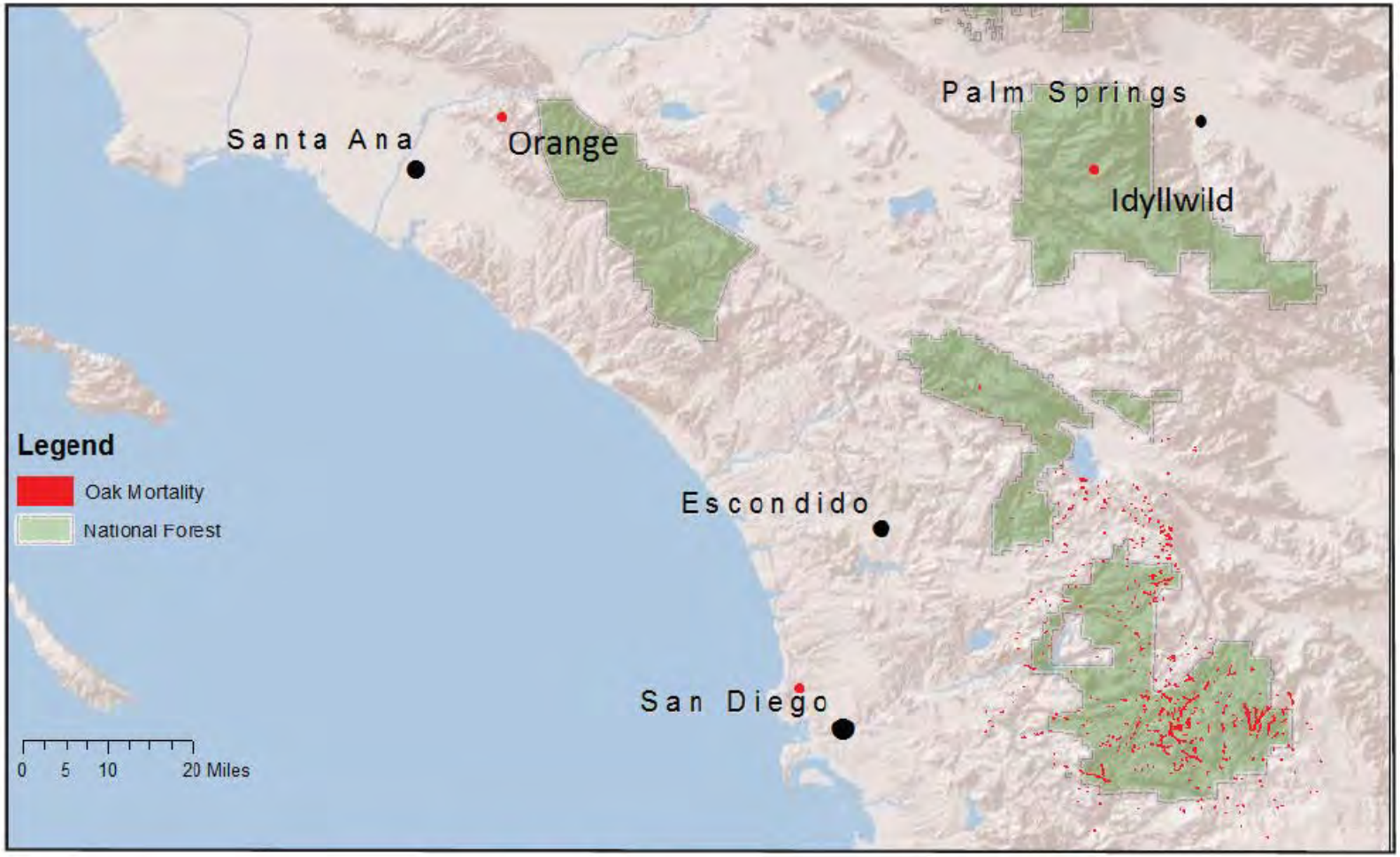


Figure 2. Aerially mapped oak mortality (red stippling) associated with the goldspotted oak borer in San Diego County in southern California (2002-2013). Disjunct infested areas (satellite populations indicated by ●) occur in San Diego County (San Diego); Riverside County (Idyllwild) and Orange County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

Coleman, T.W. *et al.* (2015) Goldspotted Oak Borer.
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf

Goldspotted Oak Borer: Connections to California Black Oak

I) GSOB attacks and kills California black oak at high elevation sites in San Diego County (Laguna Mountain, north slopes of Mount Palomar) and Riverside County (Idyllwild)

Goldspotted Oak Borer: Connections to California Black Oak

I) **GSOB attacks and kills California black oak at high elevation sites in San Diego County (Laguna Mountain, north slopes of Mount Palomar) and Riverside County (Idyllwild)**

II) **California black oak appears to be more sensitive to attack by GSOB than coast live oak, *e.g.*, dead black oaks have fewer emergence holes (30-100) than coast live oaks (300-1000) (T.W. Coleman pers. observ.)**

Goldspotted Oak Borer: Connections to California Black Oak

I) **GSOB attacks and kills California black oak at high elevation sites in San Diego County (Laguna Mountain, north slopes of Mount Palomar) and Riverside County (Idyllwild)**

II) **California black oak appears to be more sensitive to attack by GSOB than coast live oak, *e.g.*, dead black oaks have fewer emergence holes (30-100) than coast live oaks (300-1000) (T.W. Coleman pers. observ.)**

III) **GSOB adults have a preference for feeding on the foliage of California black oak**

Adults feed on foliage; larvae feed on phloem

GSOB mature larva

May 2008

4 mm

High density larval mining by GSOB in oak phloem

Sap stain on outer bark of several oak species

Symptoms: Woodpeckering and Bleeding Wounds

D-Shaped Emergence Holes and Galleries Beneath the Bark

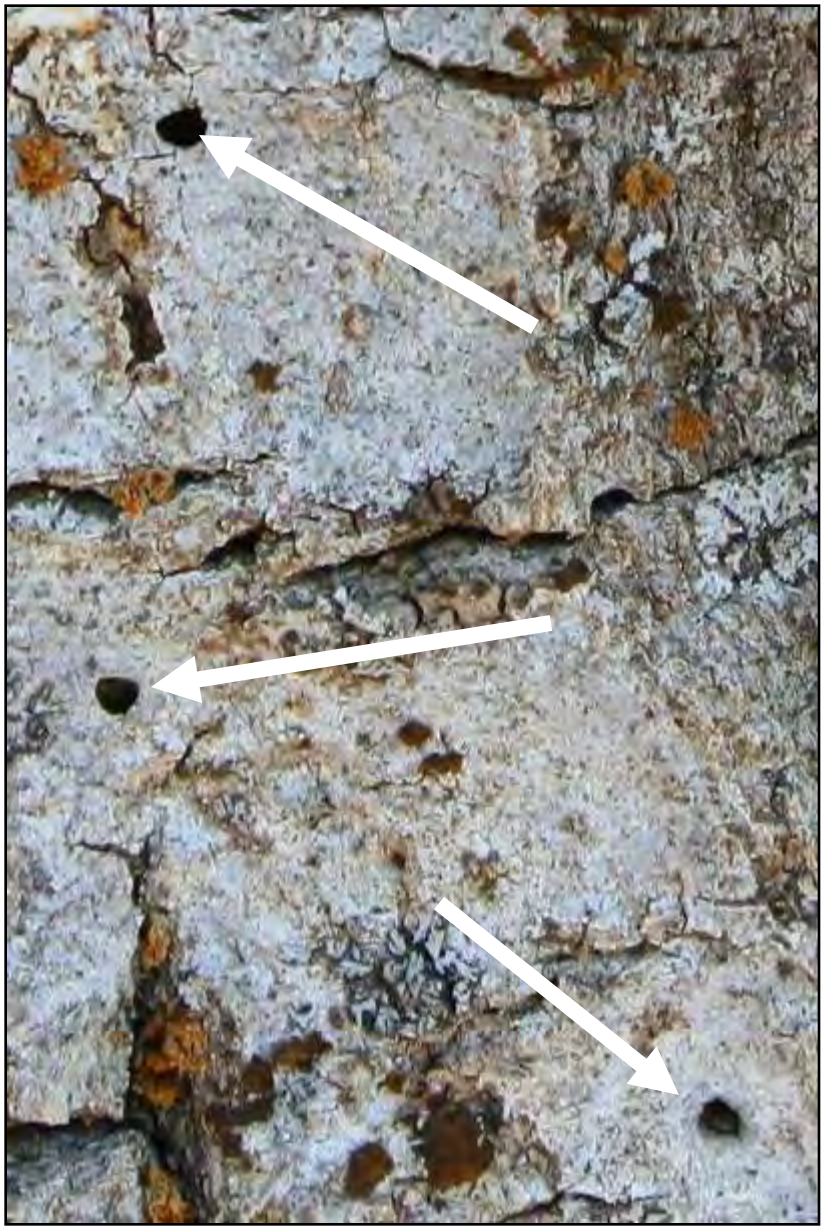


Table 1. Common Borers on Southern California Oaks and their Emergence Holes.

Family	Species	Emergence hole		Injury location
		Shape	Size*	
Beetles (Coleoptera)				
Bostrichidae (false powderpost beetles)	*Scobicia declivis* (lead cable borer)	round 	4 d	Common on smaller branches less than 5 inches in diameter.
Buprestidae (flatheaded borers)	*Agrilus auroguttatus* (goldspotted oak borer)	D-shape 	4 w	Located primarily on the lower trunk. Can reach high densities.
	Chrysobothris species (appletree and related borers)	oblong/ crescent 	5–13 w	Common on the trunk and larger branches.
Cerambycidae (roundheaded borers)	*Xylotrechus nauticus* (oak cordwood borer)	oval 	6–10 w	Common on the main trunk, especially around wounds from mechanical damage or fire.
Scolytidae (bark and ambrosia beetles)	*Monarthrum* species, *Gnathotrichus pilosus* and *Xyleborinus saxeseni* (ambrosia beetles)	round 	< 2 d (pen-tip sized)	Frequently on the main stem.
	Pseudopityophthorus species (western oak bark beetle)	round 	> 1 d (pin sized)	Most common on smaller branches.
Moths (Lepidoptera)				
Sesiidae (clearwing moths)	*Synanthedon resplendens* (western sycamore borer)	round 	5–6 d	In bark cracks near deteriorated bark and phloem.

*In millimeters, with *w* representing width and *d* diameter.

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

GSOB injury symptoms

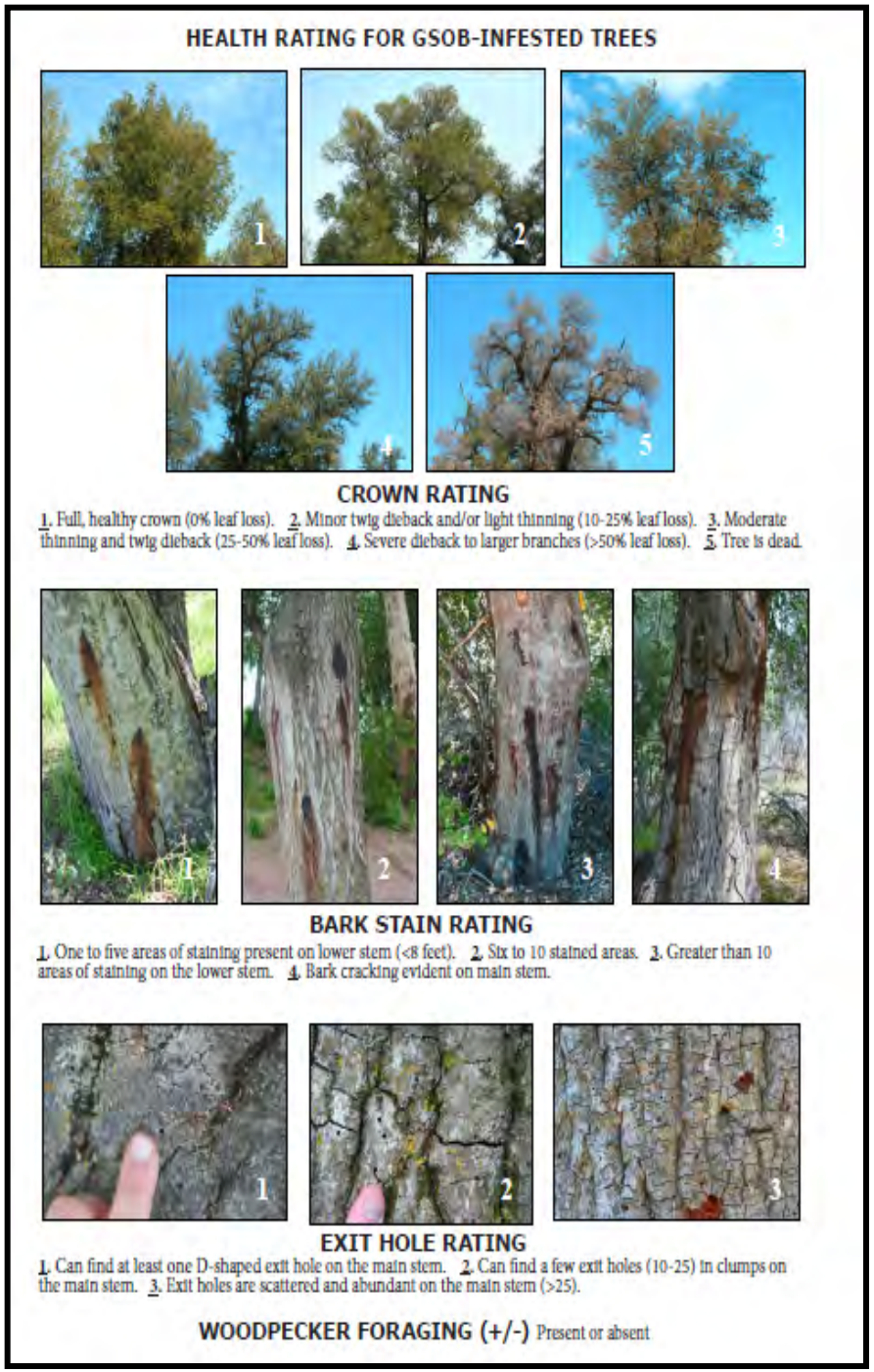
Oak Health Rating System Based on Symptoms of Injury from GSOB

–Crown condition (3 or greater)

–Number/density of emergence holes (3)

–Bark staining

–Presence/absence of woodpecker damage

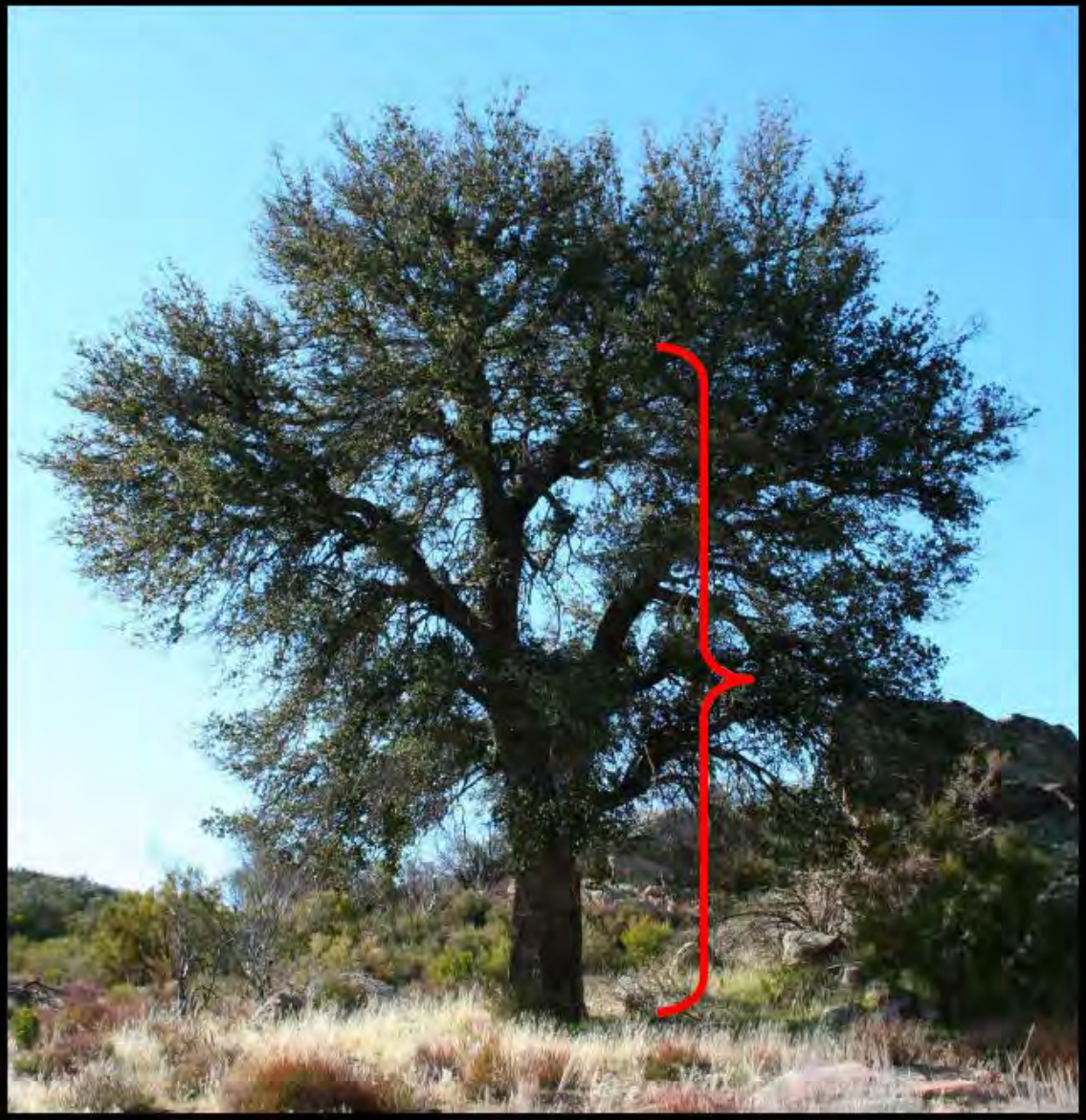


Coleman *et al.* (2011) *Forest Ecology and Management* 261:1852-1865.

