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Goldspotted Oak Borer

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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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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).

diameter trees [>17 inches in diameter at breast height (dbh)]. A sibling species, the Mexican goldspotted oak borer, *A. coxalis* Waterhouse, is native to central and southern Mexico and Guatemala, and was once synonymized with *A. auroguttatus*. Surveys have shown that Mexican GSOB feeds on both red oaks and white oaks (Section *Quercus*) in southern Mexico.

In 2004, GSOB was first detected in survey traps in southern California (San Diego Co.), but it was not linked to tree injury or mortality until 2008. In 2012, GSOB was detected in Riverside Co. and was likely introduced to this new county in infested firewood (Figure 2). The movement of infested firewood was also most likely responsible for additional satellite infestations of GSOB that have been detected elsewhere within San Diego Co., and in Orange Co. Unregulated movement of infested oak wood has presumably facilitated the dispersal of GSOB in southern California and will likely continue to play a role in its future dispersal in California and beyond.

In California, GSOB preferentially attacks and kills large-diameter coast live oaks, *Q. agrifolia* Née, and California black oaks, *Q. kelloggii* Newberry (>18 and 20 inches dbh, respectively). Interior live oak, *Q. wislizeni* A. DC., another red oak species, was susceptible to GSOB larval feeding in laboratory tests, but GSOB has not been observed to infest this oak species in the field. Goldspotted oak borer can also attack a taxonomically intermediate oak species, canyon live oak, *Q. chrysolepis* Liebm. (Section *Protobalanus*), and, on rare occasions, a white oak species, Engelmann oak, *Q. engelmannii* Greene, in California. Goldspotted oak borer has killed canyon live oak at low levels (<25% of surveyed trees) in San Diego Co.

Dead Engelmann oak trees have been observed with signs of GSOB injury (*e.g.*, larval galleries and D-shaped emergence holes, see below), but tree mortality in these cases was likely a result of a complex of factors (*e.g.*, drought and root disease). Several ornamental oak species, including holly oak, *Q. ilex* (Section *Quercus*), and cork oak, *Q. suber* (Section *Cerris*), are planted frequently in the urban areas of southern California and may be at risk. In laboratory studies, GSOB larvae fed on cork oak logs but were unable to complete development. However, it has been hypothesized that species in the Sections *Quercus* and *Cerris* are not favored by GSOB and likely not susceptible to the extensive injury needed to cause tree mortality.

In California, the range of coast live oak extends north from San Diego Co. along the Santa Anita Mountains and Transverse Mountain Range and then to northern California along the Coastal Mountain Range (Figure 3). It also extends south into Baja California Norte, Mexico. California black oak occurs on Mt. Laguna and Palomar Mountain in San Diego Co., the Transverse Mountain Range, Coastal Mountain Range, and along the Sierra Nevada Mountain Range to southern Oregon. Goldspotted oak borer-caused mortality has occurred in coast live oak at sea level as well as in California black oak at elevations up to approximately 6,000 feet in San Diego Co.; in laboratory tests, prepupae (mature larvae in a hair-pin configuration) have shown a cold-tolerance of approximately -0.4° F during the winter months. The beetle's distribution will likely expand from San Diego, Riverside, and Orange Cos. to mirror the range of its primary hosts and conducive climatic conditions in California and into Oregon and Mexico (Figure 3).

