The Goldspotted Oak Borer: Revisiting the Status of an Invasive Pest Six Years After Its Discovery[1]

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Abstract

The goldspotted oak borer, *Agrilus auroguttatus* (Coleoptera: Buprestidae), was first associated with oak mortality in San Diego County, California in May of 2008. Since that time, a research and survey program has outlined the biology of this flatheaded borer in the invaded and native habitats; delimited the invaded range; and developed the components of an integrated pest management (IPM) program. Significant advances have been made in the understanding of its host range, feeding habits, life cycle, and natural enemies in Arizona and California. Some research progress has also been made on the evaluation of techniques for the detection of the pest and treatments to ameliorate its damage. Since the original discovery, we have learned that *A. auroguttatus* feeds primarily on red oaks in the section *Lobatae* and that although its landscape-level impacts unfold slowly, it appears to be capable of killing these trees without the aid of abiotic or other biotic factors. The biology, behavior, and impact of *A. auroguttatus* have also been contrasted with a less well understood sibling species, the Mexican goldspotted oak borer, *Agrilus coxalis*. The key questions remaining about *A. auroguttatus* are: 1) Has sufficient progress been made to facilitate a functional IPM program should the expanding distribution of *A. auroguttatus* reach the urban oaks of the Los Angeles basin or woodland oaks in the foothills of the Sierra Nevada? and 2) Can we assess the risk and predict the population expansion to these lands?

Key words: *Agrilus auroguttatus*, California black oak, canyon live oak, coast live oak, goldspotted oak borer, mortality agent

Introduction

The goldspotted oak borer (GSOB), *Agrilus auroguttatus* (Coleoptera: Buprestidae) (fig. 1), is a flatheaded borer of the phloem and outer xylem that was first collected and described in the early 1900s from specimens from the Huachuca Mountains in southeastern Arizona (Schaeffer 1905). It was not noted as an economically or ecologically important associate of oaks (Brown and Eads 1965, Cibrian and others 1995, Furniss and Carolin 1977) until it was collected in survey traps in southern California in 2004 (table 1) and associated with dying oaks in eastern San Diego County in 2008 (Coleman and Seybold 2008a, b). Thus, this beetle is an indigenous exotic species (Dodds and others 2010, Seybold and Downing 2009) that has expanded its range in a discrete fashion from one native North American ecosystem to another with rather dramatic consequences to non-co-evolved oaks in the new habitat. In comparison to its pines (*Pinus* spp.) and other conifers, California

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has a relatively depauperate guild of insects that colonize the phloem and xylem of oaks and, prior to the advent of *A. auroguttatus*, none of these insect species has had a significant area-wide impact on the health of oaks (table 2).

Figure 1—Dorsal view of an adult female goldspotted oak borer, *Agrilus auroguttatus* (Coleoptera: Buprestidae). (photo: USDA Forest Service, Northeastern Area Forest Health Protection, Durham, NH Office)

Table 1—First collection records of goldspotted oak borer, *Agrilus auroguttatus*, in California[a]

Date	County	Location	Collection method	Specimens
VI-18-2004	San Diego	Chambers Park Campground, Lake Cuyamca,, N of Cuyamaca Rancho State Park	Survey trap	1, CSCA[b]
VII-16-30-2004	San Diego	Paso Picacho Campground, Cuyamaca Rancho State Park	Survey trap	2, CSCA[b]
VII-24-2006	San Diego	Julian, 4945 Heise Park Road	Funnel trap catch with exotic *Ips* lure	1, CSCA[b]
VI-27-2008	San Diego	Noble Canyon Trailhead, Cleveland National Forest	Purple flight intercept traps near *Quercus agrifolia*	2, CAS[c]
X-26-2012	Riverside	Idyllwild, along Hwy 243	Beneath the bark of *Quercus kelloggii*	2-3 larvae[d]
XII-8-2014	Orange	Weir Canyon	Beneath the bark of *Q. agrifolia*	5 larvae[d]

[a] Coleman and Seybold (2011).

[b] California State Collection of Arthropods, Sacramento, California.
[c] California Academy of Sciences, San Francisco, California.
[d] No vouchered specimens because the larvae were destructively sampled as a consequence of the mtDNA analyses conducted at UC-Riverside for Riverside County specimens (Lopez and others 2014b) and Orange County specimens (Rugman-Jones and others, unpublished data).

Table 2—The entomological context for the goldspotted oak borer, *Agrilus auroguttatus* (Coleoptera: Buprestidae), invasion of California: bark and woodboring insects associated with declining oaks and tanoaks[a]

Species	Feeding group	Significance (early vs. late in decline cycle)
Agrilus auroguttatus Schaeffer[b]	flatheaded borer, phloem and outer xylem of stem and largest branches	Highly significant, early
Coleoptera: Scolytidae		
Pseudopityophthorus pubipennis (LeConte)/ *P. agrifoliae* Blackman	bark beetles, phloem of stem and branches	Moderately significant, can be early on seriously weakened trees
Monarthrum dentiger (LeConte)/ *M. scutellare* (LeConte)	ambrosia beetles, xylem of stem and branches	Moderately significant, late—stem breakage of SOD-infected trees
Gnathotrichus pilosus (LeConte)	ambrosia beetle, xylem of stem and branches	Moderately significant, late—stem breakage of SOD-infected trees
Xyleborinus saxeseni (Ratzeburg)[b]	ambrosia beetle, xylem of stem and branches	Not significant, late, important for wood decomposition
Cyclorhipidion bodoanum (Reitter)[b]	ambrosia beetle, xylem of stem and branches	Not significant, late, important for wood decomposition
Coleoptera: Buprestidae		
Chrysobothris femorata (Olivier)/*mali* Horn/*wintu* Wellso and Manley	flatheaded borers, flatheaded appletree borer, Pacific flatheaded borer, bark and outer xylem of stem and branches	Not significant, late, important for wood decomposition
Agrilus angelicus (Horn)	flatheaded borer, Pacific oak twig girdler, xylem of small branches and twigs	Not significant, early, but attacks peripheral portions of tree
Coleoptera: Bostrichidae		
Scobicia declivis (LeConte)	false powderpost beetle, lead cable borer, xylem of stems and branches	Not significant, late, important for wood decomposition
Coleoptera: Cerambycidae		
Xylotrechus nauticus (Mannerheim)	roundheaded borer, oak cordwood borer, phloem and xylem of stem and branches	Moderately significant, can be early on seriously weakened trees
Phymatodes lecontei	roundheaded borers,	Moderately significant, can be

Linsley/*decussatus* (LeConte)	phloem and xylem of dying branches/stem	early on seriously weakened trees
Neoclytus conjunctus (LeConte)	roundheaded borer, phloem and xylem of dying branches/stem	Moderately significant, can be early on seriously weakened trees

[a] Beh and others (2014), Brown and Eads (1965), Coleman and Seybold (2008b, 2011), Furniss and Carolin (1977), Kelsey and others (2013), McPherson and others (2008), Swiecki and Bernhardt (2006)
[b] Invasive species.

Research and survey activities since 2008 have established that colonization by larvae of this beetle leads to the mortality of large diameter (>45.7 cm (18 inches) in diameter at breast height, DBH) red oaks (*Quercus*, Section *Lobatae*) and that the feeding activity of the larvae is not always associated with pathogenic fungi or other microorganisms (Lynch and others 2014). The decline of the primary hosts in California (coast live and California black oaks) is a long process (conservatively 3 to 5 years) (Chen and others 2015, Haavik and others 2015), which provides a window of opportunity for management of the pest. The key to limiting future expansion of the invaded range of *A. auroguttatus* is thought to be the prevention of the movement of infested firewood (Jones and others 2013). Based on new biological data collected since 2008, a risk assessment and a map of the projected distribution for *A. auroguttatus* are under development (Venette and others, Assessing the risks posed by goldspotted oak borer to California and beyond, these proceedings).