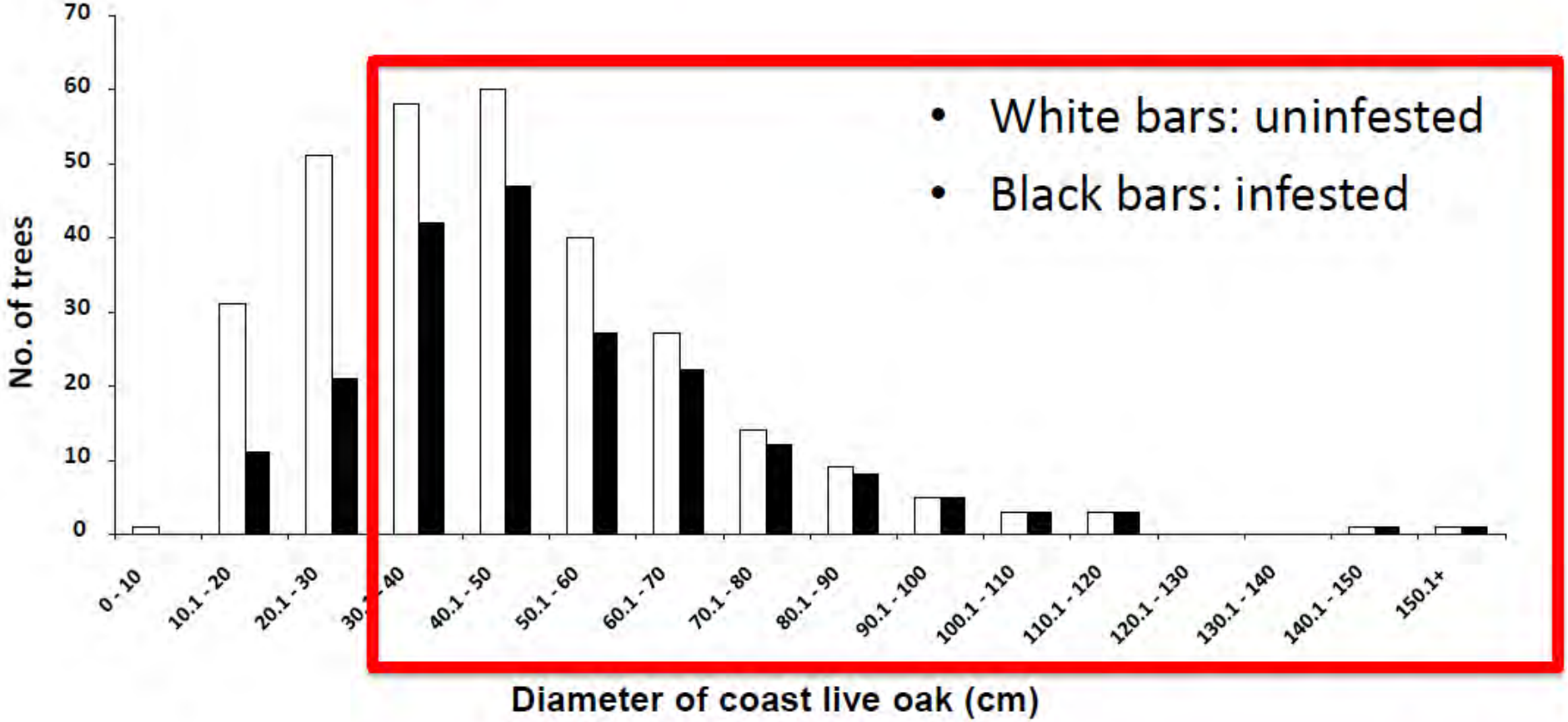
Hishinuma *et al.* (2011) Goldspotted oak borer: Field identification guide, University of California Agriculture and Natural Resources, Statewide Integrated Pest Management Program, 6 pp., Oakland, California, January 13, 2011, http://www.ipm.ucdavis.edu/PDF/MISC/GSOB field-identification-guide.pdf

GSOB injury and symptoms

- Injury commonly occurs on the lower part of the main stem and larger branches
  - Initial attack does not begin in the upper parts of the crown



Host size preference



- Larger size-classes preferred by GSOB

Coleman *et al.* (2012) *Forest Ecology and Management 276:*104-117

Host Ranges Determined through Field Surveys in Arizona, California, and Mexico

2011

The Coleopterists Bulletin, 65(2): 93–108. 2011.

Collection History and Comparison of the Interactions of the Goldspotted Oak Borer, *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae), with Host Oaks in Southern California and Southeastern Arizona, U.S.A.

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Abstract

An invasive population of the goldspotted oak borer, *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae), is colonizing and killing three species of oaks in San Diego Co., California. However, the interactions of *A. auroguttatus* with oaks in its native range in southeastern Arizona have not been recorded. We present a complete inventory of the North and Central American collection records of *A. auroguttatus* and *Agrilus coxalis* Waterhouse from the literature and from a survey of the holdings of 27 museum and personal collections. We also discuss the relationship between this collection history and the behavior of *A. auroguttatus* as an intracontinental invasive species. Surveys of native populations of *A. auroguttatus* in oak forest stands from four mountain ranges in southeastern Arizona revealed injury patterns on Emory oak, *Quercus emoryi* Torrey, and silverleaf oak, *Quercus hypoleucoides* A. Camus, similar to those observed on other "red" oaks in California. No damage was observed on "white" oaks in Arizona, and observed only rarely on a white oak, *Quercus engelmannii* Greene, in California. In Arizona, adult emergence was confirmed from bark removed from *Q. emoryi*, representing the first developmental record of *A. auroguttatus* from a native host. Late instars of *Agrilus* sp. were also recovered from *Q. hypoleucoides*, but they were not reared to the adult stage for species identification. Nonetheless, our observations of damage and the presence of larvae in the same configuration and location in the outer bark as we would expect for *A. auroguttatus* suggest that *Q. hypoleucoides* is also likely a host. Two hymenopteran parasitoids, *Calosota elongata* Gibson (Eupelmidae) and *Atanycolus simplex* Cresson (Braconidae), and two likely coleopteran predators (Trogossitidae and Elateridae) emerged from, or were collected in southeastern Arizona from, *Q. emoryi* bark infested with *A. auroguttatus*. Based on the museum survey results, the morphological similarity of individuals from the California and Arizona populations, the spatial dynamics of the pattern of infestation in California, the geographic isolation of hosts in California from native populations of the beetle, and the proximity of San Diego Co. to southeastern Arizona, we hypothesize that *A. auroguttatus* was introduced to California from Arizona or less likely from the Mexican states of Baja California, Chihuahua, or Sonora, and that the introduction most likely occurred on oak firewood. Further, we hypothesize that the oak mortality in southern California is occurring from this intracontinental invasive species because the beetle is filling a vacant niche by colonizing and developing in non-coevolved trees with low host resistance in the absence of a diverse and coevolved insect natural enemy complex.

Key Words: *Agrilus coxalis*, *Atanycolus simplex*, *Calosota elongata*, firewood, intracontinental invasive species, oak mortality

Between 2002 and 2010, aerial survey data revealed an expanding pattern of extensive oak mortality on federal, state, tribal, and private lands in San Diego Co., California (CA). Approximately 21,535 coast live oaks, *Quercus agrifolia* Née (Fagaceae), California black oaks, *Quercus kelloggii* Newberry, and canyon live oaks, *Quercus chrysolepis* Liebm., have died in a 4,903 km^2 area centered on the Descanso Ranger District, Cleveland National Forest and Cuyamaca Rancho State Park (Fig. 1A–C). Until recently, this zone of oak mortality was not contiguous with the U.S.-Mexican border on its southern flank, but it now extends from the community of Campo in the southeast to Ramona in the northwest. In 2009, an additional isolated pocket of dying oaks was found at Marion Bear Memorial

2012

Forest Ecology and Management 276 (2012) 104–117

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Forest stand composition and impacts associated with *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae) and *Agrilus coxalis* Waterhouse in oak woodlands

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ABSTRACT

From 2009–2011, we assessed the impact of the goldspotted oak borer, *Agrilus auroguttatus* Schaeffer, or its sibling species, *Agrilus coxalis* Waterhouse, at locations in southern California (denoted infested: ICA and uninfested: UCA), southeastern Arizona (AZ), and southern Mexico (MX). Our surveys examined forest composition of oak woodlands; the degree of injury and proportion of oaks infested with either *A. auroguttatus* (ICA and AZ) or *A. coxalis* (MX); and the progression of aerially mapped oak mortality in San Diego Co. (ICA). By most measures of impact that we evaluated, the effect on oaks by the two *Agrilus* spp. was relatively low in their native regions, but significantly higher by *A. auroguttatus* at ICA sites. Larger diameter red oak species have been the preferred hosts of *A. auroguttatus* in AZ and ICA sites, and red oaks greater than approx. 13 cm in DBH throughout California are likely at risk of injury from this invasive pest. At sites in AZ there was no evidence of infestation by *A. auroguttatus* on living or dead white oak species, whereas at ICA sites we recorded a minor amount of infestation by *A. auroguttatus* on living individuals of a white oak species (*Quercus engelmannii* Greene), but no mortality. In contrast, a white oak from MX sites (*Quercus peduncularis*) was more frequently infested by *A. coxalis* than were indigenous red oaks. Across all ICA sites, *A. auroguttatus* has infested 61% of the live larger diameter oaks and killed 13% of the oak component of the forest (vs. 4% infested and 2% dead in AZ, respectively). At survey plots near the predicted origin of the outbreak in CA, over 90% of the larger diameter red oaks have been infested. Nearly 90% of the dead oaks surveyed across all ICA sites showed evidence of previous injury symptoms from *A. auroguttatus*. Aerial oak mortality polygons associated with *A. auroguttatus* have expanded ~50 km in nine years, but our analysis confirms that the outbreak appears to still be confined to San Diego Co. The distance of oak mortality polygons from the predicted origin of the outbreak explained the most variance in a principal component analysis. The invasive population of *A. auroguttatus* is a significant conservation and ecological threat to the oak woodlands of California and should be managed accordingly, especially by restricting firewood movement.

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1. Introduction

Stem-infesting *Agrilus* spp. (Coleoptera: Buprestidae) phloem/xylem borers have played key roles in historic cases of oak decline and mortality in the eastern USA and Europe (Nichols, 1968; Stringer et al., 1989; Hartmann and Blank, 1993; Führer, 1998; Oszako, 1998; Thomas et al., 2002). Damage from most *Agrilus* spp. is associated with oak trees already in decline. For example, in the eastern USA, the native twolined chestnut borer, *Agrilus bilineatus* Weber, frequently attacks oaks weakened by high levels of defoliation from Lepidoptera, infection by *Armillaria* sp. (Fr.) Staude root rot, injury from frost, or drought (Chapman, 1915; Hursh and Haasis, 1931; Knull, 1932; Baker, 1941; Staley, 1965; Dunbar and Stephens, 1975; Wargo, 1977) and is typically regarded as a secondary pest on stressed oaks (Dunn et al., 1986; Haack and Acciavatti, 1992; Muzika et al., 2000). In Europe, the native oak splendor

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GSOB larval hosts

California

Arizona

Mexico

Q. peduncularis

Q. conzatti

(*A. coxalis*)

GSOB Adult Feeding Assays

Dual-choice test for GSOB adult feeding behavior

Treatments:

1. Coast live vs. California black oak
2. Coast live vs. Canyon live oak
3. Coast live vs. Engelmann oak
4. California black vs. Canyon live oak
5. California black vs. Engelmann oak
6. Canyon live vs. Engelmann oak

Small leaf disks

Small branches with leaves

GSOB: Adult Feeding Preference

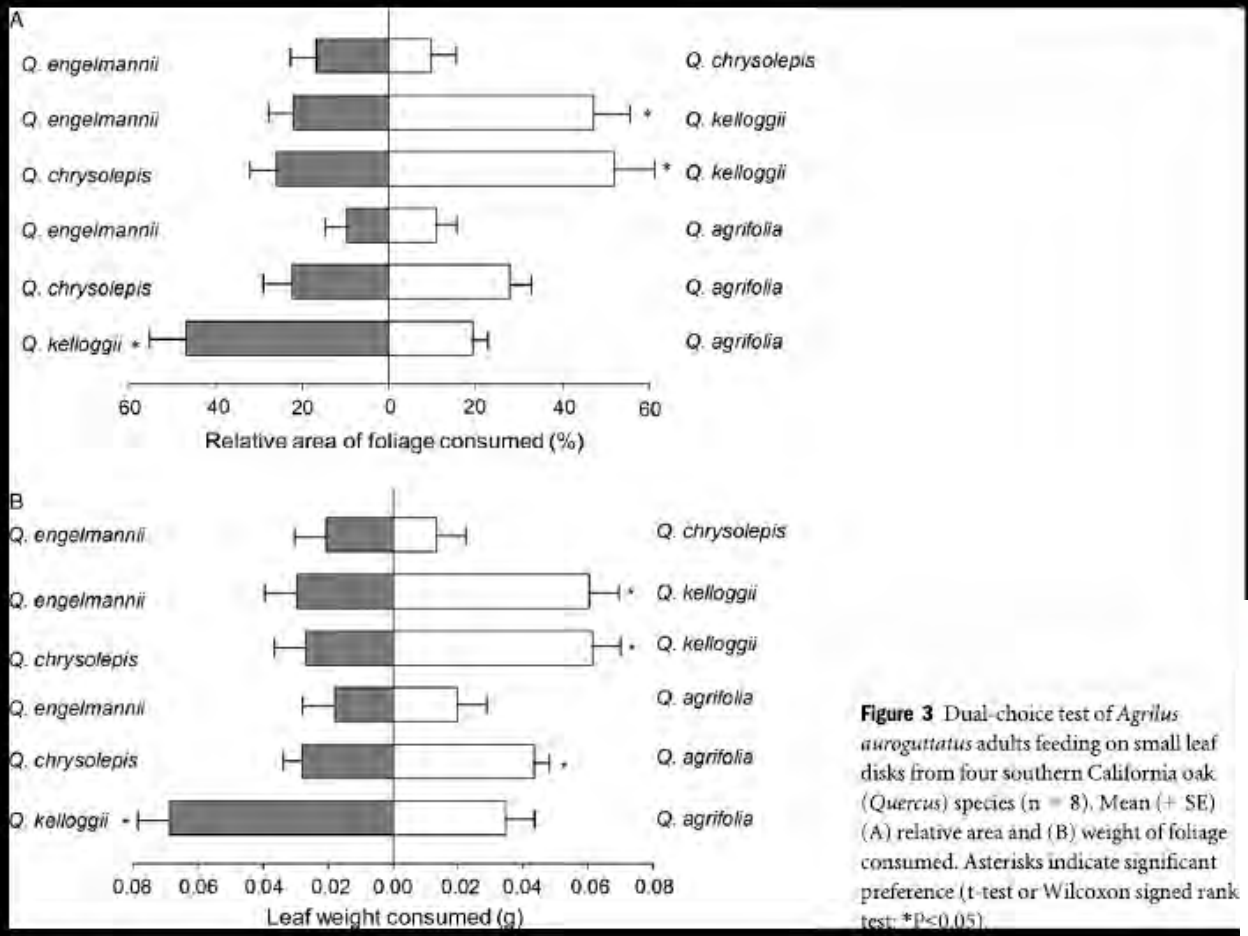


Figure 3 Dual-choice test of *Agrilus auroguttatus* adults feeding on small leaf disks from four southern California oak (*Quercus*) species (n = 8). Mean (+ SE) (A) relative area and (B) weight of foliage consumed. Asterisks indicate significant preference (t-test or Wilcoxon signed rank test: *P<0.05).