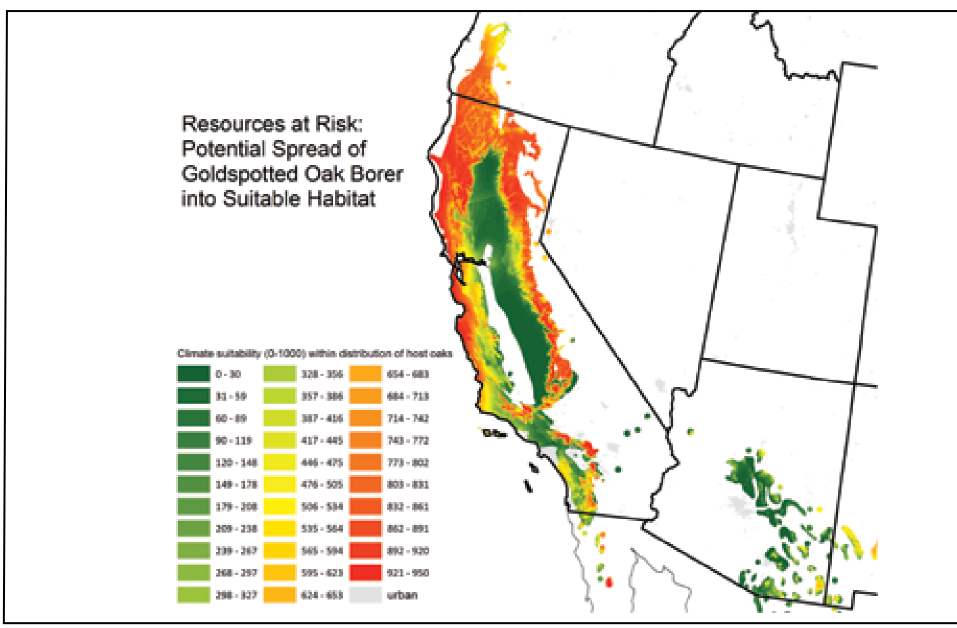


Figure 3. Potential range of goldspotted oak borer in Arizona, California, New Mexico, Oregon, and Baja California Norte, Mexico based on host distributions and climatic suitability. On the map, areas with hosts are colored, and climatically suitable areas within the distribution of hosts appear as shades of yellow (moderately suitable), orange, and red (highly suitable).

Impacts

Neither GSOB nor Mexican GSOB is considered a significant pest or threat to forest health in its native range. Instead, they have caused minor levels of injury to oaks (4% infestation rates) and have been associated with background levels of tree mortality in Arizona (2%) and Mexico (1%). As a consequence, virtually no research related to the biology and ecology of these species occurred prior to 2008 when GSOB-caused oak mortality was discovered in California.

The death of large-diameter coast live oaks and California black oaks in California results from several years of extensive larval feeding at the interface of the phloem and xylem (Figure 4). This feeding kills large sections of live tissue (Figure 4A), including the vascular cambium. As a consequence, the main stem is girdled and the oaks sustain significant injury and, eventually, mortality (Figure 4B). This process appears to be gradual, taking from 3 to 5 years. However, oaks predisposed by other injury agents (*e.g.*, drought and root disease) may succumb more quickly to the effects of GSOB larval feeding.

In coast live oak woodlands in eastern San Diego Co. where trees have suffered at least a decade of infestation from GSOB, oak mortality levels have approached 45%. Infestation rates have been high (>90%) on large-diameter oaks at the hypothetical origin of the beetle's introduction near Descanso and Guatay in San Diego Co., but the rates are lower (<10%) at the edges of the advancing infestation.

The expansion of the core area infested by GSOB has progressed slowly in San Diego Co. despite a maximum adult flight distance of approximately 0.9 miles in tethered flight mill assays in the laboratory. Moderately and severely infested trees (known as brood trees) represent <7% of the oaks in forest stands in areas that have

Figure 4. Typical goldspotted oak borer larval feeding galleries under recently removed bark of a living coast live oak tree (A) and etched on the xylem (wood) surface of a dead coast live oak tree (B). The meandering dark-colored galleries in living phloem and xylem (A) are characteristic of goldspotted oak borer larval feeding.

been infested for longer than a decade. Coast live oak brood trees were also found at low densities in newly infested sites and, based on inferred population density from emergence hole records, they contain 66 to 93% of the GSOB population at these sites. The contrast between the rate of spread of the core population and the appearance of satellite populations in Orange, Riverside, and San Diego Cos. suggests that GSOB will spread slowly *via* natural dispersal or quickly *via* human-assisted dispersal (Figure 2).

Life History

The goldspotted oak borer typically completes one generation in a year. However, anecdotal evidence suggests that populations may require more than one year to complete development in healthier hosts. In southern California, adults fly from mid-May to early October with peak flight occurring in late-June to early July (Table 1A). The majority of adult flight occurs from June to September. Adults can live for several months in the laboratory, but longevity has not been recorded in the field and is likely shorter in duration. Adults feed on oak foliage to survive, and females require approximately 10 days of feeding to become sexually mature and likely mate in the crown or on the bark surface of the main stem or larger branches. In the laboratory, a single female can lay approximately 200-500 eggs. Females lay eggs in fissures and crevices on the bark surface of the main stem and larger branches, either singly or in clusters (Figure 5). The eggs are oval, approximately 0.01 inches wide, tan-colored, and very difficult to find on the bark surface. Eggs develop in approximately 12 days and first instar larvae bore through the bark into the phloem.

Figure 5. Goldspotted oak borer eggs laid on the bark surface of coast live oak.