Invasion history, feeding habits, host range, and life history

The awareness that a new pest might be damaging oaks in San Diego County developed slowly in the 1990s and 2000s when anecdotal reports of dying trees were attributed variously to drought; deteriorating air quality; a native flatheaded borer called the Pacific twig girdler, *Agrilus angelicus*; or pathogens in the genus *Phytophthora* (Bohne and Rios 2006, 2007, 2008; Garbelotto and Hüberli 2006, Rizzo and Garbelotto 2003; Pavel Švihra, University of California Cooperative Extension, retired, personal correspondence). Although it was tempting to connect the areawide demise of the coast live oaks, *Quercus agrifolia*, California black oaks, *Q. kelloggii*, and canyon live oaks, *Q. chrysolepis*, in San Diego County to sudden oak death, caused by *Phytophthora ramorum*, which was causing oak mortality further to the north in California (Rizzo and Garbelotto 2003), no evidence of *P. ramorum* was ever detected in the San Diego County zone of oak mortality (P.A. Nolan, County of San Diego, personal communication). Because no cause could be linked to the decline of these oaks, the syndrome was described ambiguously as "oak croak," and considered to be a drought-related event (Bohne and Rios 2006, 2007, 2008).

In May 2008, larvae of a buprestid in the genus *Agrilus* were recovered from the main stem of declining oaks on the Descanso Ranger District of the Cleveland National Forest (Coleman and Seybold 2008b). Because there were no records of a main-stem-infesting species of *Agrilus* on California oaks (Furniss and Carolin 1977), we speculated at first amongst ourselves that these might be an introduced population of the twolined chestnut borer, *Agrilus bilineatus*, from the eastern United States (Haack and Benjamin 1982) or of the oak splendour beetle, *Agrilus biguttatus* from central Europe (Moraal and Hilszczański 2000). However, rearing of the larvae and flight trapping at the site revealed that the species that was killing these oaks was a taxon or taxa that had been known to coleopterists for many years as either *Agrilus coxalis* or *A. auroguttatus*. The relatively "ancient" taxonomic literature (Fisher 1928, Schaeffer 1905,Waterhouse 1889) that accompanied these taxa provided the only biological background on these pests in the absence of the traditional forest entomological monographs for western North America (Cibrian and others 1995, Furniss and Carolin 1977). A survey of museum collections established the complete, but sparse, collection history of both taxa (Coleman and Seybold 2011), which provided some limited data on the seasonal activity of the adults. In addition to specimens recovered from declining oaks, the invasive *Agrilus* in California had been trapped in 2004 and 2006 in the vicinity of the infested area of the Cleveland National Forest by survey entomologists with the California Department of Food and Agriculture (table 1). These finds had been reported as a new locality record in the taxonomic literature (Westcott 2005). Following a period of discussion, analysis, and deliberation by morphologists and molecular population geneticists, it became clear that the population of this organism in San Diego County was *A. auroguttatus* and that its introduction into California was consistent with a source population from the Dragoon Mountains (fig. 2) in southeastern Arizona (Coleman and Seybold 2009, Coleman and others 2012b, Hespenheide 1979, Hespenheide and Bellamy 2009, Hespenheide and others 2011, Lopez and others 2014b, Westcott 2005). *Agrilus auroguttatus* had also been collected on one occasion from southern Baja California (Westcott 2005) and is also thought to occur elsewhere in northern Mexico and perhaps in New Mexico (Coleman and Seybold 2011). *Agrilus coxalis*, on the other hand, is only known from the area from the central Mexican mainland south to Guatemala (Coleman and Seybold 2008b, 2011; Coleman and others 2012a,b, 2015a). Although there were unsubstantiated reports of the importation of oak firewood into the general area of eastern San Diego County from Mexico and the high probability of the movement of firewood along the general tourist route from New Mexico and Arizona via Interstate Highway 8 to San Diego, the specific details of where, when, and how *A. auroguttatus* came to be established in and around the rural communities of Descanso, Guatay, and Pine Valley, California have not been ascertained. The two species have been assigned common names: the goldspotted oak borer, *A. auroguttatus*, and the Mexican goldspotted oak borer, *A. coxalis*.

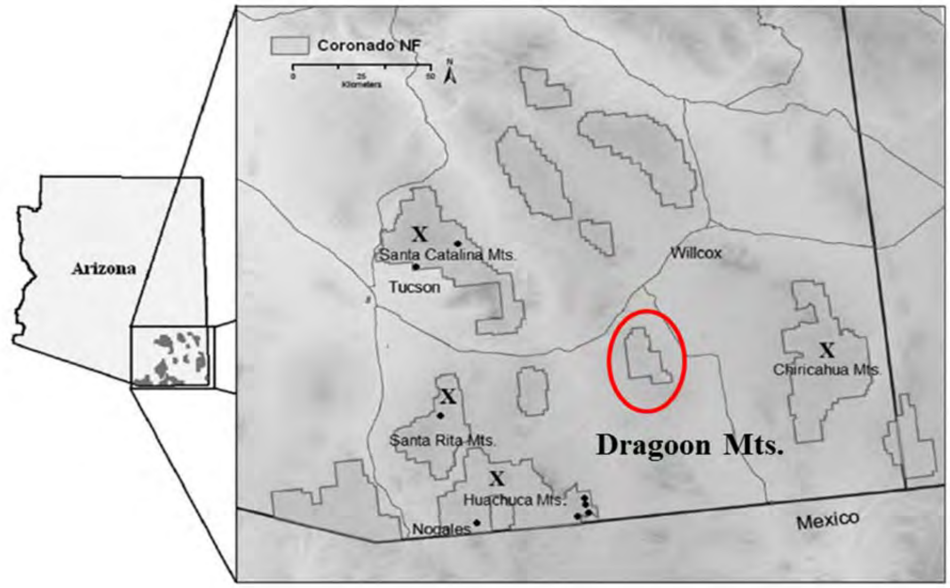

Figure 2—Historical collection records of the goldspotted oak borer, *Agrilus auroguttatus*, from four mountain ranges (Santa Catalina, Santa Rita, Huachuca, and Chiricahua) in the Coronado National Forest in southeastern Arizona (Coleman and Seybold 2011). General collection localities are denoted by an X, whereas specific locations from collection labels are indicated by black dots (•). The putative origin of the population of *A*. *auroguttatus* that has been introduced into California is circled in red (Lopez and others 2014b).

Adult *A. auroguttatus* feed on oak foliage; larvae feed on the phloem and outer xylem. The adult feeding removes foliar tissue from the periphery of oak leaves, but appears to have little bearing on the health of the crown. Details of the foliage feeding behavior of the adults in the field have not been observed. In contrast, much more is known about the larval feeding habits (Coleman and Seybold 2008b, Haavik and others 2013). Larvae mine initially through the phloem in a general radial direction, ingest this tissue, and create meandering and generally longitudinal galleries filled with boring dust (frass) where the phloem meets the xylem. These subcortical galleries are stained black in color when the outer bark is removed for examination of the larvae. The larvae appear to feed primarily at the interface between the xylem and phloem. Thus, the feeding activity of the larvae damages the nutritive and water-conducting tissue of the tree as well as the morphogenic thin layer of cambium responsible for formation of the xylem and phloem. The feeding activity also elicits oak sap flow, which is manifested as pools of sap around the patches of necrotic tissue below the bark as well as sap staining on the bark surface. In some cases in *Q. agrifolia*, the tree exudes a deep red sap secretion that forms globules on the bark surface in response to the underlying feeding activity. Larval frass is never observed on the bark surface.