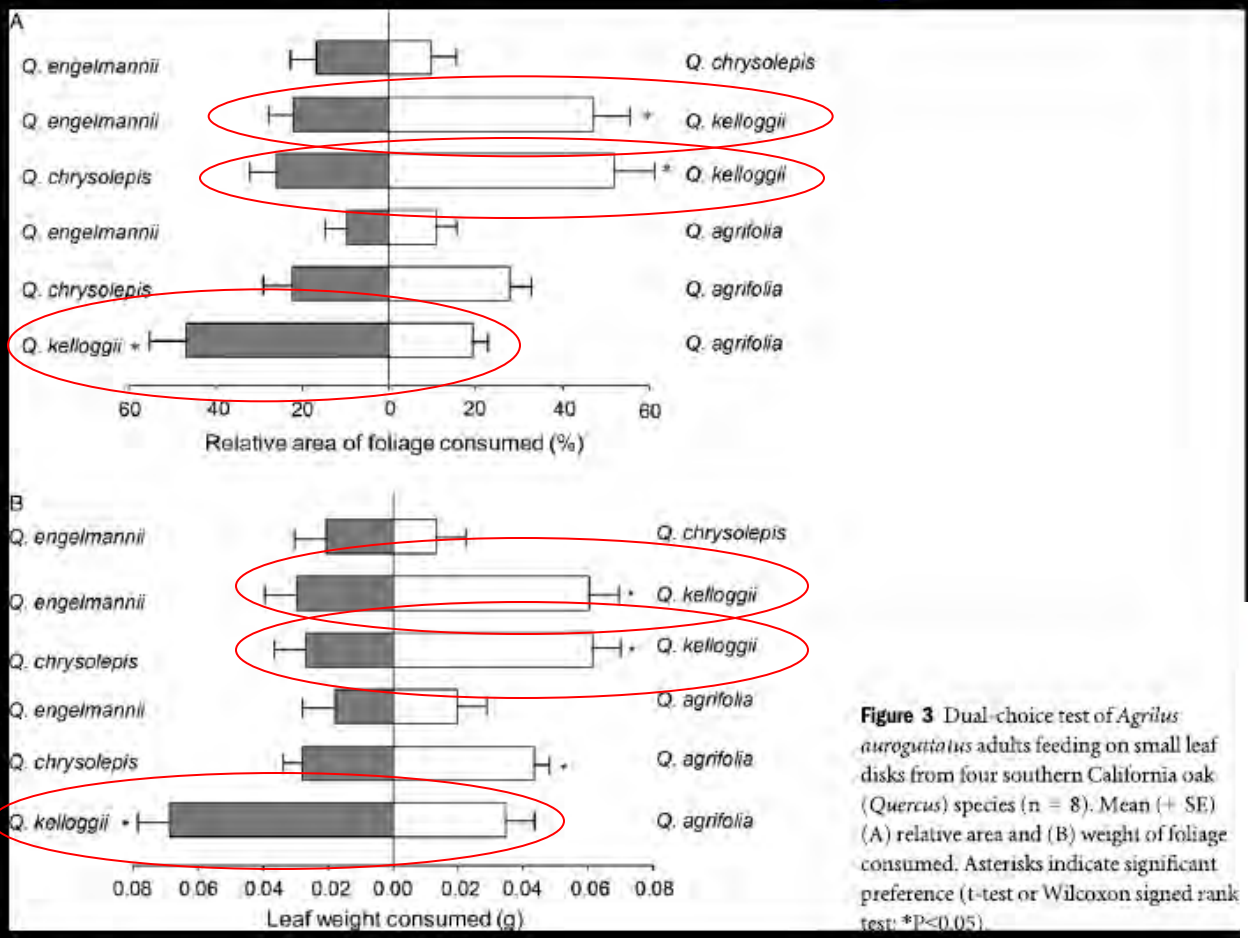
Yigen Chen
UC Davis


Foliar nutrients explain goldspotted oak borer, *Agrilus auroguttatus*, adult feeding preference among four California oak species

- Adult leaf feeding assays
  - GSOB adults favor California black oak in all assays

Chen et al. (2013) *Entomologia Experimentalis et Applicata* 149:57-66

GSOB: Adult Feeding Preference



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Yigen Chen
UC Davis

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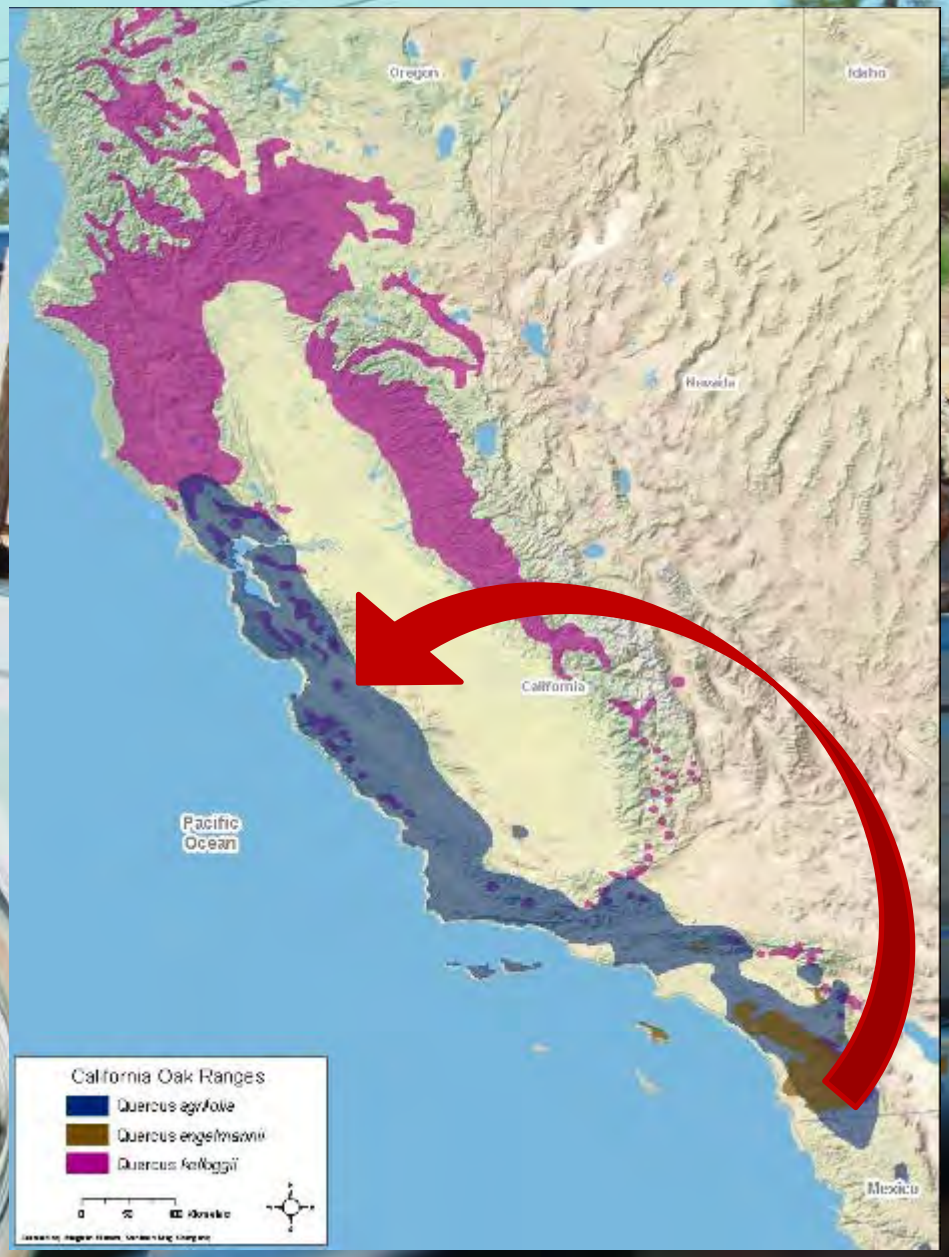
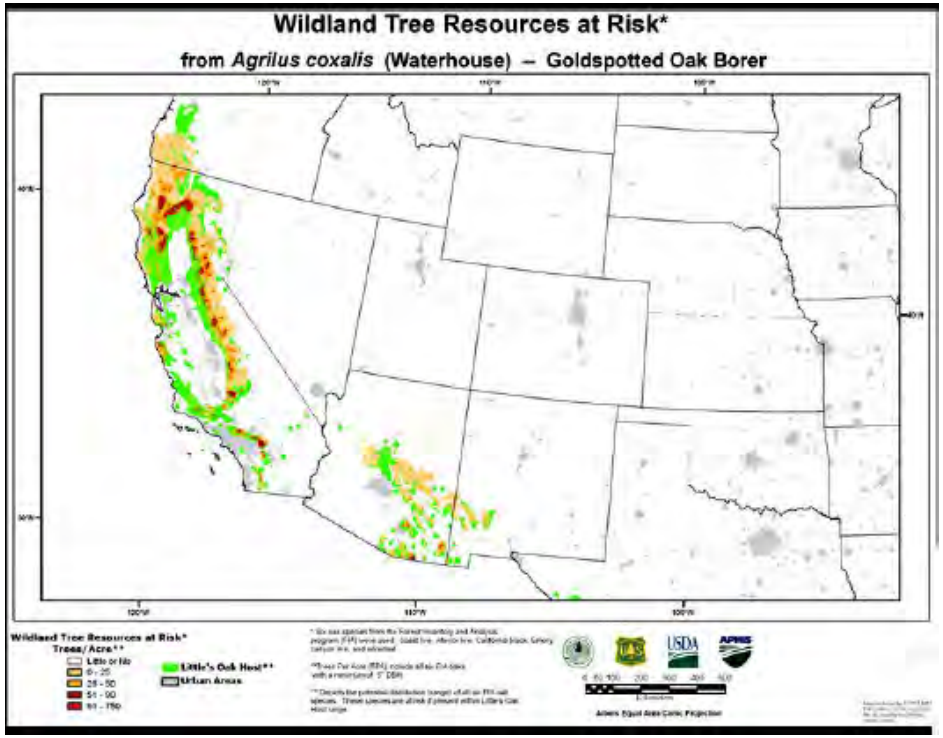
  - GSOB adults favor California black oak in all assays

Chen et al. (2013) *Entomologia Experimentalis et Applicata* 149:57-66

GSOB: Risk to California?



GSOB Risk Assessment

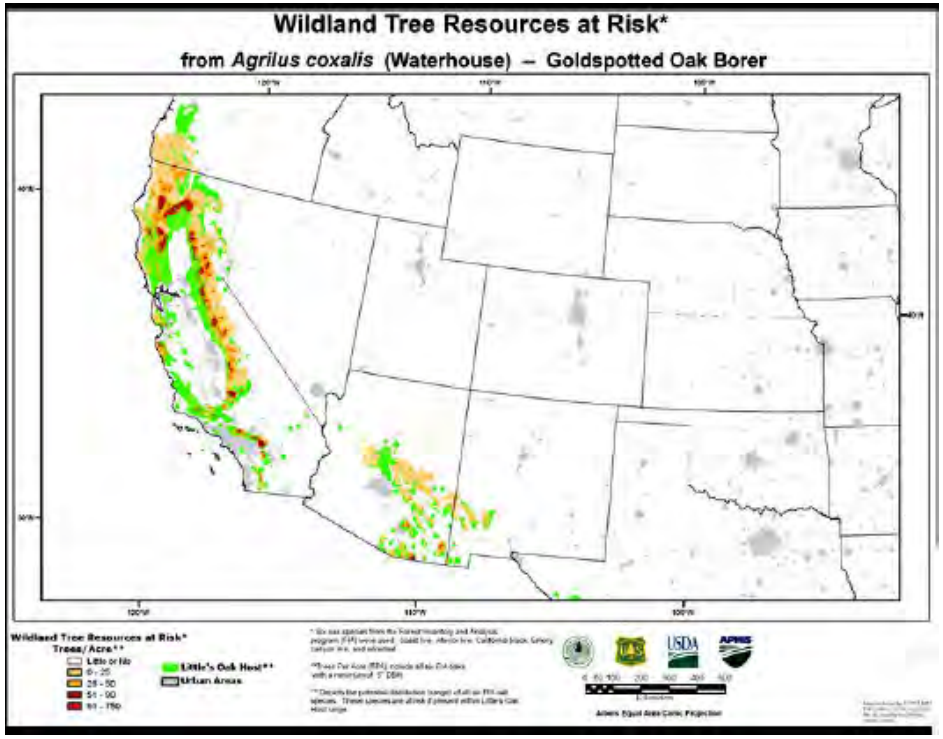


Initial Risk Assessment, 2008/2009

Based on:

Range of Potential Hosts

GSOB Risk Assessment



Initial Risk Assessment, 2008/2009

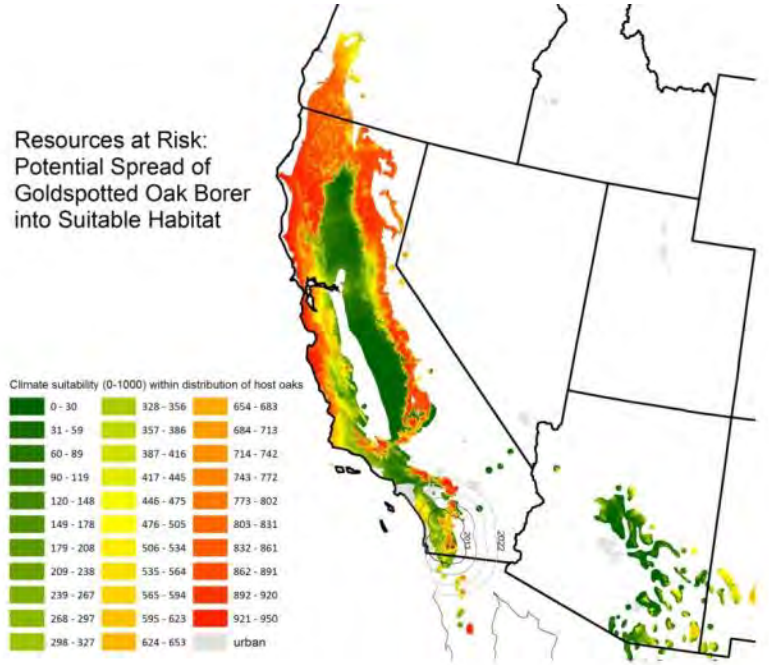
Rob Venette
USDA FS
Northern Res. Station
St. Paul, MN

Rob Venette

Advanced Risk Assessment, 2015

Based on:

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



Venette *et al.* (2015) Assessing the risks posed by goldspotted oak borer in California and beyond, pp. 1-12, *in* R. Standiford and J. Kleijunas (eds.).
Proc. 7th California Oak Symposium. 3-6 November, 2014, Visalia, California, x pp. (in press).