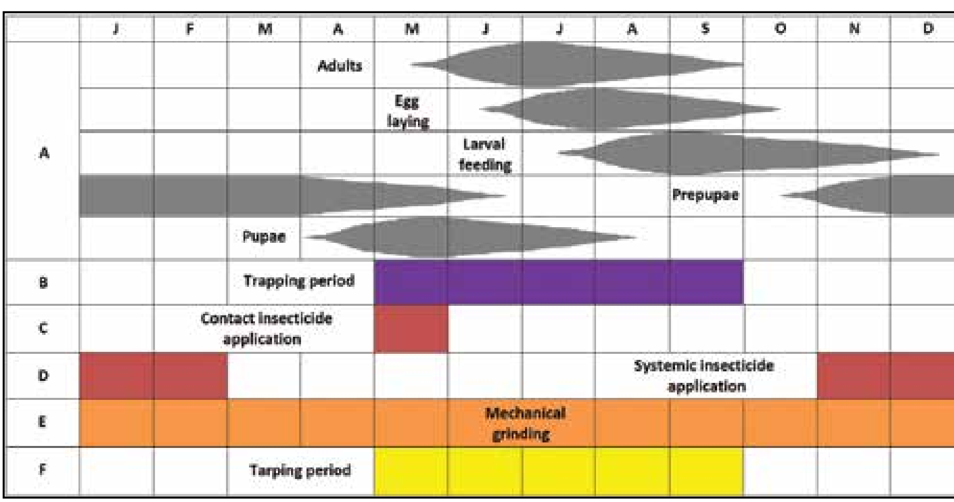


Table 1. Approximate timing of the goldspotted oak borer life cycle in southern California (A) and optimal timing of trapping period (B); application of contact (C) and systemic insecticides (D); and timing of mechanical grinding (E) and tarping (F) of infested oak wood.

Goldspotted oak borer larvae likely complete four instars. Larvae are white, legless, and approximately 0.8 inches long by 0.1 inches wide when fully mature. First instar larvae are <0.05 inches long and difficult to locate in the phloem (Figure 6A). Larvae have C-shaped spiracles (holes where air exchange occurs) and a pair of spines at the tip of the abdomen, both of which can be used to identify all *Agrilus* larvae (Figure 6B). In southern California, larvae can be found feeding from July to mid-December in the phloem and primarily on the outer xylem surface (Table 1A). Mature larvae migrate to the outer phloem just beneath the bark where they create a pupal cell and form a prepupa (Figure 6C,D). Prepupae have been found in the outer phloem nearly year round, but at higher densities during the cooler months (November to May) (Table 1A). Ground surveys and sampling of trees for live GSOB should be conducted at this time of year because mature larvae (prepupae) can be observed easily in the outer phloem (Figure 7).

Immediately prior to pupation, larvae begin to constrict to adult length in the pupal cell (Figure 6D). Pupae and teneral (newly formed) adults are present from April to August in the pupal cells. Pupae are the same size as adults, but initially are white and soft-bodied (Figure 6E). Pupae transform into teneral adults when their exoskeleton begins to sclerotize, or harden, and darken in color.

Adults are black to dark green with three dorsal pairs of gold-colored pubescent spots on the elytra and one faint pair located dorsolaterally on the thorax (Figures 1 and 6F). Additional gold-colored pubescence is located laterally on the thorax and abdomen (Figure 1). Males can be differentiated from females by a ventral groove on the first male abdominal segment. Adults chew a D-shaped emergence hole through the outer bark and are seldom observed in the forest. Adults cause minor and barely noticeable feeding damage to oak foliage, which does not substantially impact tree health.

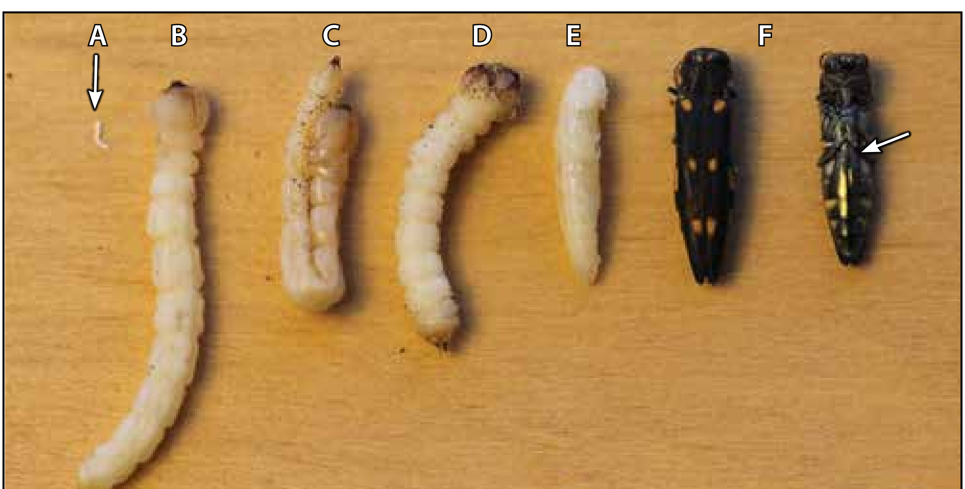


Figure 6. A goldspotted oak borer first instar larva (A), fourth instar larva (B), mature larva/prepupa (C), constricted larva/prepupa (D), pupa (E), and adults (F). The second arrow depicts the location of the ventral longitudinal groove on the abdomen of males.