The host range has been examined in both the adults and the larvae. In laboratory tests, Chen and others (2013) found that adult *A. auroguttatus* generally had a preference for *Q. kelloggii* foliage when tested in dual choice arrangements with *Q. agrifolia*, *Q. chrysolepis*, and *Q. engelmannii* (a white oak, *Quercus* Section *Quercus*). In a no-choice laboratory study, foliage from white alder, *Alnus rhombifolia*, elicited overall poor performance of adults when compared with oaks (Haavik and others 2014b). Field surveys in Arizona, California, and Mexico (*A. coxalis*) provided initial assessments of the host ranges of the larvae (Coleman and Seybold 2011; Coleman and others 2012a, 2012b, 2015a). In California, larval *A. auroguttatus* have been observed in the field in the phloem of *Q. agrifolia*, *Q. chrysolepis*, and *Q. kelloggii*, and rarely in *Q. engelmannii*. Adult emergence through the outer bark has occurred on all of these species (Coleman and others 2015b). In Arizona, *A. auroguttatus* develops in two red oaks (Section *Lobatae*) Emory oak, *Q. emoryi*, and silverleaf oak, *Q. hypoleucoides*, as hosts (Coleman and Seybold 2011, Haavik and others 2014a), whereas in Mexico, *A. coxalis* develops in a red oak (Section *Lobatae*), *Q. conzatti*, and a white oak (Section *Quercus*), *Q. peduncularis* (Coleman and others 2012b). The complete host range of *A. coxalis* is poorly understood. In laboratory tests with cut oak logs, larvae of *A. auroguttatus* rarely completed development fully (Haavik and others 2014b). However, quantification of partial larval development suggested that larvae of this species would feed on both red and white oaks as well as taxonomically intermediate species, *Q. chrysolepis* (*Quercus* Section *Protobalanus*) and *Q. suber* (*Quercus* Section *Cerris*). Of note, phloem of one white oak, valley oak, *Q. lobata*, was fed on by larvae during the laboratory assays, whereas phloem of two other white oaks, Oregon white oak, *Q. garryana*, and *Q. engelmannii* were not fed on by larvae (Haavik and others

2014b). The quantitative differences in preference by *A. auroguttatus* for its various hosts as assessed in the laboratory and in the field could bear more research scrutiny, as could its potential to feed on oak species from eastern North America.

A newly published U.S. Department of Agriculture, Forest Service Forest Insect and Disease Leaflet (Coleman and others 2015b) and a University of California Cooperative Extension Pest Note (Flint and others 2013) provide thorough summaries of the life history (fig. 3) and photographs of the life stages of *A. auroguttatus* in California. These summaries are based largely on the research of L.J. Haavik at University of California Davis (Haavik and others, 2012a, 2012b, 2013, 2014a, 2014b, 2015) and V.M. Lopez at University of California, Riverside (Lopez 2013, Lopez and Hoddle 2013, 2014, Lopez and others 2014a, 2014b). In brief, the eggs are thought to be laid in crevices on the bark surface shortly after the initiation of the adult flight season (middle of May-end of September). By analogy to other *Agrilus* sp., the adults are expected to feed on the foliage in the upper crown after emergence (Rodriguez-Saona and others 2007). Mating also may take place at this location, though *Agrilus* in eastern North America on birch, *Betula*, and poplar, *Populus*, appear to mate on the vertical or prostrate (in other words, fallen) stems of these trees in these genera (Carlson and Knight 1969). Males and females of *A. bilineatus* also have been reported to mate on the branches and trunks of *Quercus* in eastern North America (Haack and Acciavatti 1992), whereas males and females of the emerald ash borer, *Agrilus planipennis*, have been reported to mate on the foliage and stems of ash, *Fraxinus*, in China (Wang and others 2010). In North America, male *A. planipennis* have landed and attempted to mate with female decoys on both the stems (Rodriguez-Saona and others 2007) and the foliage (Lelito and others 2007) of ash. Rodriquez-Saona and others (2007) proposed that the “primary mate-finding strategy of *A. planipennis* involves active visual search by males for females on tree trunks.” Nothing further of the location of mating behavior of *A. planipennis* seems to be known from the invasive North American population (Herms and McCullough 2014). Unlike *A. planipennis*, which colonizes ash trees by initiating oviposition in the upper crown before the main stem (Herms and McCullough 2014), female *A. auroguttatus* tend to move to the lower bole (Coleman and others 2014) to oviposit. Males are also found to land on the main stem (Coleman and others 2014), which suggests that mating may occur here too. Under optimal conditions in the laboratory, female adults can survive for 72.1 (±6.3) days. When paired with a single male and water and oak foliage, females become sexually mature after 8 days; have an ovipositional period of 43.6 (±7.4) days; and lay approximately 200 eggs (Lopez and Hoddle 2014). In the field, larvae hatch from the eggs, mine through the outer bark and into and through the phloem. Larval feeding occurs primarily from mid-June to late November and considerable feeding occurs where the phloem meets the xylem. After completing their feeding activity, larvae tunnel back toward the bark surface where they create a small pupal cell about 3.2 to 6.4 mm (1/8 to 1/4 inches) below the bark. This late larval stage (the pre-pupa) can be found throughout most of the year (mid-October to mid-June) when compared to the other life stages (Haavik and others 2013). There are four larval instars (Haavik and others 2013). The pupa is present from early April to late July after which metamorphosis to the adult occurs followed by emergence through a distinctive D-shaped hole in the bark surface. The life cycle is thought to take a complete year (univoltine), but some individuals may require an additional fraction of a year to complete development (Haavik and others 2013).

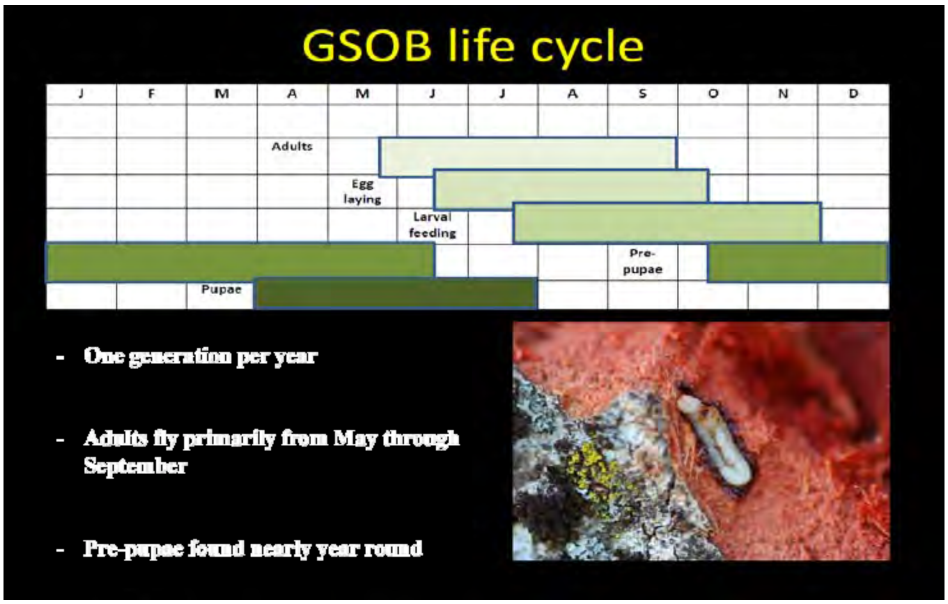

Figure 3—Univoltine life cycle of the goldspotted oak borer, *Agrilus auroguttatus*. Lower right: Pre-pupa or “J-larva” in quiescent repose in a pupal cell near the bark surface of coast live oak, *Quercus agrifolia* (T.W. Coleman, photo). This is the most frequently encountered life stage (Haavik and others 2013).