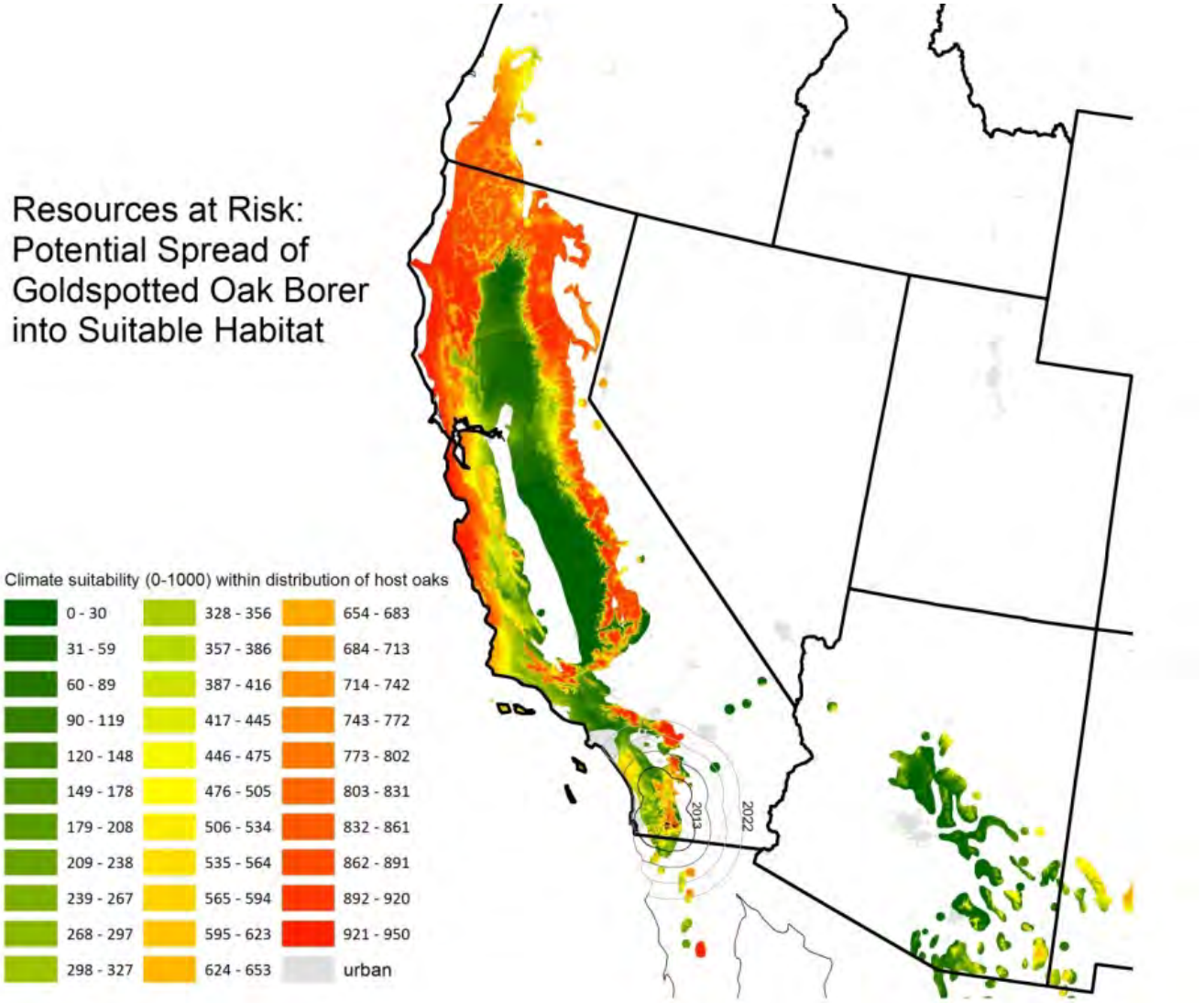
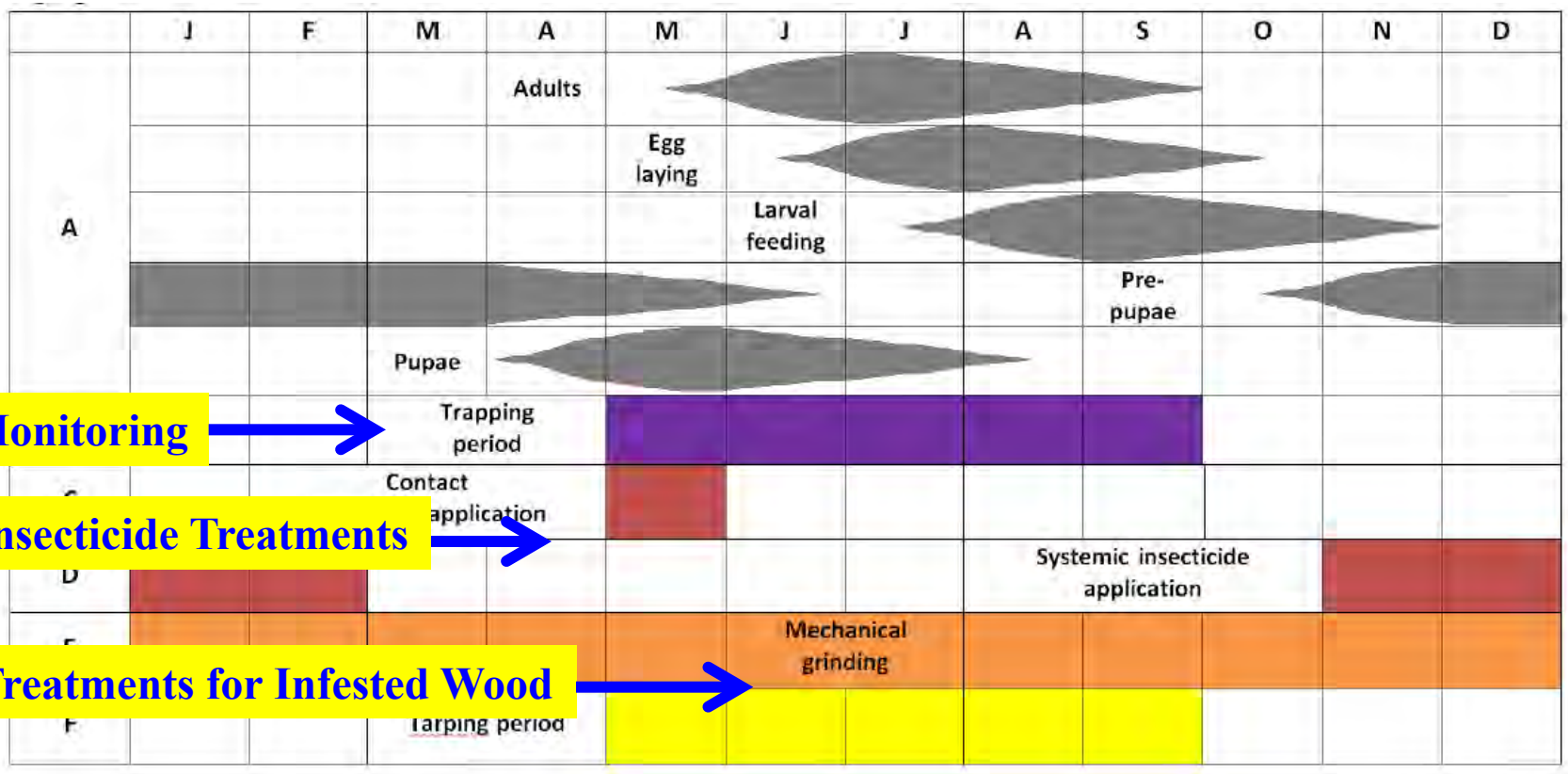


Figure 1—Composite risk map for *Agrilus auroguttatus* depicting the degree of climate suitability and potential extent of natural spread from 2013 – 2022 within the range of confirmed and suspected hosts. United States states outside New Mexico, Arizona, California, and Oregon are presumed to have little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

Coordination of Life Cycle and Management Activities for GSOB

An IPM Framework



Yigen Chen
UC-Davis

Tom Coleman
USDA FS
San Bernardino

Coordination of Life Cycle and Management Activities for GSOB

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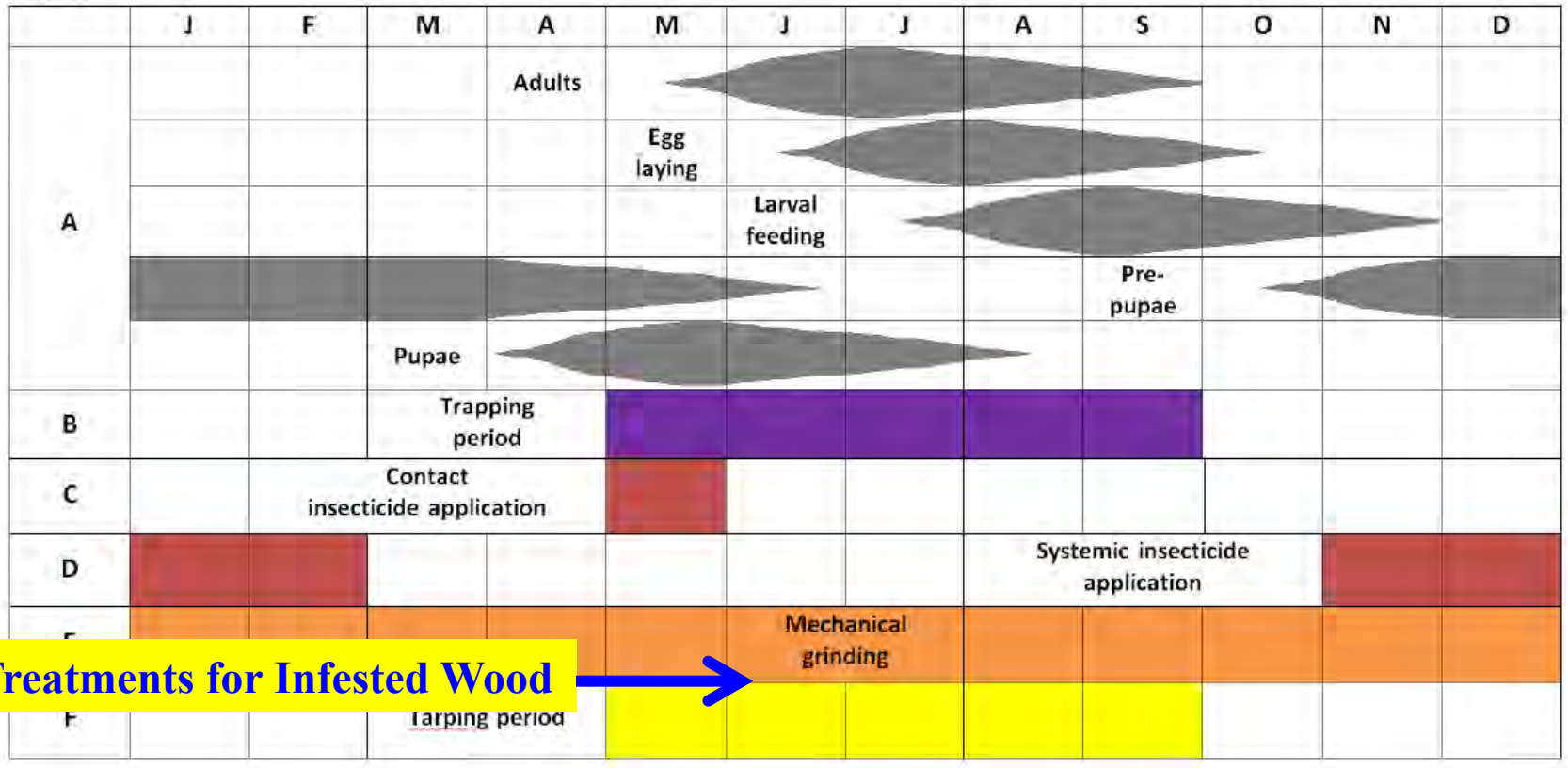
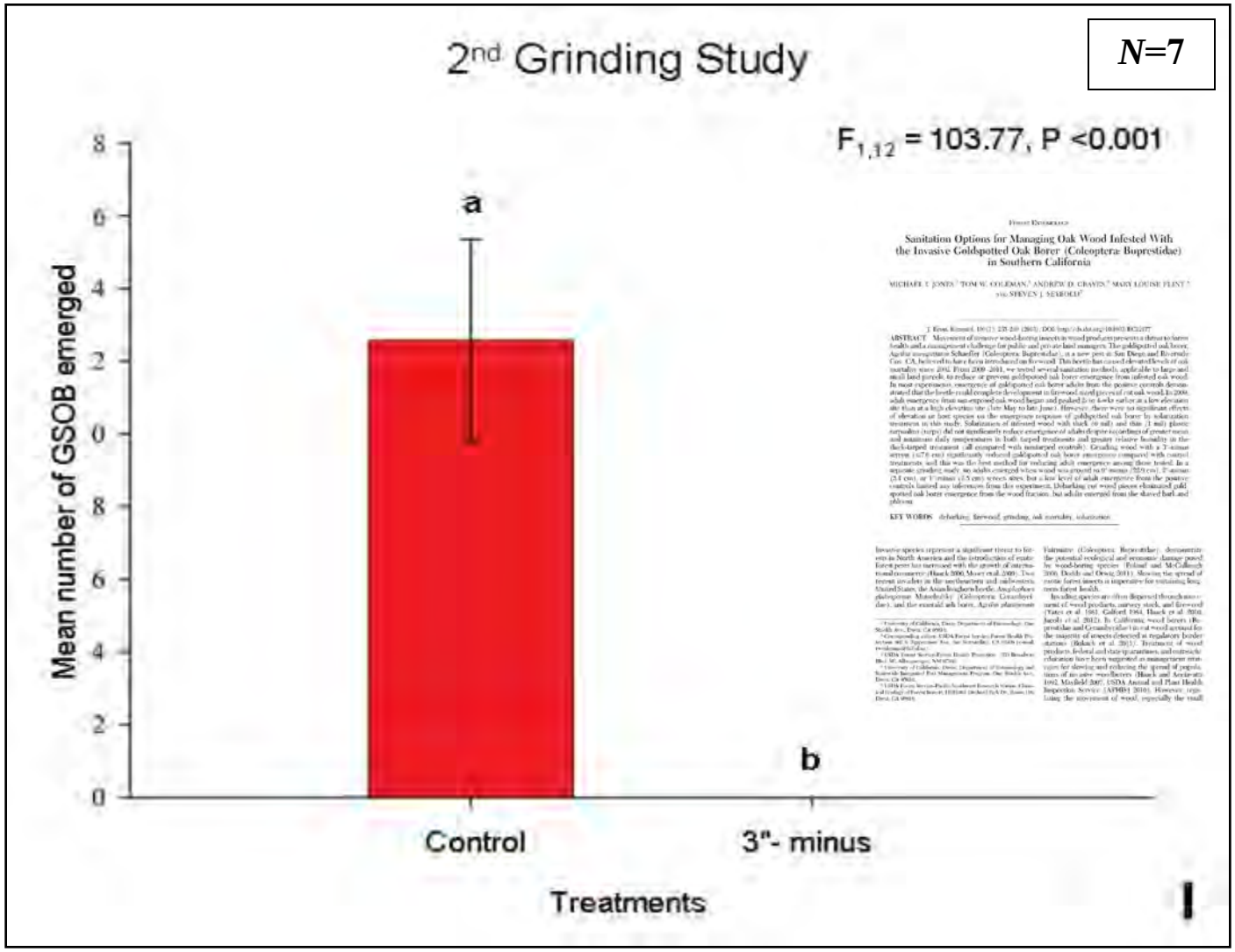


Yigen Chen
UC-Davis

Tom Coleman
USDA FS
San Bernardino

Treatments: Management of Wood from Infested Areas

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



Jones, M.I *et al.* (2013) Sanitation options for managing oak wood infested with the invasive goldspotted oak borer (Coleoptera: Buprestidae) in southern California. *J. Econ. Entomol.* 106 235–246. doi: http://dx.doi.org/10.1603/EC12177

www.dontmovefirewood.org

California Black Oak Defoliator:
Fruit tree leafroller, *Archips argyrospila* (Tortricidae)

Figure 11. Fruit tree leafroller caterpillar hanging from silken thread.