Figure 7. Goldspotted oak borer mature larva or prepupa can be found in the phloem adjacent to the bark surface of coast live oak.

Evidence of Infestation

Crown thinning and dieback are common indicators of declining oak health and typical of trees that are moderately and severely infested by GSOB. Newly infested trees may have healthy, full crowns, but thinning and dieback become evident following successive years of larval feeding. Crown color of coast live oak trees infested by GSOB or by the impact of various stress factors range from dark green (healthy) to grayish green (severely injured). Thinning crowns can be used to identify potentially infested trees for scrutiny for additional symptoms (see below). However, crown thinning does not always indicate GSOB infestation (*e.g.*, distinct twig or branch mortality (flagging) in the crown can indicate injury by twig girdlers, bark beetles, or scale insects).

Goldspotted oak borer is the only subcortical insect that constructs D-shaped emergence holes on the main stem and larger branches (>8 inches in diameter) of oaks in California, making the presence of these holes a diagnostic sign of infestation by this exotic pest (Figure 8A).

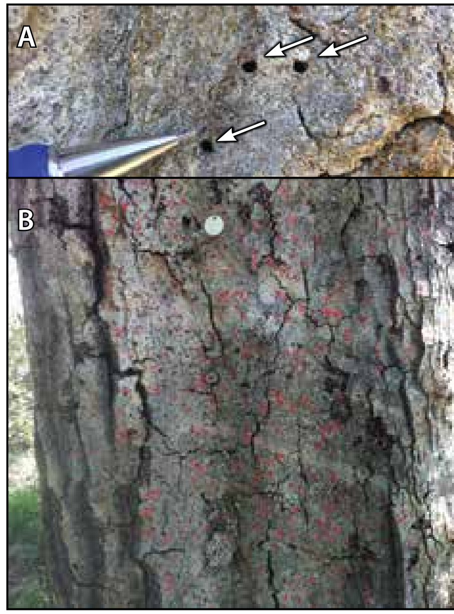


Figure 8. Goldspotted oak borer D-shaped emergence holes on the bark surface of coast live oak (A). High densities of emergence holes (marked in red paint, B) are observed frequently on coast live oak killed by goldspotted oak borer in California.

Unlike some other wood-boring *Agrilus* species, GSOB does not attack the upper branches in the crown during the early stages of infestation. The GSOB adult emergence holes (approximately 0.15 inches in diameter) can appear before any other injury symptoms are observed, but can be easily overlooked when they occur at low densities. A high density of emergence holes (10's to 1,000's/8 feet of lower stem) on coast live oak and California black oak is not uncommon when trees have been infested for several years (Figure 8B). As the population density increases, emergence holes can be observed easily on the lower part of the main stem (<8 feet) of infested oaks. Thus, performing a total count of the emergence holes in this area of the stem can provide an estimate of the extent of GSOB injury.

Removing the outer bark and phloem exposes larvae and the signs of their feeding at the interface of the phloem and xylem. Larval galleries have a meandering pattern; are dark in color when the fresh bark is recently removed; are about 0.16 inches wide when larvae are mature; and are tightly packed with black boring dust (frass). Following infestation by GSOB, secondary wood borers, including other flatheaded borers, *Chrysobothris mali* Horn and *Chrysobothris wintu* Wellso and Manley (Coleoptera: Buprestidae), oak cordwood borers, *Xylotrechus nauticus* Mannerheim (Coleoptera: Cerambycidae), oak ambrosia beetles, *Monarthrum* spp. Kirsch and *Gnathotrichus pilosus* LeConte (both Coleoptera: Scolytidae), and western oak bark beetles, *Pseudopityophthorus* spp. Swaine (Coleoptera: Scolytidae), frequently attack these stressed oaks in southern California. Injury symptoms associated with these secondary insects can be mistaken for GSOB injury; see Flint *et al.* (2013) for a description of their emergence holes.