Impact on California oaks and landscapes

As a phloem/cambium/xylem borer of the main stem (Mattson and others 1988), *A. auroguttatus* belongs to a class of pests that ranks amongst the most pernicious of forest insects in terms of its impact to the health of trees. As a newcomer to California’s oak ecosystems, *A. auroguttatus* appears to find itself in a habitat with highly vulnerable host species accompanied by limited biological regulation of its population. The loss of functional phloem as a consequence of the high densities of larval mines on the xylem surface of dead and dying oaks accompanied by a similarly high density of adult emergence holes through the bark surface (Chen and others 2015, Haavik and others 2014a) are together a testament to the impact of *A. auroguttatus* on the trees. Necrosis of the outer xylem and phloem leads to crown decline and loss of photosynthetic capacity. These declines appear to occur gradually. Coast live oaks under more advanced cases of infestation show physiological symptoms of water stress that resemble trees experiencing drought (Coleman and others 2011). With coast live oak, host colonization by *A. auroguttatus* has been recorded primarily on trees greater than 15 to 20 cm in DBH; trees below this threshold appear to escape colonization (Chen and others 2015, Coleman and others 2012a, Haavik and others 2014a).

In landscape-level surveys throughout the infested area in San Diego County, just over 60 percent of oaks show evidence of colonization by *A. auroguttatus* (Coleman and others 2012a). In the core area where tree mortality appears to have been occurring for about 10 years, this estimate approaches 90 percent (Coleman and others 2012a). At two experimental sites in the core area, the rates of new infestation of *Q. agrifolia* over a 2.5 year study period were 50 percent and 32 percent (Chen and others 2015). Oak mortality throughout the infested area has been assessed at 13 percent, with the estimate climbing to 50 percent in the core area (Coleman and others 2012a). In contrast, mean oak infestation rates for *A. auroguttatus* and *A. coxalis* were approximately 4 percent in their respective native habitats in Arizona and southern Mexico. Mean rates of oak mortality were only 2 percent in these instances (Coleman and others 2012a). Across the landscape in San Diego County, nearly 28,000 trees have been thought to have been killed by *A. auroguttatus* (USDA FS FHM 2014) with aerial detection showing mortality occurring at a generally expanding radial pattern through 2010 and intensification over the infested area with time. Sites at the periphery show new cases of infestation and mortality that occur at a relatively gradual rate (Haavik and others 2015). In the core area the dynamics of decline and mortality also appear to be gradual (Chen and others 2015), but where trees have died and have not been salvaged for firewood, rather dramatic changes in the structure and distribution of fuels are occurring in the canopy, in the understory, and on the surface of the forest floor (Coleman, Influence of the goldspotted oak borer on fuel loading in southern California, these proceedings).

Management, dispersal, and risk assessment—what can we do and what is the risk of doing nothing?

Since its discovery on oaks in 2008, considerable research on *A. auroguttatus* has been conducted to provide the foundation for an integrated pest management (IPM) program (table 3). For an IPM program to be efficacious, a certain degree of synthesis must occur between our knowledge of the biology of this pest and our approaches to monitor the organism and control its populations (fig. 4). The techniques to detect and control the pest have to be tested and validated.

Table 3—Developing the elements of an integrated pest management program for the goldspotted oak borer (GSOB), *Agrilus auroguttatus*, in California

Element	Key findings	References
Biology and host range	Discovery of injury in CA Adult feeding preference on foliage Larval feeding preference on cut logs Number, phenology, and feeding location of larval instars Distinguishing adult males and females Adult longevity and flight capacity	Chen and others (2013); Coleman and Seybold (2008b, 2009, 2010b); Haavik and others (2013, 2014b); Lopez and Hoddle (2013, 2014); Lopez and others (2014a).
Quantifying impact	Injury symptoms and tree health rating system Induced water stress as a consequence of larval feeding Interaction with other wood borers in CA and AZ Infestation and injury rates in CA, AZ, and MX	Chen and others (2015); Coleman and others (2011, 2012a); Coleman and Seybold (2010a); Haavik and others (2012b, 2014a,b, 2015); Hishinuma and others (2011); Lynch and others (2014); Seybold and Coleman (2010a).
Monitoring and detection	Monitoring guidelines and trapping techniques	Coleman and others (2014).
Control-biological	Discovery of GSOB natural enemies in AZ and CA Description of *Calosota elongata* from AZ Distribution of *Calosota elongata* in CA GSOB population genetics and origin of invasive population in CA	Coleman and others (2012b, 2015a); Coleman and Seybold (2011); Gibson (2010); Haavik and others (2012a); Lopez (2013); Lopez and others (2014b).
Control-mechanical	Use of sanitation (tarping, grinding, and debarking) as a management tool for infested wood	Jones and others, (2013); Seybold and others (2010a).
Control-chemical	Systemic insecticide options for GSOB	Chen and others (2015); Coleman and others (in preparation).
Outreach/ synthesis	Summaries of identification, biology, life history, and management strategies	Coleman and Seybold (2008a); Coleman and others (2009, 2015b); Flint and others (2011, 2012, 2013); Seybold and Coleman (2010b).

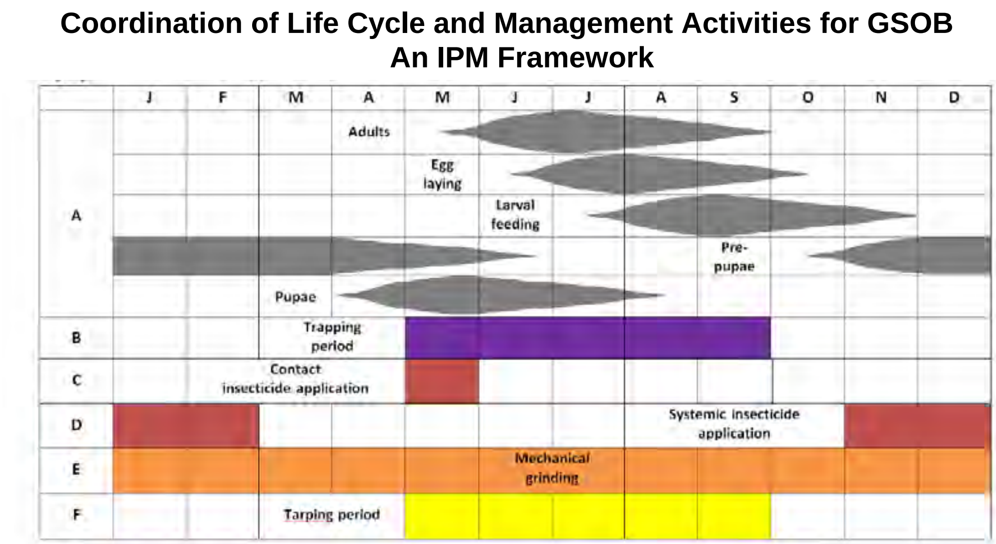

Figure 4—Synthesis of the goldspotted oak borer, *Agrilus auroguttatus*, life cycle with the monitoring and control steps of an integrated pest management program (Coleman and others 2015b).

With *A. auroguttatus* we have a primitive monitoring tool, which is an unbaited purple-colored sticky trap (Coleman and others 2014, Francese and others 2008). This trap has been used to delimit the invasive population in San Diego County (fig. 5). However, it failed to detect a satellite population in Riverside County because the survey traps there were too distant from the point of introduction. Presently, this trap cannot be used to provide a quantitative estimate of populations of *A. auroguttatus*, but it has been used to outline the period of seasonal flight activity (Coleman and others 2014, Haavik and others 2013). A lure to increase the trap catch is still lacking, and complexity revealed by work on the chemical ecology of *A. planipennis* suggests that developing a powerful olfactory-based lure for *A. auroguttatus* may be difficult (Crook and Mastro 2010). Field assays with potential semiochemicals originating from oak foliage and stem volatiles have not revealed any attractants for *A. auroguttatus*, though some of these prospective behavioral chemicals have elicited electrophysiological responses from the antennae of *A. auroguttatus* (Coleman and others 2014).