California Black Oak Defoliator:
Fruit tree leafroller, *Archips argyrospila* (Tortricidae)

Figure 10. Damage to newly expanding valley oak leaves from feeding of fruit tree leafroller larvae.

Historical outbreaks on California black oak in the San Bernardino Mountains

1) **1951-1953**
2) **1999-2003**

California Black Oak Defoliators

Defoliators

Black Oak Leaf Miner

Eriocraniella aurosparsella

Contributions by: Danny Cluck

Blotch mining of California black oak leaves by the black oak leaf miner in the Blue Canyon area, Tahoe National Forest, decreased in 2010 (Placer County, M261E). During the cool and wet spring, snow remained on the previous outbreak site during the emergence period of this moth (which pupates in the soil), possibly reducing the adult population. Light defoliation was observed only in a small area (~500 acres), east of Emigrant Gap off of Interstate 80. Activity decreased from approximately 7,000 acres in 2009.

M261E

Fruittree Leaf Roller

Archips argyrospila

Contributions by: Tom Coleman

Fruittree leaf roller continued to cause moderate levels of defoliation on California black oak near the communities of Crestline, Mountaintop Ranger District, San Bernardino National Forest (San Bernardino County, M262B). The defoliation covered an estimated 60 acres. Defoliation has continued in this area for several years, but tree mortality was not evident.

M262B

Emerging Pest Issues: *Chrysobothris costifrons*
New flatheaded wood borer in San Diego County

THE PAN-PACIFIC ENTOMOLOGIST
91(2):200–202, (2015)

Scientific Note

Discovery of *Chrysobothris costifrons costifrons* Waterhouse, 1887 (Coleoptera: Buprestidae) in southern California, U.S.A.

In September 2005 one of us (RJW) collected a large buprestid beetle at her home near Julian, San Diego Co., California and sent it to another of us (JPB) who identified it as *Chrysobothris costifrons costifrons* Waterhouse, 1887 (Fig. 1). The identification was confirmed by the third author. In October 2008, RJW collected another individual of the same species as it flew into her garage! She photographed it and posted the image on BugGuide (bugguide.net/node/view/371262/; accessed 3 February 2015). Specimen label data are as follows: CALIFORNIA, San Diego Co., Julian, 5893 Mt. Meadow Rd, 33.0150° N, -116.6166° W, elev. 1268 m, 27-IX-2005, R. J. Waayers [J. P. Basham Collection]; same locality, 25-X-2008, R. J. Waayers, [R. J. Waayers Collection]. The locality is 4.5 miles SbW of Julian. This species ranges in length from 15.2–19.5 mm (Westcott 1983).

These specimens are of special interest because another buprestid, *Agrilus auroguttatus* Schaeffer, 1905 (formerly considered a synonym or subspecies of *Agrilus coxalis* Waterhouse, 1889), the (now) notorious goldspotted oak borer (GSOB), became a widespread and damaging pest after being introduced, undoubtedly from southern Arizona, into the same general area of San Diego Co., California (Coleman & Seybold 2011). The first GSOB in California were caught in Lindgren funnel traps during 2004 (Westcott 2005), at two sites located 2.7 and 4.4 miles SE from the locality reported here for *C. c. costifrons*. Later, many GSOB were reared from infested wood cut in William Heise Co. Park (Coleman et al. 2012), which is only 2.4 miles NE of the *C. c. costifrons* site. Both species occur sympatrically in their native range and are known to breed only in oaks, *Quercus* spp. (Fagaceae), in some instances the same species. This is food for speculation. Coleman et al. (2012), referring to GSOB, wrote: "…the California population may have possibly arisen from a single truck load of firewood." Maybe both species did! It seems strange that more specimens of *C. c. costifrons* have not been collected in this area. It appears not to have been nearly as successful as GSOB in adapting to a new habitat, i.e. in an area receiving most of its rainfall during winter rather than summer.

Chrysobothris costifrons is widely distributed in Mexico, where it is represented by all three of its subspecies. Only the nominate subspecies occurs in the U.S., having been recorded there only from southeastern Arizona. Known larval hosts are *Quercus arizonica* Sarg. and *Q. emoryi* Torr. (Westcott 1983). The locality in the Cuyamaca Mts. where the specimens of that subspecies were collected in California consists of forest dominated by oak, pine and cedar, containing scattered patches of chaparral, and open spaces that are largely due to disturbance by development and a severe burn, the Cedar Fire, which occurred in October 2003. There are numerous residences in the area. The vegetation includes four species of oaks: *Q. agrifolia* Nee, *Q. chrysolepis* Liebm., *Q. engelmannii* Greene, and *Q. kelloggii* Newberry. The beetle collected in 2005 was taken on a resprouted *Q. agrifolia* **(new adult host record)** in a localized spot that was severely burned in the Cedar Fire. This region on North Peak of the Cuyamaca Mts. contains a mixture of severely burned but re-growing vegetation with stands of unburned mature oaks and pines scattered within it.

Figure 1. *Chrysobothris costifrons costifrons* Waterhouse, adult male, 4.5 mi SbW Julian, California, U.S.A.

Forest Health Challenges to California Black Oak

I) Insects

A) Phloem feeders: Oak bark (and ambrosia) beetles

B) Phloem feeders: Goldspotted oak borer

C) Defoliators: Fruit tree leafroller

II) Pathogens

A) Stem cankers: *Phytophthora ramorum* and sudden oak death

B) Root diseases: *Armillaria mellea/gallica-Armillaria* root rot

C) Foliage (twig) diseases: *Apiognomonia errabunda* and oak anthracnose

Stem cankers:

Phytophthora ramorum and sudden oak death

Infection of the phloem and outer xylem (wood) of the main stem and lower scaffold branches by a brown algal pathogen. Oaks in the red oak group (*Lobatae*) and tanoak are impacted.

Humboldt County

Marin County

Big Sur

Wildland distribution of *Phytophthora ramorum*

Original map from M. Kelly, UC-Berkeley


Marin County, CA
June 2000


Big Sur, 2010


Big Sur
S. Frankel

Oaks

Quercus agrifolia
Q. kelloggii
Q. parvula* var. *shrevei
Q. chrysolepis

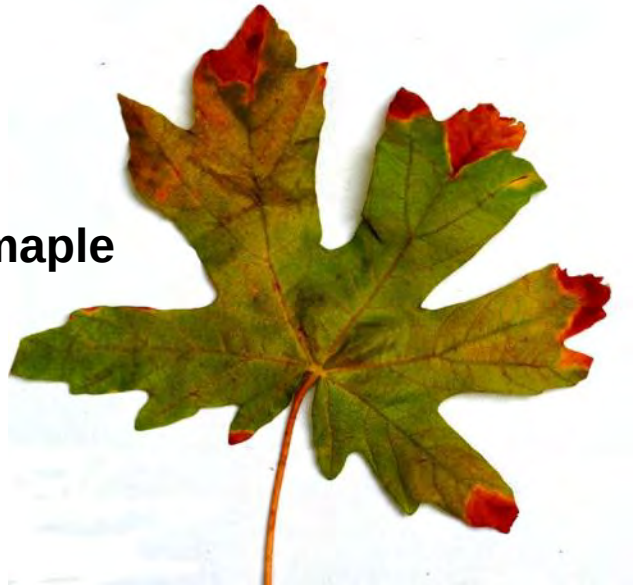
Tanoak

Notholithocarpus densiflorus

Tanoak

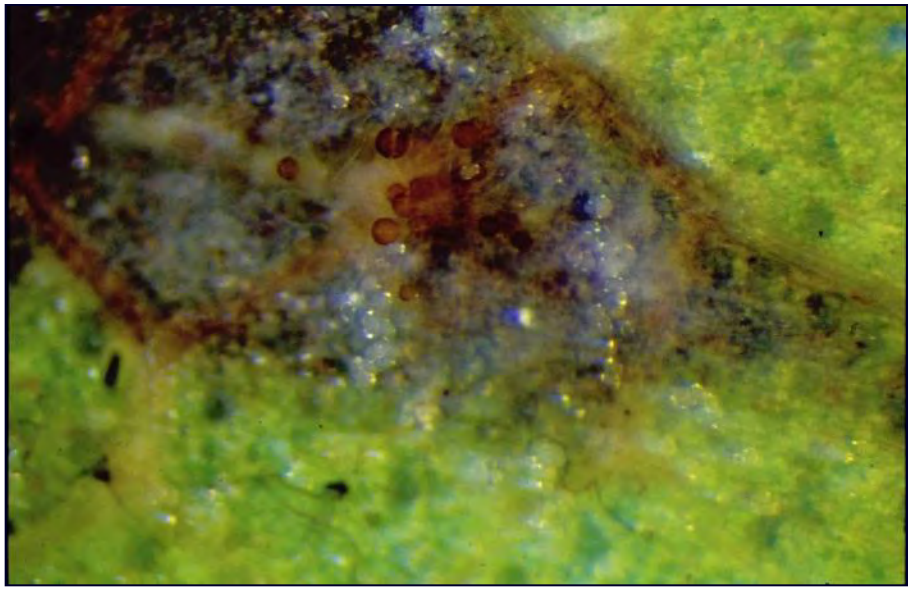
Infections and lesions on leaves, twigs, and small stems of a variety of native species in coastal California forests

Bigleaf maple



Coast redwood

Maidenhair fern



Known Host Range of *Phytophthora ramorum*

Andrew's clintonia bead lily
Ardisia
Bigleaf maple
Blueblossom
California bay laurel
California black oak
California buckeye
California coffeeberry
California hazelnut
California honeysuckle
California maidenhair fern
California nutmeg
California wood fern
Camellia species
Camphor tree
Canyon live oak
Cascara
Chinese witchhazel
Coast live oak
Coast redwood
Douglas fir
Drooping leucothoe
European ash
European beech
European turkey oak
European yew
Evergreen huckleberry
Evergreen maple
False Solomon's seal
Formosa firethorn
Fetterbush
Goat willow
Grand fir
Griselinia
Holly olive
Holm oak
Horse chestnut
Hybrid witchhazel
Japanese evergreen oak
Japanese larch
Laurustinus
Lilac
Madrone
Magnolia varieties
Manzanita
Michelia
Mountain laurel
Northern red oak
Oleander
Oregon ash
Osmanthus
Pacific yew
Persian ironwood
Pieris varieties
Planetree maple
Poison oak
Port-Orford cedar
Portuguese laurel cherry
Red fir
Red tip photinia
Redwood ivy
Rhododendron species
Roble beech
Rugosa rose
Salal
Salmonberry
Scotch heather
Sessile oak
Sheep laurel
Shreve oak
Southern red oak
Spicebush
Spreading euonymus
Star magnolia
Strawberry tree
Striped bark maple
Sweet bay laurel
Sweet chestnut
Sweet Cicely
Sweet olive
Tanoak
Toyon
Viburnum varieties
Victorian box
Vine maple
Western hemlock
Western maidenhair fern
Western starflower
White fir
Winter's bark
Witch hazel
Wood rose
Yew

Root disease:

Armillaria mellea/gallica-Armillaria root rot/oak root fungus

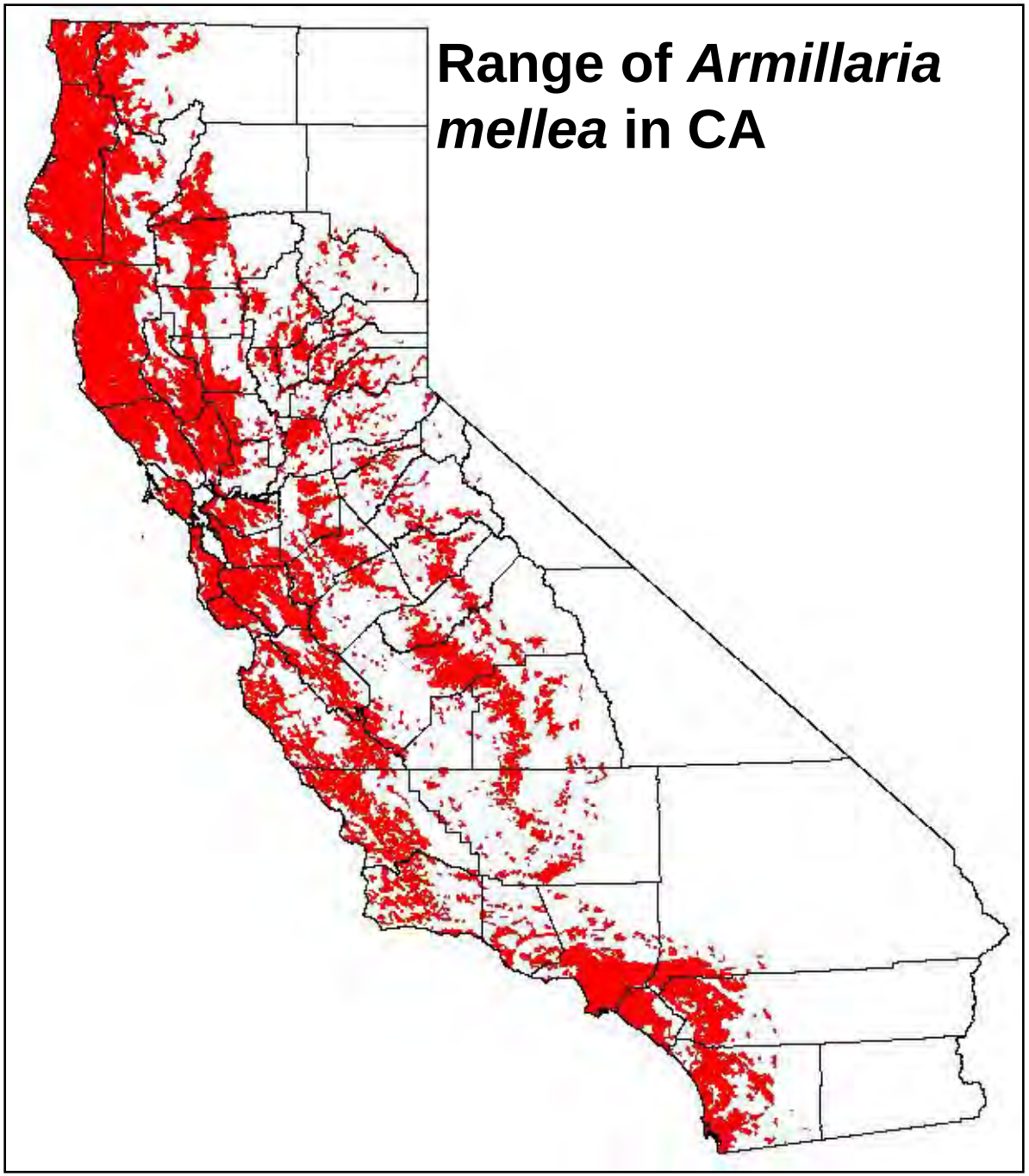
Figure 136. Young cluster of *A. mellea* mushrooms.

Figure 135. Close-up *A. mellea* mushroom showing attached, slightly decurrent gills.