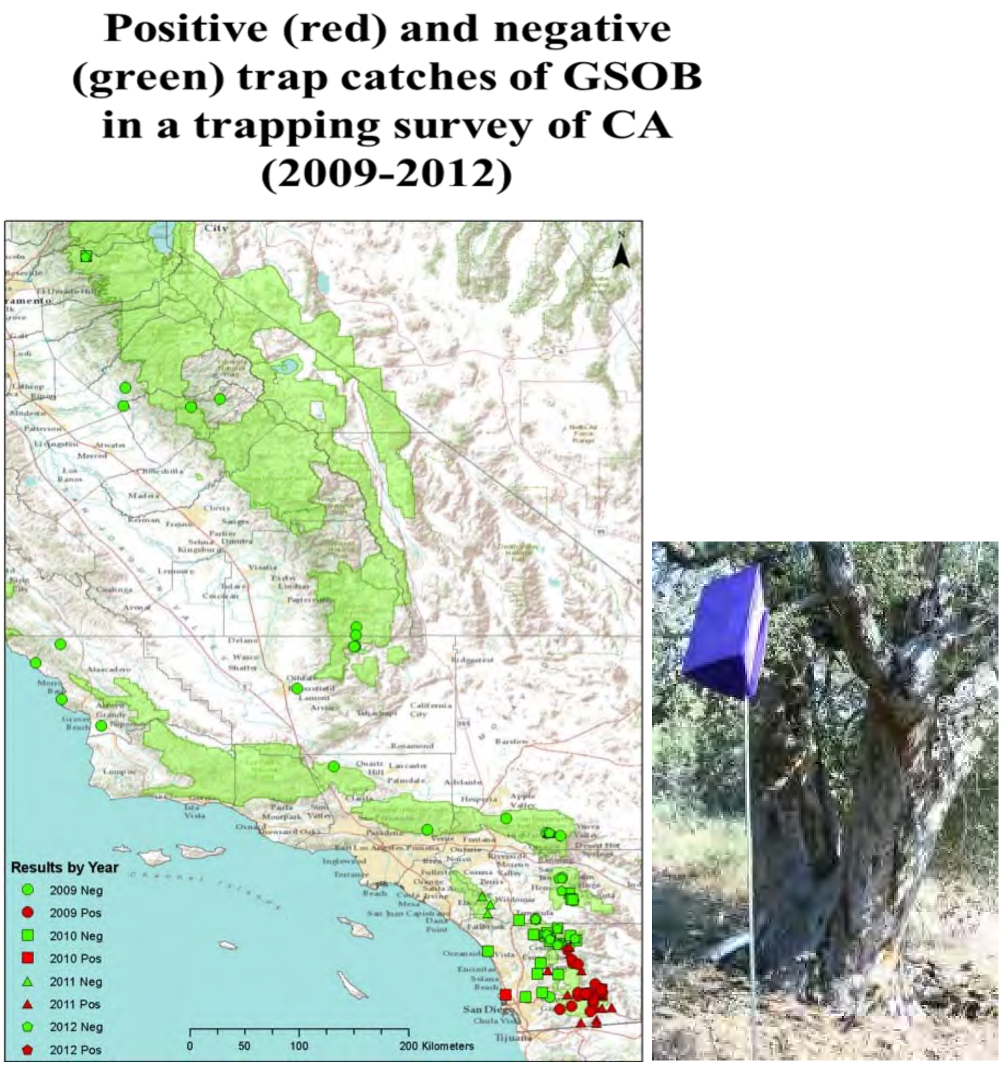

Figure 5—Delimited distribution of the goldspotted oak borer, *Agrilus auroguttatus*, in southern California based on a 4-year flight trapping survey with purple prism sticky traps (right) (Coleman and others 2014). The borer was only trapped in flight in San Diego County during the survey. Since the end of this survey period, the beetle has also been found in Riverside and Orange Counties (not shown).

Control of populations of *A. auroguttatus* can be approached from three perspectives: biological control; mechanical control; and chemical control. Although considerable effort has been expended to lay the groundwork for biological control (Lopez 2013), it appears that the difficulties encountered in mass rearing *A. auroguttatus* will preclude our capacity to rear and release its natural enemies. An ensemble of natural enemies has been identified (table 3), and this “alpha-level” effort has also resulted in the description of a new wasp species, *Calosota elongata*, which appears to specialize on larvae of *A. auroguttatus* (Coleman and Seybold 2011, Gibson 2010). This exophytic larval parasitoid occurs both in the native (Coleman and Seybold 2011) and invaded (Haavik and others 2012a) habitats of *A. auroguttatus*. The expansion of the distribution of *A. auroguttatus* in southern California (Coleman and others 2014, Haavik and others 2015) and the relatively high levels of oak mortality in the core area of the distribution (Coleman and others 2012a) suggest that none of the natural enemies documented so far appears to have had much of an impact in regulating the population density of the invasive pest. It is possible that the introduction of *C. elongata* to San Diego County is a fairly recent event and that there is a delay in the biological regulation until this parasitoid has increased its own population density. Nonetheless, further exploration may be necessary to reveal additional natural enemies, particularly egg parasitoids that may have greater specificity for *A. auroguttatus*. This exploration might take place in Arizona, New Mexico, and northern Mexico in the native range of *A. auroguttatus* or in southern Mexico and Guatemala in the native range of the sibling species. Conservation of the limited arthropod natural enemies in the invaded habitat through judicious use of insecticides may be an important factor (see below). One obvious class of predators of *A. auroguttatus* are woodpeckers such as the acorn woodpecker, *Melanerpes formicivorus* and Nuttall's woodpecker, *Picoides nuttallii* (both Piciformes: Picidae) (Coleman and others 2011), but the degree of impact of these birds on the sessile larvae, pre-pupae, and pupae of *A. auroguttatus* has not been quantified.

Sanitation techniques for reducing the population density of *A. auroguttatus* have involved tarping, debarking, or chipping/grinding firewood-sized pieces of oak wood (Jones and others 2013). This research has demonstrated unequivocally that *A. auroguttatus* will develop and emerge from firewood and that tarping the wood and exposure to intense sunlight will not prevent the adults from emerging. Further, care must be taken with chipping the wood in attempts to destroy the larvae. Only grinding the wood to a 7.6 cm (3 inches) chip size is sufficient to prevent adult emergence from the treated firewood pieces (fig. 6). Debarking firewood is also an effective means of separating the beetle life stages from the xylem, but the bark itself must be treated subsequently to kill the remaining insects (Jones and others 2013). Techniques for protecting oaks from *A. auroguttatus* with insecticides have been explored in two studies in San Diego County (Chen and others 2015, Coleman and others, unpublished data). It is likely that only uninfested or newly infested trees (0 to 25 emergence holes on the lower stem) will have a high probability of being protected by these treatments (Coleman and others 2015b). By analogy with the work on *A. planipennis* and ash trees (Herms and others 2014), the focus of this research has been on systemic insecticides based on emamectin benzoate and imidacloprid as active ingredients. Neither of these insecticide trials have provided overwhelming evidence of the efficacy of these materials and one study (Chen and others 2015) is continuing for another 3 years with re-treatment of the test trees in December 2014.

In 2008-2009, a preliminary risk assessment for *A. auroguttatus* (then thought to be *A. coxalis*) was developed to project the distribution based solely on the range of the hosts (Downing and others 2009). A more elaborate risk assessment has been prepared (Venette and others, Assessing the risks posed by goldspotted oak borer to California and beyond, these proceedings), and this projection of the potential spread of the beetle into suitable habitat is based on biological data related to freeze tolerance, host susceptibility, and dispersal capacity of the adult beetle (table 3), as well as on the temperature/precipitation conditions of the habitat under assessment.