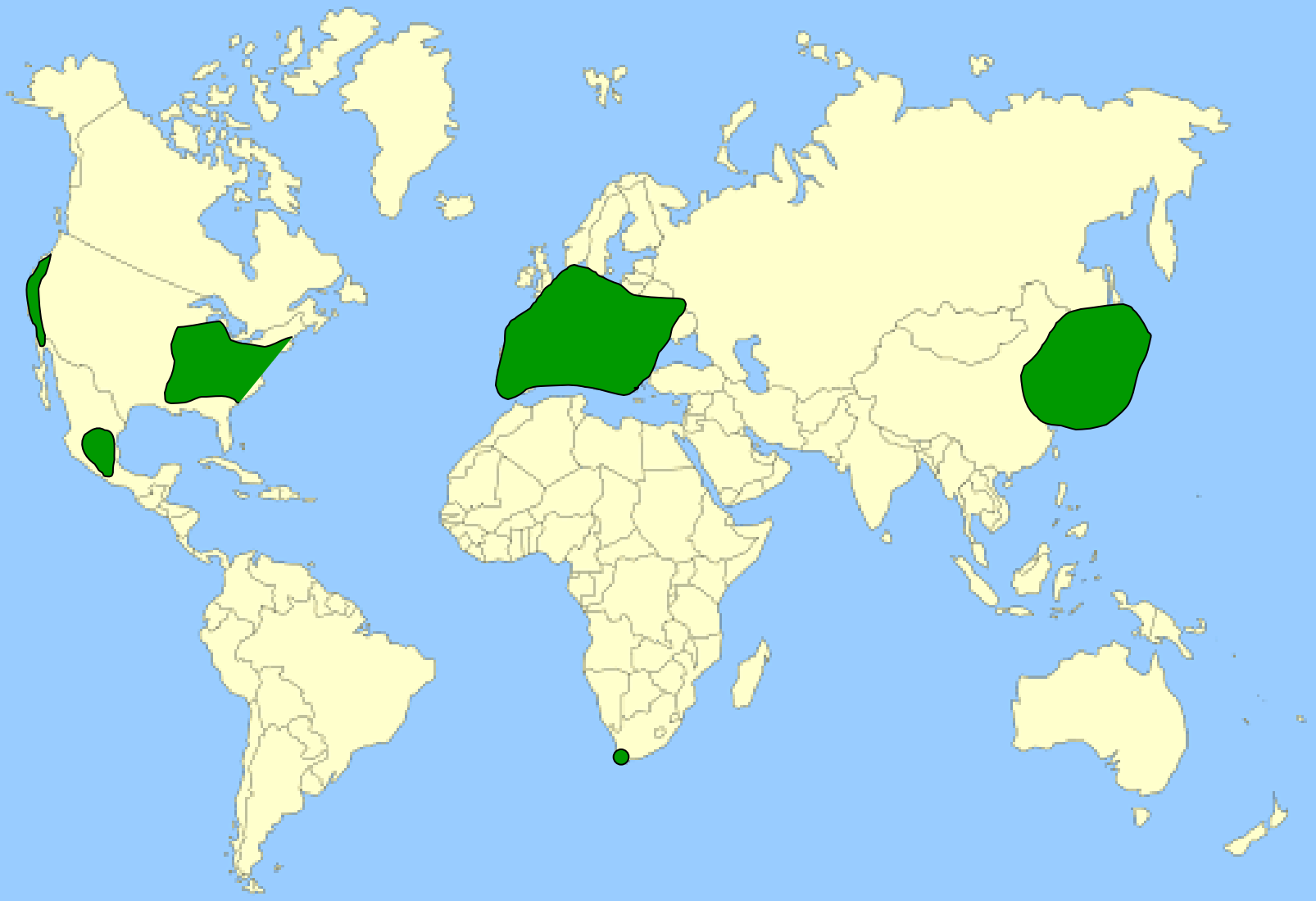
Infection of healthy roots leading to decay of roots and lower stem. Infection occurs *via* "rhizomorphs" or direct contact between infected and healthy roots. Oaks, other hardwoods, and conifers are impacted (especially in mixed stands).

Infection

- Invades the root, root collar and trunk base (usually no higher than 2 meters)
- Initial decay of the phloem, cambium, and sapwood
- Fungus restricted to the sapwood while host is alive
- After host dies, moves into heartwood


Range of *Armillaria mellea* in CA

Armillaria mellea



Identification

- **Mycelial fans**

- **Rhizomorphs**

- **Wet stringy white rot, sometimes with hard black plates (zone lines)**

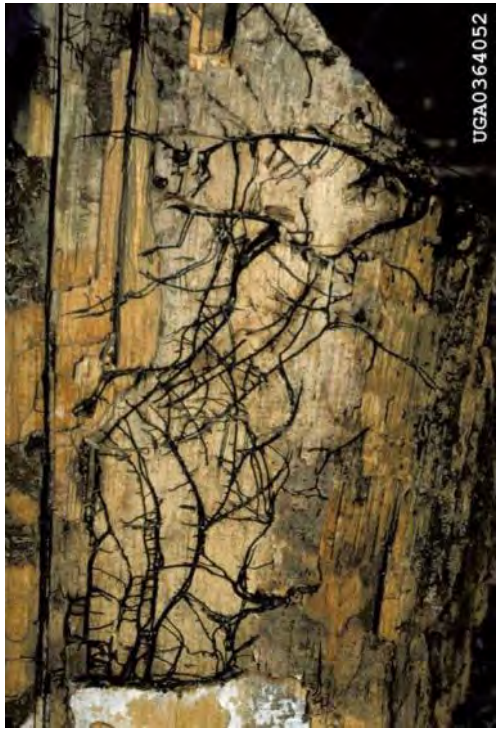
- **Fruiting bodies**

Dispersal

Rhizomorphs

- Extend several meters from the resource base
- 0.2 to 2 meters/year
- Translocation of water and nutrients, establishment of new infections
- Will infect directly or “lie in wait” under the bark surface and attack when the tree becomes stressed

Produce spores, not significant in disease development



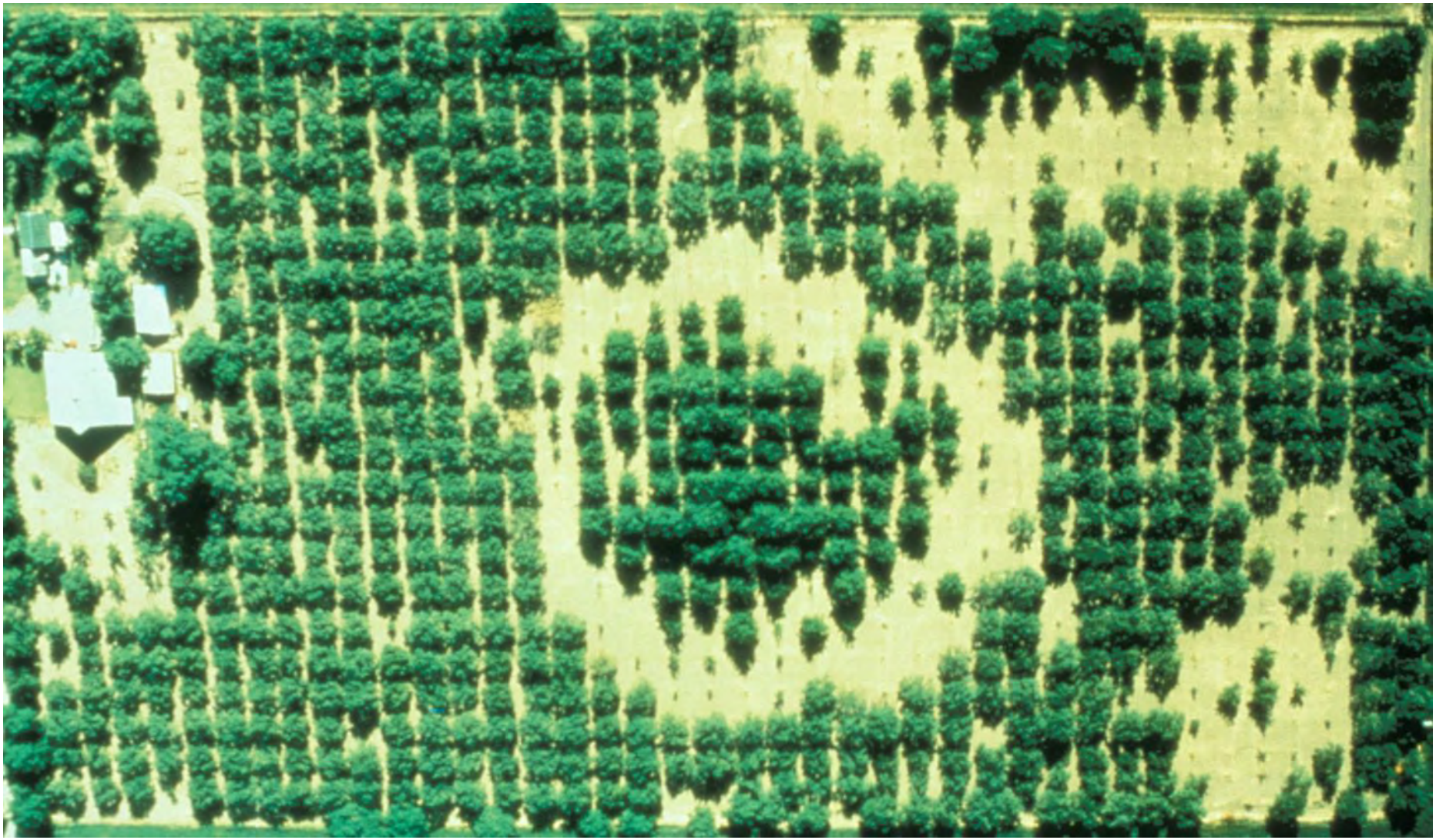
Persistence

- **Effective saprobes, persist on dead material**
- **Spread from tree to tree, slowly enlarging root disease centers**
- **Colony can persist for decades or centuries**
  - **Few square meters to hundreds of hectares**

Armillaria mellea associated gap

Gap started at a suppressed and infected black oak.

All tree species may be killed.



Foliage (twig) diseases:

Apiognomonia errabunda and oak anthracnose

Figure 83. Anthracnose symptoms on California black oak.

Photo: Bruce Hagen, CDF.

Figure 84. Anthracnose symptoms on coast live oak.

Figure 86. Dark spots are *C. cinerescens* acervuli erupting through bark of an oak twig.

Photo: Bruce Hagen, CDF.

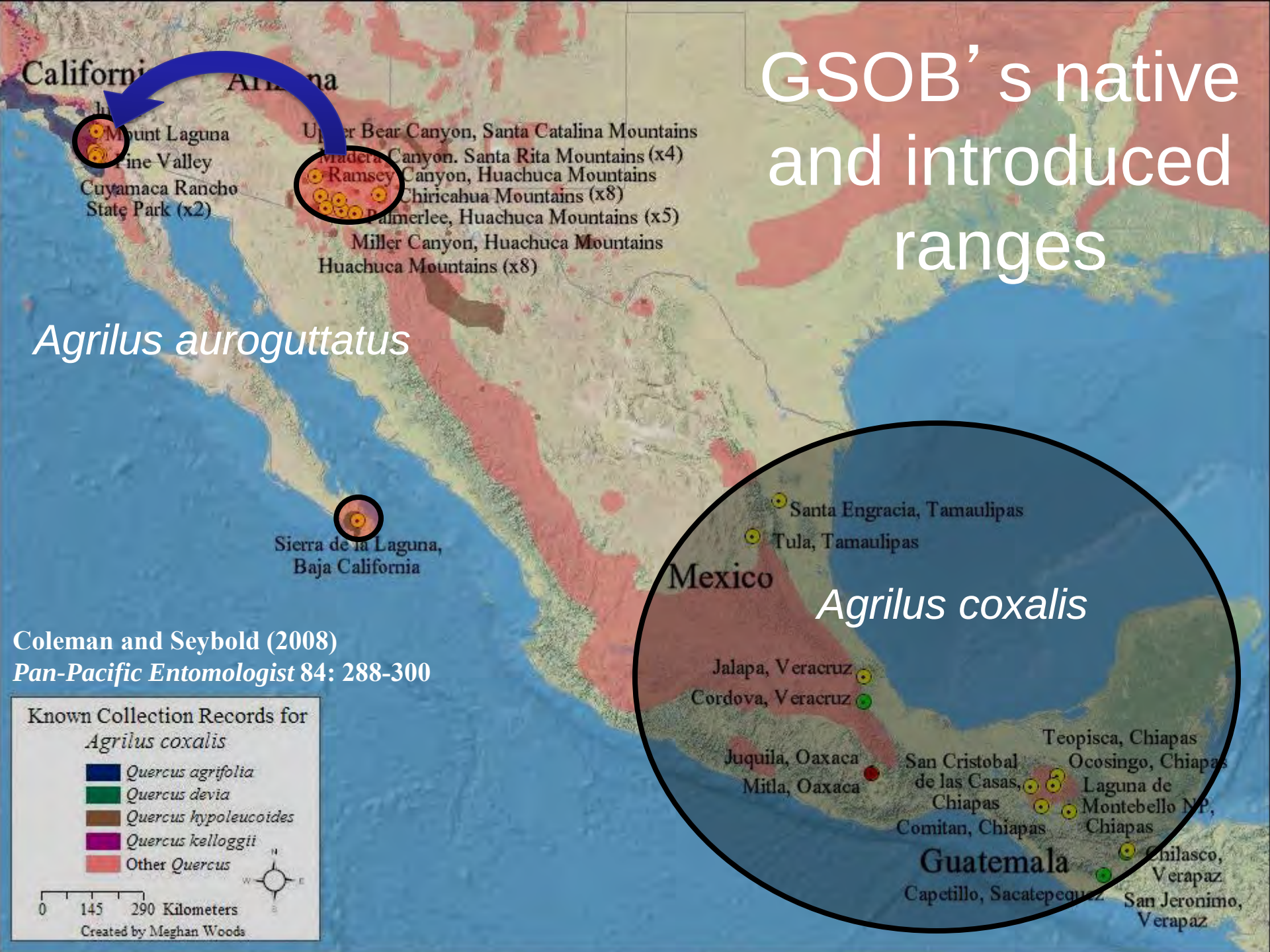
"One thing you might want to mention is oak anthracnose. In 2005-2006 when it was really wet, we saw a lot of this disease on black oak in the coastal ranges. It caused complete defoliation in many cases, although most trees put on new leaves by mid-summer. With potentially increased rainfall this year, it could be a problem again (D.M. Rizzo, pers. corresp., Nov. 10, 2015)."

Doomsday Scenario?

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

Thank you for your Attention

Questions and Discussion?