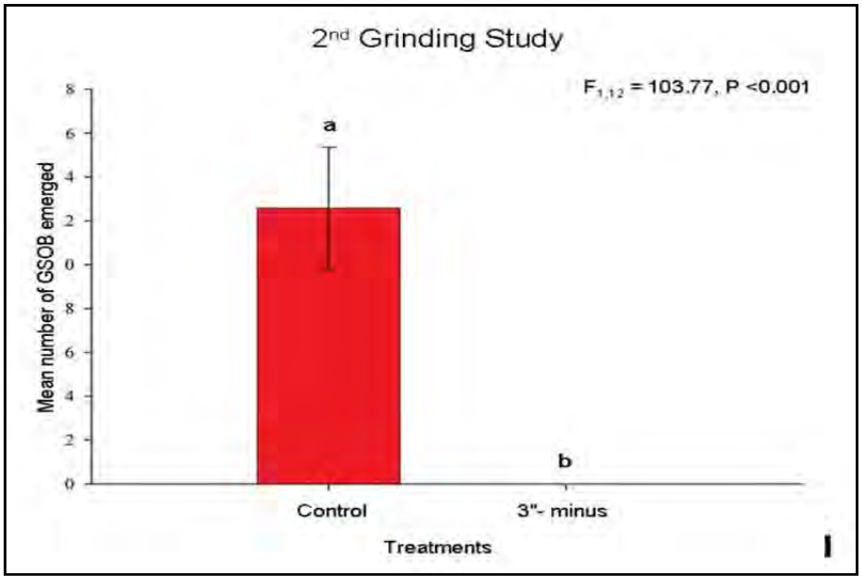

Figure 6—The most effective sanitation technique for managing the goldspotted oak borer, *Agrilus auroguttatus*, in firewood is grinding to a 3 inch piece size (Jones and others 2013).

Conclusions

Since *A. auroguttatus* was first associated with oaks in California in 2008, significant advances have been made in understanding its host range, feeding habits, life cycle, natural enemies, and impact in Arizona and California. A suite of management approaches have been tested individually during this period as well. The outlines of an IPM program are beginning to take shape and these guidelines have been made available to the public in the technology transfer literature (Coleman and others 2015b, Flint and others 2013). Progress in assembling and transferring this information is occurring none-to-soon, as *A. auroguttatus* has moved in the last several years into two counties north of its San Diego County point of establishment (table 1). Our understanding of the risk that *A. auroguttatus* poses to oak resources in California and Oregon is coming into focus as the key biological data are being analyzed and synthesized into a formal assessment (Venette and others, Assessing the risks posed by goldspotted oak borer to California and beyond, these proceedings). However, the specter remains of a calamity for red oaks in a predicted zone of convergence of the invasive distributions of sudden oak death (Rizzo and Garbelotto 2003) and *A. auroguttatus* in the coastal areas north of the Los Angeles Basin.

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References

Beh, M.M.; Metz, M.R.; Seybold, S.J.; Rizzo, D.M. 2014. **The novel interaction between *Phytophthora ramorum* and wildfire elicits elevated ambrosia beetle landing rates on tanoak, *Notholithocarpus densiflorus*.** Forest Ecology and Management 318: 21–33. http://dx.doi.org/10.1016/j.foreco.2014.01.007. (21 February 2015).

Bohne, M.; Rios, J., eds. 2006. **California forest pest conditions-2005**. California Forest Pest Council, Sacramento, CA: California Department of Forestry and Fire Protection. 72 p.

Bohne, M.; Rios, J., eds. 2007. **California forest pest conditions-2006**. California Forest Pest Council, Sacramento, CA: California Department of Forestry and Fire Protection. 57 p.

Bohne, M.; Rios, J., eds. 2008. **California forest pest conditions-2007**. California Forest Pest Council, Sacramento, CA: California Department of Forestry and Fire Protection. 61 p.

Brown, L.; Eads, C.O. 1965. **A technical study of insects affecting the oak tree in southern California.** California Agricultural Experiment Station Bulletin 810. 106 p.

Carlson, R.W.; Knight, F.B. 1969. **Biology, taxonomy, and evolution of four sympatric *Agrilus* beetles (Coleoptera: Buprestidae)**. Contributions of the American Entomological Institute 4(3): 1–105.

Chen, Y.; Coleman, W.; Jones, M.I.; Flint, M.L.; Seybold, S.J. 2013. **Foliar nutrients explain goldspotted oak borer, *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae), adult feeding preference among four California oak species.** Entomologia Experimentalis et Applicata 149: 57–66. doi: 10.1111/eea.12110.

Chen, Y.; Flint, M.L.; Coleman, T.W.; Doccola, J.J.; Grosman, D.M.; Wood, D.L.; Seybold, S.J. 2015. **Impact of the goldspotted oak borer, *Agrilus auroguttatus*, on the health of coast live oak before and after treatment with two systemic insecticides**. Pest Management Science. http://onlinelibrary.wiley.com/doi/10.1002/ps.3959/pdf. (05 February 2015).

Cibrian, T.C.; Mendez, M.J.T.; Campos, B.R.; Yates, H.O. III; Flores-Lara, J. 1995. **Insectos forestales de Mexico/Forest insects of Mexico**. North American Forestry Commission Publication No. 6. Chapingo, Estado de Mexico, Mexico: Universidad Autonoma Chapingo. 453 p.

Coleman, T.W.; Seybold, S.J. 2008a. **New pest in California: the goldspotted oak borer, *Agrilus coxalis* Waterhouse.** Pest Alert R5-RP-022. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Forest Health Protection, Pacific Southwest Region. 4 p.

Coleman, T.W.; Seybold, S.J. 2008b. **Previously unrecorded damage to oak, *Quercus* spp., in southern California by the goldspotted oak borer, *Agrilus coxalis* Waterhouse (Coleoptera: Buprestidae)**. The Pan-Pacific Entomologist 84: 288–300.

Coleman, T.W.; Seybold, S.J. 2009. **Striking gold in southern California: discovery of the goldspotted oak borer and its central role in oak mortality.** In: McManus, K.A.; Gottschalk, K.W., eds. Proceedings, 20th U.S. Department of Agriculture Interagency Research Forum on invasive species, Gen. Tech. Rep. NRS-P-51, Newtown Square, Pennsylvania: U.S. Department of Agriculture, Forest Service, Northern Research Station: 12–16.

Coleman, T.W.; Seybold, S.J. 2010a. **GSOB ≠ SOD: tree mortality from the goldspotted oak borer in oak woodlands of southern California**. In: Frankel, S.J.; Kliejunas, J.T.; Palmieri, K.M., tech. coords. Proceedings of the sudden oak death fourth science symposium. Gen. Tech. Rep. PSW-GTR-229, Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 58–63.

Coleman, T.W.; Seybold, S.J. 2010b. **Verification of a useful character for separating the sexes of the goldspotted oak borer, *Agrilus coxalis auroguttatus* (Coleoptera: Buprestidae).** The Pan-Pacific Entomologist 86: 58–62.

Coleman, T.W.; Seybold, S.J. 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.** The Coleopterists Bulletin 65: 93–108.

Coleman, T.W.; Chen, Y.; Graves, A.D.; Hishinuma, S.M.; Grulke, N.E.; Flint, M.L.; Seybold, S.J. 2014. **Developing monitoring techniques for the invasive goldspotted oak borer (Coleoptera: Buprestidae) in California**. Environmental Entomology. 43: 729–743. http://dx.doi.org/10.1603/EN13162. (05 February 2015).

Coleman, T.W.; Flint, M.L.; Seybold, S.J. 2009. **Managing the invasive goldspotted oak borer in the California wildland-urban interface: Outlines of an IPM Program**. The sixth international IPM symposium, Portland, OR: Abstract P159, P132 (poster).

Coleman, T.W.; Graves, A.D.; Hoddle, M.S.; Heath, Z.; Flint, M.L.; Chen, Y.; Seybold, S.J. 2012a. **Forest stand composition and impacts associated with *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae) and *Agrilus coxalis* Waterhouse in oak woodlands**. Forest Ecology and Management 276: 104–117. http://dx.doi.org/10.1016/j.foreco.2012.03.011. (05 February 2015).