GSOB's native and introduced ranges
Agrilus auroguttatus
Mount Laguna
Pine Valley
Cuyamaca Rancho State Park (x2)
Upper Bear Canyon, Santa Catalina Mountains
Madera Canyon. Santa Rita Mountains (x4)
Ramsey Canyon, Huachuca Mountains
Chiricahua Mountains (x8)
Palmerlee, Huachuca Mountains (x5)
Miller Canyon, Huachuca Mountains
Huachuca Mountains (x8)
Sierra de la Laguna, Baja California
Agrilus coxalis
Santa Engracia, Tamaulipas
Tula, Tamaulipas
Mexico
Jalapa, Veracruz
Cordova, Veracruz
Juquila, Oaxaca
Mitla, Oaxaca
San Cristobal de las Casas, Chiapas
Comitan, Chiapas
Teopisca, Chiapas
Ocosingo, Chiapas
Laguna de Montebello NP, Chiapas
Guatemala
Chilasco, Verapaz
Capetillo, Sacatepequez
San Jeronimo, Verapaz
Coleman and Seybold (2008)
Pan-Pacific Entomologist 84: 288-300
Known Collection Records for Agrilus coxalis
Quercus agrifolia
Quercus devia
Quercus hypoleucoides
Quercus kelloggii
Other Quercus
0 145 290 Kilometers
Created by Meghan Woods

Historical Collection Records of GSOB in Southeastern AZ

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

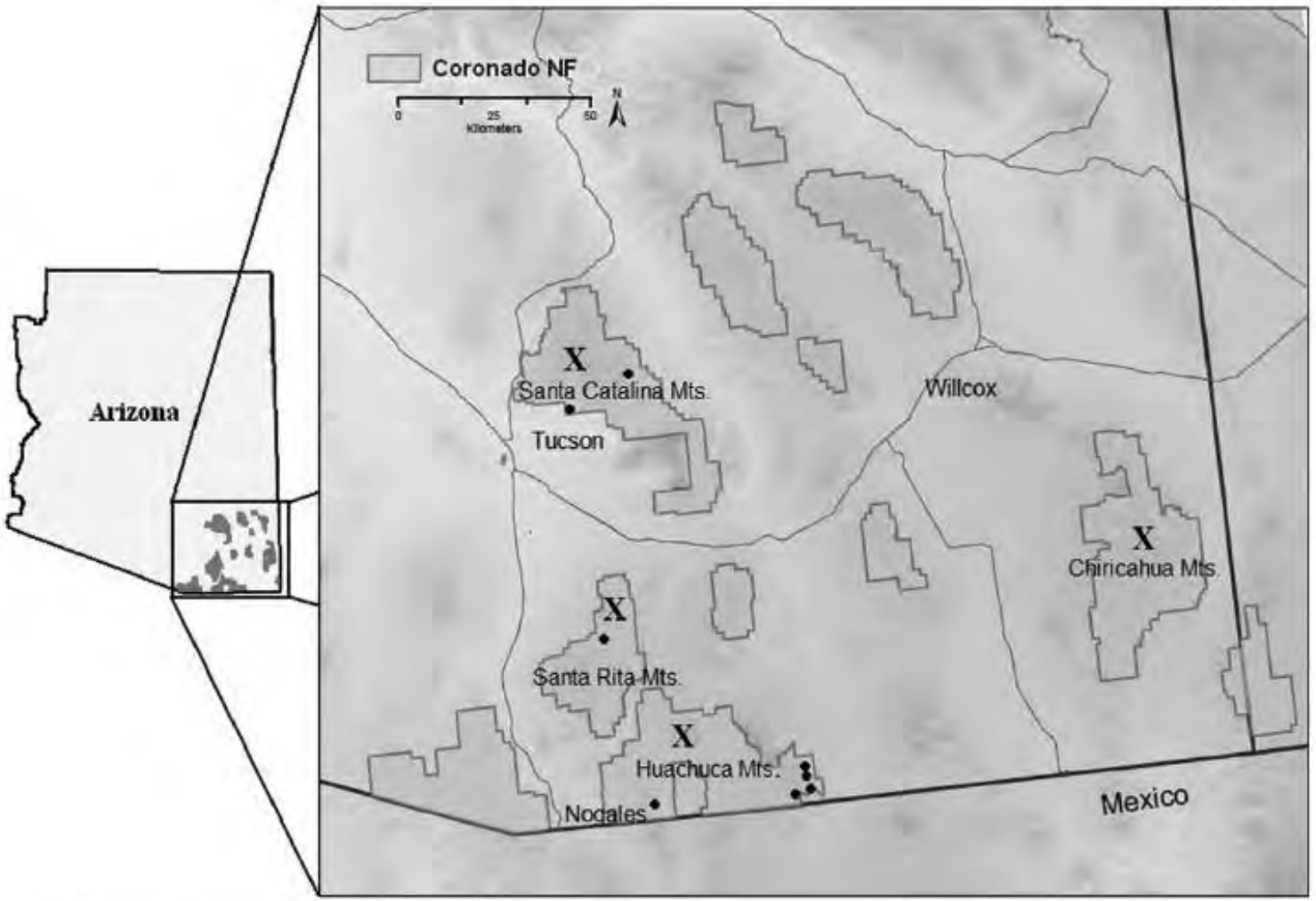


Fig. 2. The four mountain ranges (Santa Catalina, Santa Rita, Huachuca, and Chiricahua) in the Coronado National Forest in southeastern Arizona where historical collections of *Agrilus auroguttatus* were made. General localities (X) are noted on the four mountain ranges, but a few exact localities (•)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

Historical Collection Records of GSOB in Southeastern AZ

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

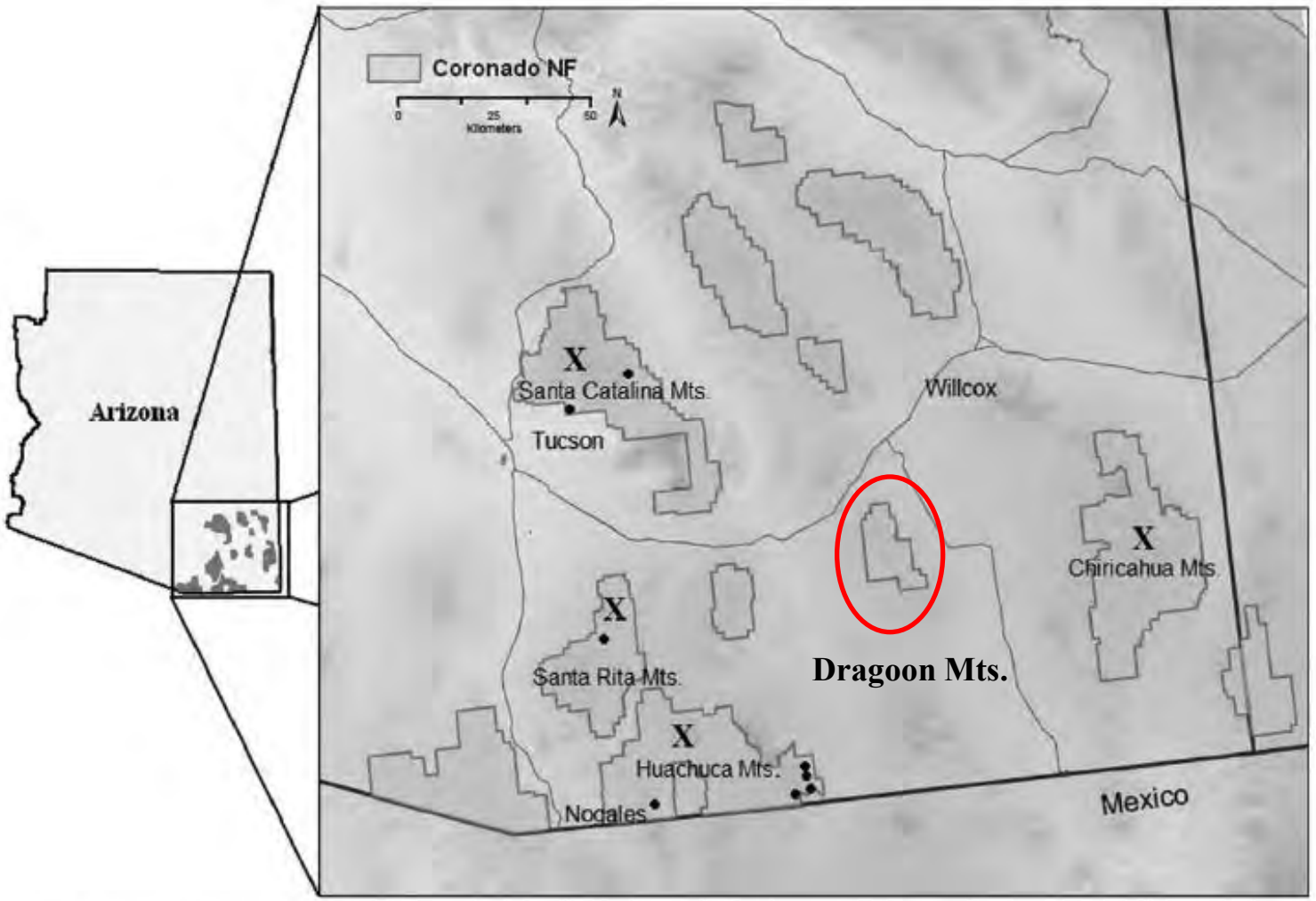
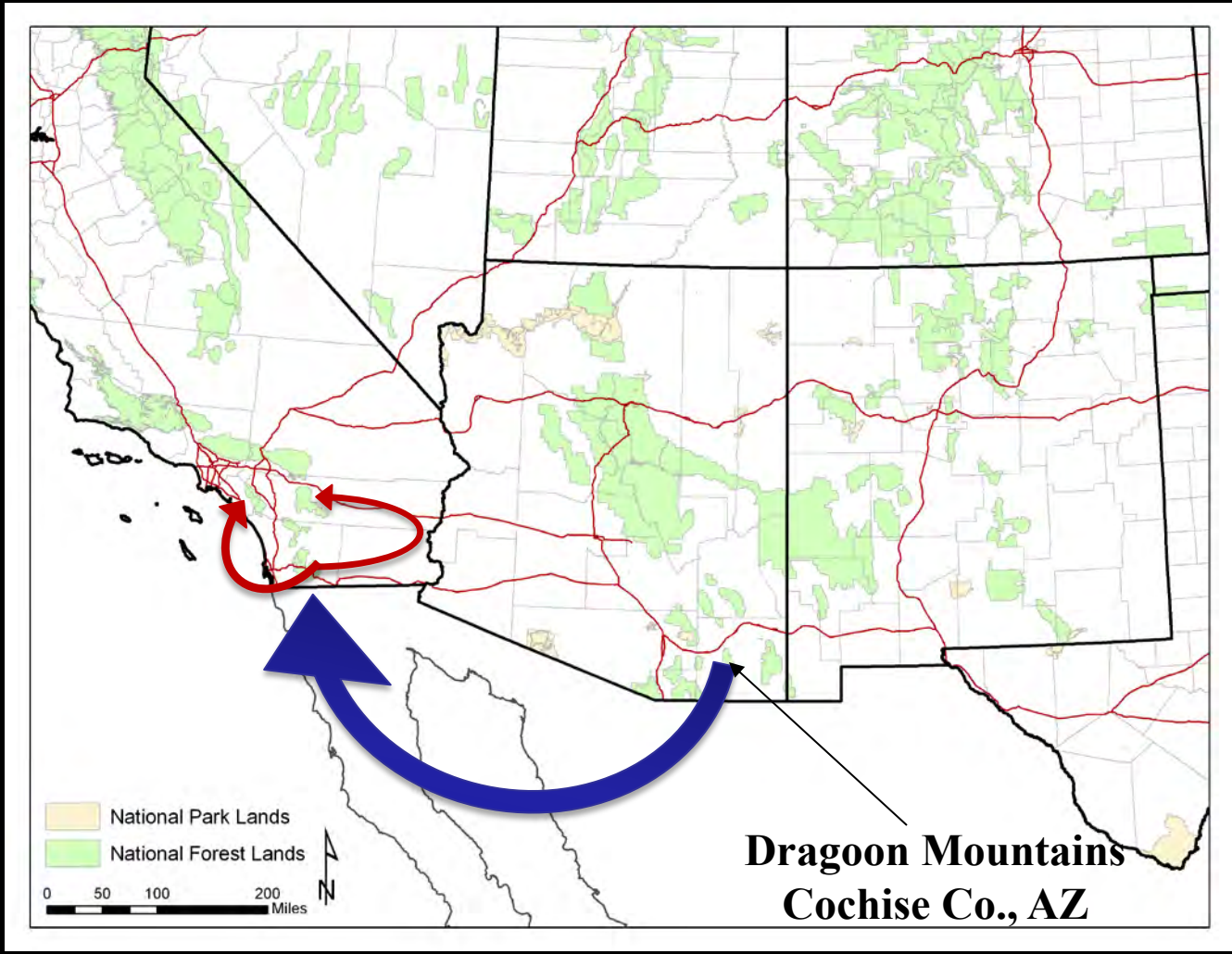


Fig. 2. The four mountain ranges (Santa Catalina, Santa Rita, Huachuca, and Chiricahua) in the Coronado National Forest in southeastern Arizona where historical collections of *Agrilus auroguttatus* were made. General localities (X) are noted on the four mountain ranges, but a few exact localities (•)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

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 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

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 coxidase I · Phylogeography · Wood-borer

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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

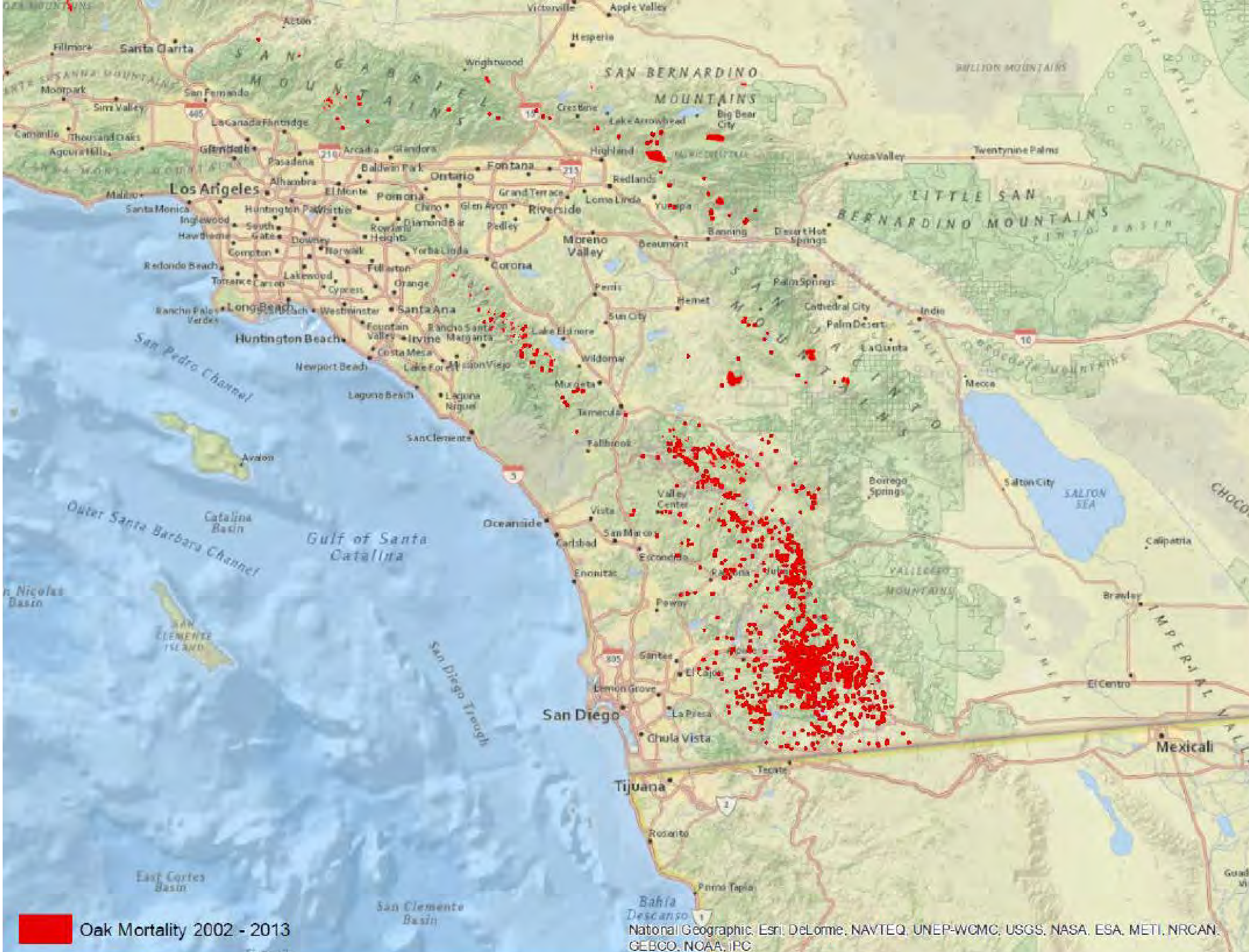
Vanessa Lopez

Richard Stouthamer

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

Oak Mortality 2002 - 2005
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, IPC
SAN GABRIEL MOUNTAINS
SAN BERNARDINO MOUNTAINS
LITTLE SAN BERNARDINO MOUNTAINS
SAN JACINTO MOUNTAINS
Los Angeles
San Diego
Tijuana
Mexicali
Riverside
Santa Ana
Long Beach
Huntington Beach
Oceanside
Gulf of Santa Catalina
San Pedro Channel
Outer Santa Barbara Channel
SALTON SEA
Santa Clarita
Victorville
Apple Valley
Hesperia
Fontana
Ontario
Pomona
Corona
Moreno Valley
Redlands
Palm Springs
Indio
Temecula
Escondido
Chula Vista
El Centro
Brawley