Coleman, T.W.; Grulke, N.E.; Daly, M.; Godinez, C.; Schilling, S.L.; Riggan, P.J.; Seybold, S.J. 2011. **Coast live oak, *Quercus agrifolia*, susceptibility and response to goldspotted oak borer, *Agrilus auroguttatus*, injury in southern California**. Forest Ecology and Management 261: 1852–1865. doi:10.1016/j.foreco.2011.02.008.

Coleman, T.W.; Jones, M.I.; Hoddle, M.S.; Haavik, L.J.; Moser, J.C.; Flint, M.L.; Seybold, S.J. 2015a. ***Pyemotes tritici* (Acari: Pyemotidae): A parasitoid of *Agrilus auroguttatus* and *Agrilus coxalis* (Coleoptera: Buprestidae) in the southwestern United States of America and southern Mexico**. The Canadian Entomologist 147: 244–248. doi:10.4039/tce.2014.38.

Coleman, T.W.; Jones, M.I.; Smith, S.L.; Venette, R.C.; Flint, M.L.; Seybold, S.J. 2015b. **Goldspotted oak borer, *Agrilus auroguttatus*.** Forest Insect & Disease Leaflet No. 183. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region (R6). 16 p. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3833276.pdf. (10 April 2015).

Coleman, T.W.; Lopez, V.; Rugman-Jones, P.F.; Stouthamer, R.; Seybold, S.J.; Reardon, R.; Hoddle, M.S. 2012b. **Can the destruction of California's oak woodlands be**

prevented? Potential for biological control of the goldspotted oak borer, *Agrilus auroguttatus*. BioControl 57: 211–225. doi: 10.1007/s10526-011-9404-4.

Crook, D.J.; Mastro, V.C. 2010. **Chemical ecology of the emerald ash borer, *Agrilus planipennis.*** Journal of Chemical Ecology 36: 101–112.

Dodds, K.J.; Gilmore, D.W.; Seybold, S.J. 2010. **Assessing the threat posed by indigenous exotics: a case study of two North American bark beetle species**. Annals of the Entomological Society of America 103: 39–49.

Downing, M.C.; Coleman, T.W.; Koch, F.H.; Smith, B.D.; Smith, S.L.; Seybold, S.J.; Venette, R.C. 2009. **Invasive pest risk map: goldspotted oak borer**. U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. http://www.fs.fed.us/foresthealth/technology/invasives_agriluscoxalis_riskmaps.shtml. (05 February 2015).

Fisher, W.S. 1928. **A revision of the North American species of buprestid beetles belonging to the genus *Agrilus*.** Bulletin 145. Government Printing Office, Washington DC: Smithsonian Institution, United States National Museum. 347 p.

Flint, M.L.; Coleman, T.W.; Seybold, S.J. 2011. **Goldspotted oak borer threatens California oaks**. CAPCA Advisor Magazine, Sept. 2011, 14(5): 22–23.

Flint, M.L.; Coleman, T.W.; Seybold, S.J. 2012. **California oaks threatened by invading wood borer.** The Western Front Newsletter. Davis, CA: Western Integrated Pest Management Center, University of California, Davis. February: 1, 8.

Flint, M.L.; Jones, M.I.; Coleman, T.W.; Seybold, S.J. 2013. **Goldspotted oak borer**. Publication 74163. Oakland, CA: University of California Statewide Integrated Pest Management Program, Agriculture and Natural Resources Pest Notes. 7 p. http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn74163.html. (16 February 2015).

Francese, J.A.; Oliver, J.B.; Fraser, I.; Lance, D. R.; Youssef, N.; Sawyer, A.J.; Mastro, V.C. 2008. **Influence of trap placement and design on capture of emerald ash borer (Coleoptera: Buprestidae).** Journal of Economic Entomology101: 1831–1837.

Furniss, R.L.; Carolin, V.M. 1977. **Western forest insects**. Miscellaneous Publication No. 1339, Washington, DC: U.S. Department of Agriculture, Forest Service. 655 p.

Garbelotto, M.; Hüberli, D. 2006. **First report on an infestation of *Phytophthora cinnamomi* in natural oak woodlands of California and its differential impact on two native oak species**. Plant Disease 90: 685.

Gibson, G.A.P. 2010. ***Calosota* Curtis (Hymenoptera, Chalcidoidea, Eupelmidae) - review of the New World and European fauna including revision of species from the West Indies and Central and North America**. ZooKeys 55: 1–75.

Haack, R.A.; Acciavatti, R.E. 1992. **Twolined chestnut borer**. Forest Insect and Disease Leaflet 168. Newtown Square, Pennsylvania: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Northeastern Area. 10 p.

Haack, R.A.; Benjamin, D.M. 1982. **The biology and ecology of the twolined chestnut borer, *Agrilus bilineatus* (Coleoptera: Buprestidae), on oaks, *Quercus* spp., in Wisconsin**. The Canadian Entomologist 114: 385–396.

Haavik, L.J.; Coleman, T.W.; Chen, Y.; Jones, M.I.; Venette, R.C.; Flint, M.L.; Seybold, S.J. 2012a. **First occurrence of the goldspotted oak borer parasitoid, *Calosota elongata* (Hymenoptera: Eupelmidae), in California**. The Pan-Pacific Entomologist 88: 374–376.

Haavik, L.J.; Coleman, T.W.; Flint, M.L.; Venette, R.C.; Seybold, S.J. 2012b. ***Agrilus auroguttatus* exit hole distributions on *Quercus agrifolia* boles and a sampling method to estimate their density on individual trees**. The Canadian Entomologist 144: 1–12.

Haavik, L.J.; Coleman, T.W.; Flint, M.L.; Venette, R.C.; Seybold, S.J. 2013. ***Agrilus auroguttatus* (Coleoptera: Buprestidae) seasonal development within *Quercus agrifolia* (Fagales: Fagaceae) in southern California**. Annals of the Entomological Society of America 106: 189–197.

Haavik, L.J.; Coleman, T.W.; Flint, M.L.; Venette, R.C.; Seybold, S.J. 2014a. **Densities of *Agrilus auroguttatus* and other borers in California and Arizona oaks**. Insects 4: 287–300. doi:10.3390/insects40x000x.

Haavik, L.J.; Graves, A.D.; Coleman, T.W.; Flint, M.L.; Venette, R.C.; Seybold, S.J. 2014b. **Suitability of native and ornamental oak species in California for *Agrilus auroguttatus***. Entomologia Experimentalis et Applicata 150: 86–97 doi: 10.1111/eea.12141.

Haavik, L.J.; Flint, M.L.; Coleman, T.W.; Venette, R.C.; Seybold, S.J. 2015. **Goldspotted oak borer effects on tree health and colonization patterns at six newly-established sites**. Agricultural and Forest Entomology 17: 146–157. doi: 10.1111/afe.12090.

Herms, D.A.; McCullough, D.G. 2014. **Emerald ash borer invasion of North America: history, biology, ecology, impacts, and management**. Annual Review of Entomology 59: 13–30.

Herms, D.A.; McCullough, D.G.; Smitley, D.R.; Sadof, C.S.; Cranshaw, W. 2014. **Insecticide options for protecting ash trees from emerald ash borer. 2nd edition.** North Central IPM Center Bulletin. 16 p.

Hespenheide, H.A. 1979. **Nomenclature notes on the Agrilinae (Buprestidae). IV**. The Coleopterists Bulletin 33:105–120.

Hespenheide, H.A.; Bellamy, C.L. 2009. **New species, taxonomic notes, and records for *Agrilus* Curtis (Coleoptera: Buprestidae) of México and the United States**. Zootaxa 2084: 50–68.

Hespenheide, H.A.; Westcott, R.L.; Bellamy, C.L. 2011. ***Agrilus* Curtis (Coleoptera: Buprestidae) of the Baja California peninsula, México**. Zootaxa 2805: 36–56.

Hishinuma, S.; Coleman, T.W.; Flint, M.L.; Seybold, S.J. 2011. **Goldspotted oak borer: field identification guide**. Oakland, CA: University of California Agriculture and Natural Resources, Statewide Integrated Pest Management Program. 6 p. http://www.ipm.ucdavis.edu/PDF/MISC/GSOB_field-identification-guide.pdf. (05 February 2015).

Jones, M.I.; Coleman, T.W.; Graves, A.D.; Flint, M.L.; Seybold, S.J. 2013. **Sanitation options for managing oak wood infested with the invasive goldspotted oak borer (Coleoptera: Buprestidae) in southern California**. Journal of Economic Entomology 106: 235–246. doi: http://dx.doi.org/10.1603/EC12177.

Kelsey, R.G.; Beh, M.M.; Shaw, D.C.; Manter, D.K. 2013. **Ethanol attracts scolytid beetles to *Phytophthora ramorum* cankers on coast live oak.** Journal of Chemical Ecology 39: 494–506.

Lelito, J.P.; Fraser, I.; Mastro, V.C.; Tumlinson, J.H.; Boroczky, K.; Baker, T.C. 2007. **Visually mediated 'paratrooper copulations' in the mating behavior of *Agrilus planipennis* (Coleoptera: Buprestidae), a highly destructive invasive pest of North American ash trees**. Journal of Insect Behavior 20: 537–552.

Lopez, V.M. 2013. **Developing a biological control program for the invasive goldspotted oak borer (*Agrilus auroguttatus* Schaeffer) in southern California**. Riverside, CA: University of California, Riverside. 137 p. Ph.D. thesis.

Lopez, V.M.; Hoddle, M.S. 2013. **Mortality factors affecting *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae) eggs in the native and invaded ranges**. Biological Control 67: 143–148.

Lopez, V.M.; Hoddle, M.S. 2014. **Effects of body size, diet, and mating on the fecundity and longevity of the goldspotted oak borer (Coleoptera: Buprestidae)**. Annals of the Entomological Society of America 107: 539–548. doi: http://dx.doi.org/10.1603/AN13158.

Lopez, V.M.; McClanahan, M.N.; Graham, L.; Hoddle, M.S. 2014a. **Assessing the flight capabilities of the goldspotted oak borer, *Agrilus auroguttatus* Schaeffer (Coleoptera:**

Buprestidae), with computerized flight mills. Journal of Economic Entomology 107: 1127–1135. doi: http://dx.doi.org/10.1603/EC13525.

Lopez, V.M.; Rugman-Jones, P.F.; Coleman, T.W.; Hoddle, M.S.; Stouthamer, R. 2014b. **Population genetics of goldspotted oak borer, *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae): investigating the origin of an invasive pest of native oaks in California**. Biological Invasions 16: 2393–2402. doi 10.1007/s10530-014-0672-7.

Lynch, S.C.; Zambino, P.J.; Scott, T.A.; Eskalen, A. 2014. **Occurrence, incidence and associations among fungal pathogens and *Agrilus auroguttatus*, and their roles in *Quercus agrifolia* decline in California**. Forest Pathology 44: 62–74.

Mattson, W.J.; Lawrence, R.K.; Haack, R.A.; Herms, D.A.; Charles, P.J. 1988. **Defensive strategies of woody plants against different insect-feeding guilds in relation to plant ecological strategies and intimacy of association with insects**, In: Mattson W.J.; Levieux J.; Bernard-Dagan C., eds. Mechanisms of woody plant defenses against insects, search for pattern. New York: Springer-Verlag: 1–38.

McPherson, B.A.; Erbilgin, N.; Wood, D.L.; Švihra, P.; Storer, A.J.; Standiford, R.B. 2008. **Attraction of ambrosia and bark beetles to coast live oaks infected by *Phytophthora ramorum***. Agricultural and Forest Entomology10: 315–321.

Moraal, L.G.; Hilszczański, J. 2000. **The oak buprestid beetle, *Agrilus biguttatus* (F.) (Col., Buprestidae), a recent factor in oak decline in Europe**. Journal of Pest Science 73: 134–138.

Rizzo, D.M.; Garbelotto, M. 2003. **Sudden oak death: endangering California and Oregon forest ecosystems**. Frontiers in Ecology and the Environment 1: 197–204.

Rodriguez-Saona, C.R.; Miller, J.R.; Poland, T.M.; Kuhn, T.M.; Otis, G.W.; Turk, T.; Ward, D.L. 2007. **Behaviors of adult *Agrilus planipennis* (Coleoptera: Buprestidae)**. Great Lakes Entomologist 40: 1–16.

Schaeffer, C. 1905**. Some additional new genera and species of Coleoptera found within the limit of the United States**. Museum of the Brooklyn Institute of Arts and Sciences, Science Bulletin 1(7): 141–179.

Seybold, S.J.; Coleman, T.W. 2010a. **Goldspotted oak borer: a surprising primary mortality agent on oaks in southern California**. In: Parrotta, J.A.; Carr, M.A., eds. Forests for the future: sustaining society and the environment. XXIII IUFRO World Congress, Seoul, Republic of Korea. The International Forestry Review 12(5): 374. (Abstract). www.cfa-international.org. (16 February 2015).

Seybold, S.J.; Coleman, T.W. 2010b. **The goldspotted oak borer: an overview of a research program for "California's emerald ash borer."** In: McManus, K.A.; Gottschalk, K.W., eds. Proceedings, 21st U.S. Department of Agriculture Interagency research forum on invasive species. Gen. Tech. Rep. NRS-P-75, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 123–127.

Seybold, S.J.; Downing, M. 2009. **What risk do invasive bark beetles and woodborers pose to forests of the western U.S.? A case study of the Mediterranean pine engraver, *Orthotomicus erosus***. In: Hayes, J.L.; Lundquist, J.E., compilers. The Western Bark Beetle Research Group: a unique collaboration with forest health protection. Gen. Tech. Rep. GTR–PNW-784. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 111–134.

Seybold, S.J.; Coleman, T.W.; Flint, M.L. 2010a**. Burn it, chip it, or tarp it, but just don't move it: managing oak firewood infested with the goldspotted oak borer, *Agrilus coxalis auroguttatus***. In: Frankel, S.J.; Kliejunas, J.T.; Palmieri, K.M., tech. cords. Proceedings of the sudden oak death fourth science symposium. Gen. Tech. Rep. PSW-GTR-229. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 365–369.

Seybold, S.J.; Grulke, N.E.; Graves, A.D.; Coleman, T.W. 2010b. **Drought and forest insects: interacting stressors on forest ecosystem health**. In: Parrotta, J.A.; Carr, M.A., eds. Forests for the future: sustaining society and the environment. XXIII IUFRO World Congress, Seoul, Republic of Korea. The International Forestry Review 12(5): 357. (Abstract). www.cfa-international.org. (16 February 2015).

Swiecki, T.J.; Bernhardt, E.A. 2006. **A field guide to insects and diseases of California oaks**. Gen. Tech. Rep. PSW-GTR-197. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 151 p.

Wang, X.Y.; Yang, Z.Q.; Gould, J.R.; Zhang, Y.N.; Liu, G.J.; Liu, E.S. 2010. **The biology and ecology of the emerald ash borer, *Agrilus planipennis*, in China**. Journal of Insect Science 10: 128. doi: http://dx.doi.org/10.1673/031.010.12801.

Waterhouse, C.O. 1889. **Insecta. Coleoptera. Serricornia. 62. *Agrilus coxalis***. Biologia Centrali-Americana: Vol. III, Pt. 1.

Westcott, R.L. 2005**. A new species of *Chrysobothris* Eschscholtz from Oregon and Washington, with notes on other Buprestidae (Coleoptera) occurring in the United States and Canada**. Zootaxa 1044: 1–15.