Oak Mortality 2002 - 2007
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
SAN GABRIEL MOUNTAINS
SAN BERNARDINO MOUNTAINS
LITTLE SAN BERNARDINO MOUNTAINS
SAN JACINTO MOUNTAINS
Los Angeles
Santa Clarita
San Fernando
Pasadena
Fontana
Ontario
Pomona
Riverside
Redlands
Highland
Big Bear City
Yucca Valley
Twentynine Palms
Moreno Valley
Corona
Santa Ana
Long Beach
Huntington Beach
Irvine
Palm Springs
Cathedral City
Palm Desert
Indio
La Quinta
Temecula
Fallbrook
Valley Center
Vista
Oceanside
Carlsbad
Escondido
Ramona
Julian
Poway
Alpine
El Cajon
San Diego
Chula Vista
Tijuana
Tecate
Mexicali
El Centro
Brawley
Calipatria
Salton City
SALTON SEA
Borrego Springs
Gulf of Santa Catalina
San Pedro Channel
Outer Santa Barbara Channel
Avalon
Catalina Basin
San Diego Trough
Rosarito


Oak Mortality 2002 - 2013
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
SAN GABRIEL MOUNTAINS
SAN BERNARDINO MOUNTAINS
LITTLE SAN BERNARDINO MOUNTAINS
SAN JACINTO MOUNTAINS
Victorville
Apple Valley
Hesperia
Santa Clarita
Fillmore
Moorpark
Simi Valley
San Fernando
Camarillo
Thousand Oaks
Agoura Hills
Glendale
Pasadena
Arcadia
Glendora
Baldwin Park
Ontario
Fontana
Los Angeles
Alhambra
El Monte
Pomona
Riverside
Redlands
Highland
Wrightwood
Crestline
Lake Arrowhead
Big Bear City
Yucca Valley
Twentynine Palms
Santa Monica
Inglewood
Hawthorne
Compton
Redondo Beach
Torrance
Long Beach
Downey
Norwalk
Fullerton
Orange
Santa Ana
Corona
Moreno Valley
Beaumont
Banning
Yucaipa
Desert Hot Springs
Palm Springs
Cathedral City
Palm Desert
La Quinta
Indio
Hemet
Perris
Sun City
Lake Elsinore
Wildomar
Murrieta
Temecula
Fallbrook
Huntington Beach
Irvine
Costa Mesa
Newport Beach
Laguna Beach
San Clemente
Oceanside
Carlsbad
Vista
San Marcos
Escondido
Valley Center
Ramona
Encinitas
Poway
Santee
El Cajon
Lemon Grove
La Presa
San Diego
Chula Vista
Tijuana
Tecate
Rosarito
Mexicali
Mecca
Salton City
SALTON SEA
Borrego Springs
Calipatria
Brawley
El Centro
Avalon
San Pedro Channel
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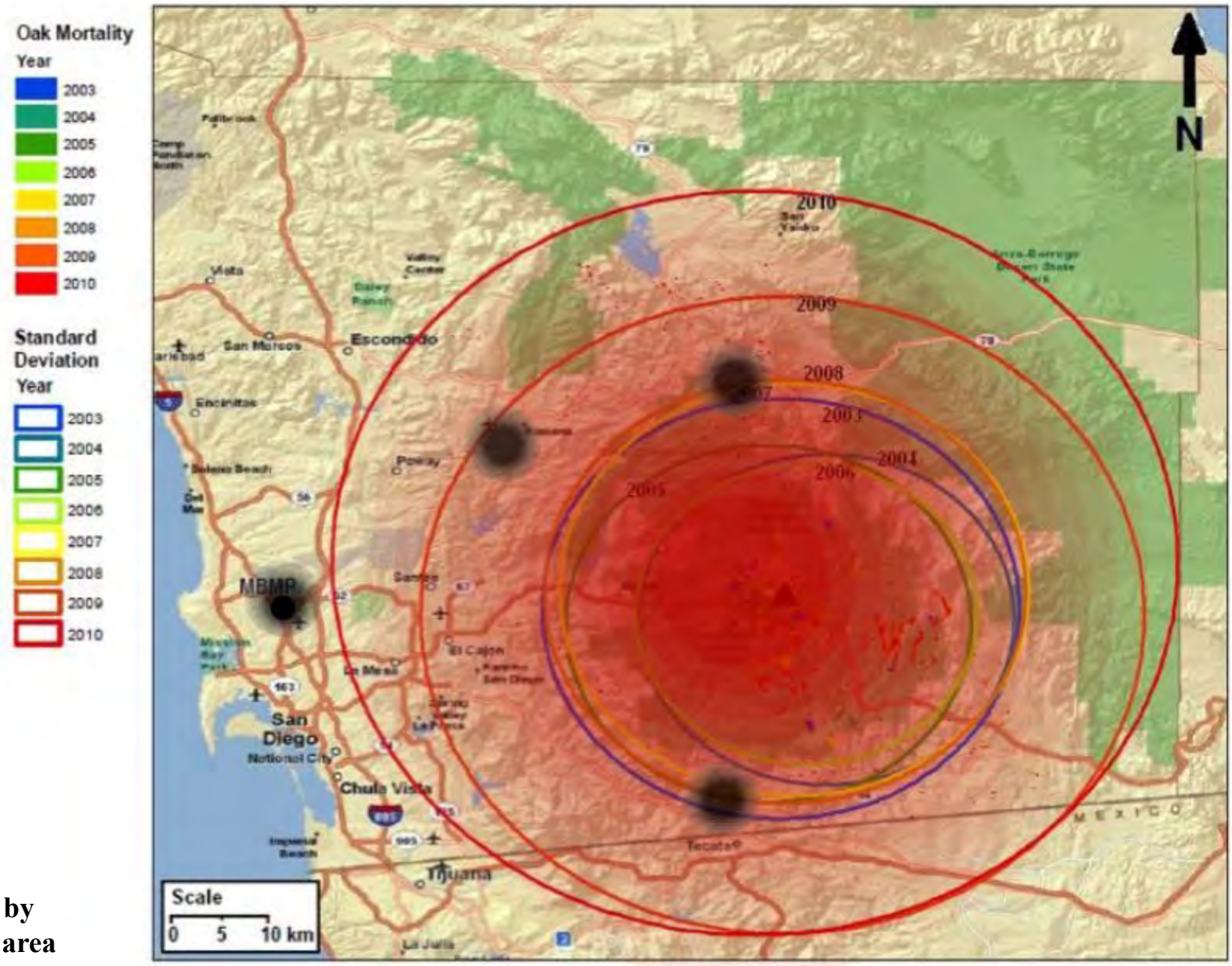
Catalina Basin
Outer Santa Barbara Channel
San Diego Trough
San Clemente Basin
East Cortes Basin
Bahía Descanso



~25,000 oaks Have been killed by GSOB within an area of 212,460 ha in San Diego Co. (USDA FS, FHM 2013).

Coleman et al. (2012) *Forest Ecology and Management 276:*104-117

Aerial Detection of Southern California Oak Mortality

Time from infection to mortality

- ***Armillaria*** **& Host Species**
- **Inoculum potential of the individual fungus**
  - **Larger resource base = more aggressive**
- **Health and age of the host**
  - **Young trees (less than 15 years old, especially in plantations) often girdled**
  - **Older trees can often contain the infection**
- **Environment**
  - **Moist conditions**

In Managed Forests

- **In some western US forests, up to 35% of annual mortality**

- **Especially aggressive ar**
  damaging in young trees

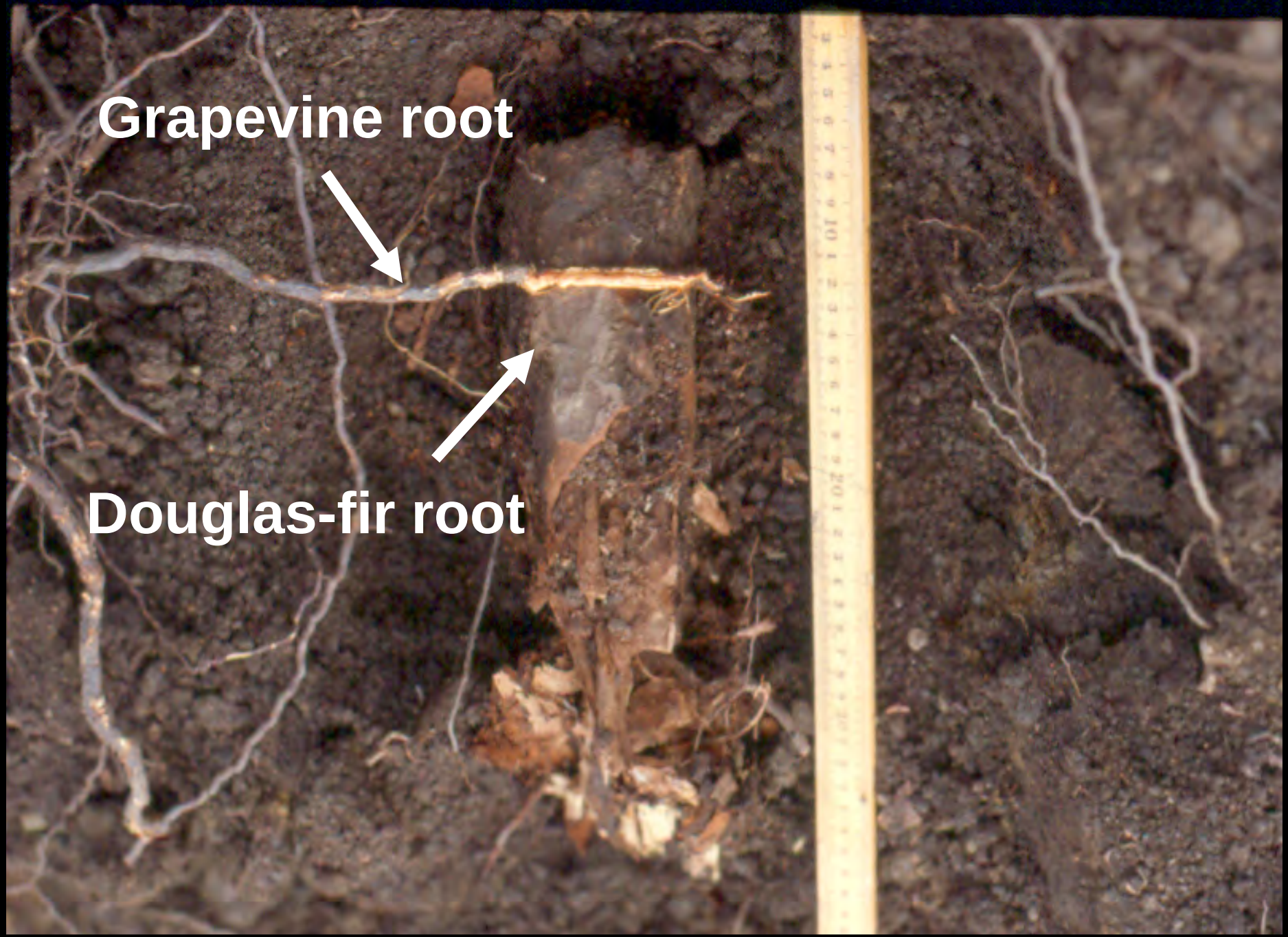
- **High risk of infection lasts 10-15 years after logging (primary inoculum)**

Control

- **Avoid off-site trees that may be stressed and pre-disposed**
- **Removal of inoculum = tree and root system removal**

Landscape, Vineyards, Orchards

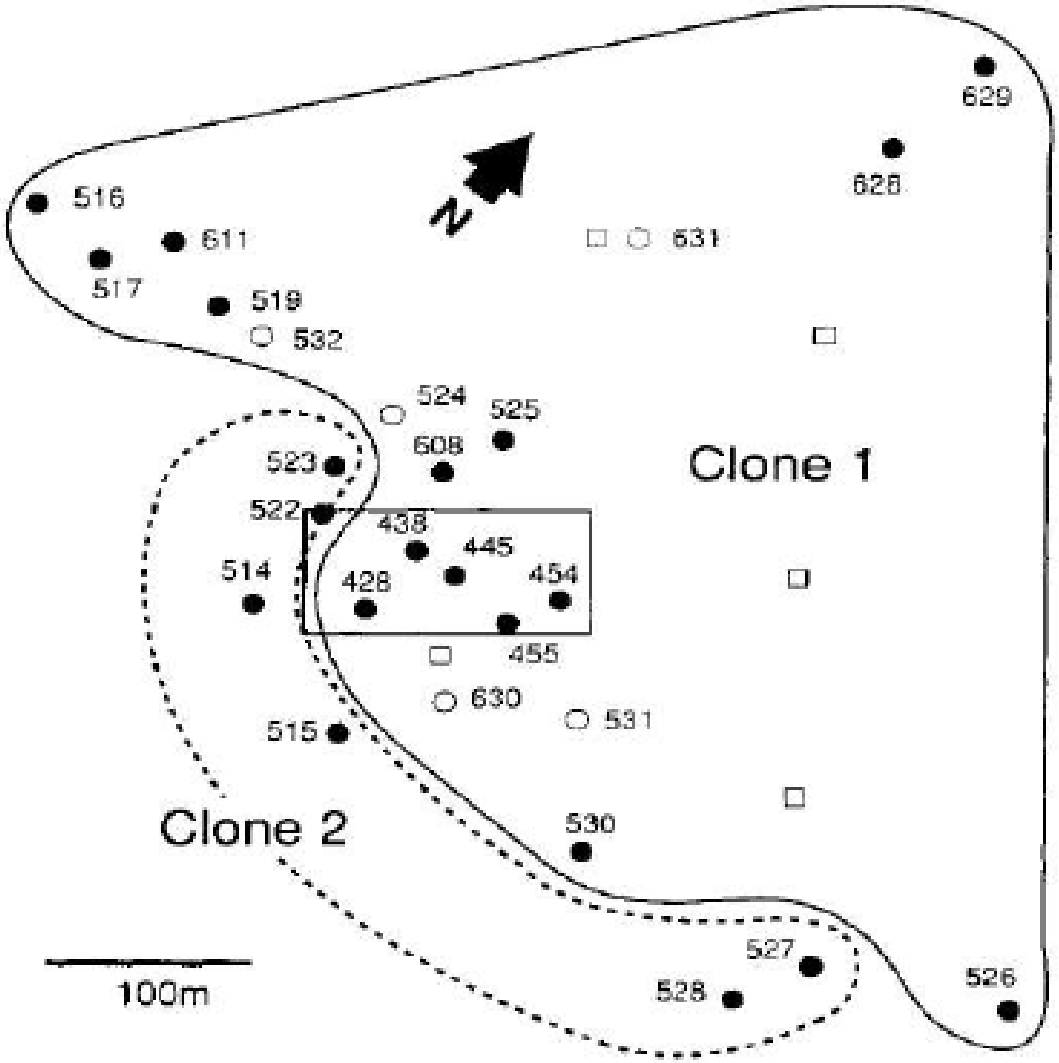
- Common in Urban settin
- Important disease of sto
  fruits, also infects citrus, walnuts, and grapes
- Most severe on sites previously occupied by hardwoods, especially oaks (reason for the common name


Grapevine root
Douglas-fir root

Control: Urban & Agricultural

- **Avoid Overwatering**
- **Reduce wounding**
- **Removal of stumps/dead wood that can harbor the fungus**
- **If hot and dry, can removal of soil from the root collar can help infected hosts recover, may kill the fungus**

Smith, M.L., J.N. Bruhn & J.B. Anderson. (1992) The fungus *Armillaria bulbosa* is among the largest and oldest living organisms. **Nature** 356(2) 428-431.

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37-ACRE "HUMONGOUS FUNGUS"
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Top 10 Interesting Facts about the 37-Acre Fungus

10. Came out of hiding to appear as character witness in Gotti trial.
9. Bill Clinton once tried smoking some of it.
8. Has vanity plate: "FUNGUS-1".
7. Some polls show it's running neck-and-neck with Jerry Brown.
6. Elvis once had staff try to bulldoze it onto 40-acre pizza.
5. Section of it used to make William Shatner's hairpiece.
4. Might be an old YMCA they forgot to disinfect.
3. Smarter than Quayle.
2. Nickname: "Debbie".
1. Tastes a little like chicken.

April 9, 1992