Dark-colored sap stains on the bark surface can indicate a GSOB-infested tree (Figure 9). Sometimes sap exudate over GSOB-infested areas can manifest as a blood-red secretion that hardens as it dries. Bark staining associated with GSOB injury is frequently observed along the main stem and larger branches, and is not associated with invaginations along the stem, at branch junctions, or mechanically and structurally wounded areas. Several secondary fungi can be associated with these dark-stained bark areas, but they are not always present on infested trees and may only occur after GSOB has already severely injured the tree.

Figure 9. Dark-colored wet staining or red bleeding on the bark is sometimes associated with larval feeding by goldspotted oak borers. Bark staining does not always indicate goldspotted oak borer injury and may only appear after extensive injury has occurred.

Acorn woodpeckers, *Melanerpes formicivorus* Swainson (Piciformes: Picidae), forage for larvae, prepupae, and pupae just beneath the bark surface in the outer phloem. Woodpecker foraging occurs frequently from fall to early summer when larval densities are highest in these areas of the tree stem. Woodpeckers chip away the outer oak bark exposing the red phloem (in coast live oak) and the dark-colored larval galleries and pupal cells (Figure 10). The phloem exposed by woodpecker foraging turns black with age and thus becomes less evident over time. The degree of woodpecker foraging can vary greatly by site, but can be very extensive on heavily infested trees.

Figure 10 Woodpecker foraging for goldspotted oak borer prepupae on the main stem can expose larval galleries, pupal cells, and red phloem of coast live oak.

Management

Monitoring

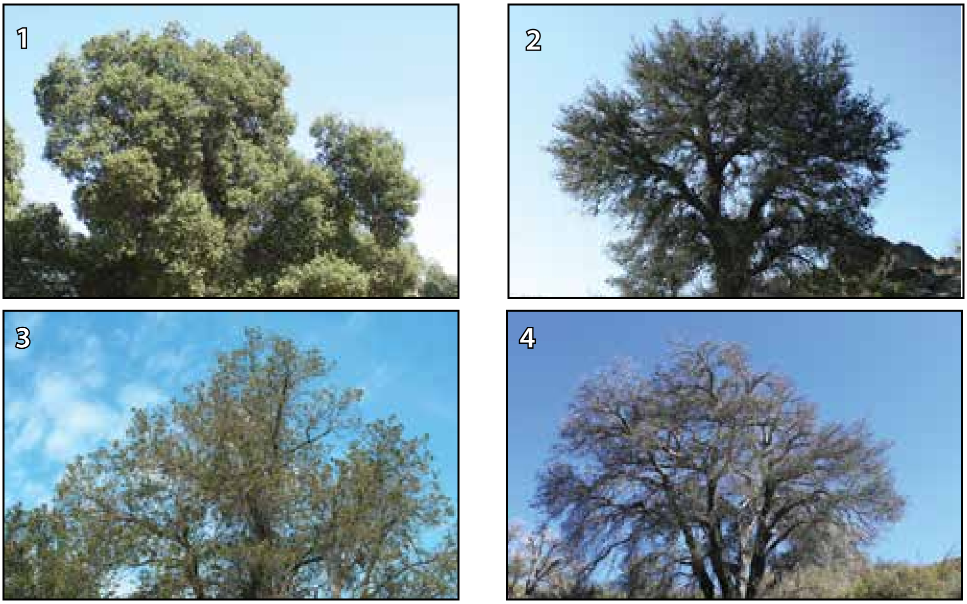
Ground surveys are the most effective method for detecting GSOB infestations and determining the level of injury caused by GSOB. However, ground surveys are time consuming and GSOB-caused injury symptoms are often not obvious during the early stages of infestation. In its native range, rates of GSOB infestation and tree mortality are low (4% and 2%, respectively, in a forest stand). These rates have been much higher (90% and 45%, respectively) in the invaded range. Large-diameter red oaks are the preferred host and should be the focus of ground surveys. Furthermore, oaks along the forest stand edge should be checked first because there is an initial preference for GSOB to attack trees along the edges of a stand (<150 feet from the forest stand edge). To facilitate detection of GSOB, the outer bark of heavily infested trees should be chipped away to expose prepupae and pupae in the outer phloem or the black meandering larval galleries on the xylem surface. Tree injury symptoms caused by GSOB, including the degree of crown thinning; density of D-shaped emergence holes and bark staining; and the presence/absence of woodpecker foraging, have been integrated into a system to rank tree health and guide management decisions (Figure 11).

Stickem-coated purple prism panel flight-intercept traps are the most effective traps for detecting GSOB (Figure 12). Traps should be monitored from May to September when most adult flight occurs (Table 1B). Traps should be positioned adjacent to the crowns of oaks on the southern aspect of a tree and hung at 9-10 feet. At sites with low population densities of GSOB (<20% infestation), the traps may be ineffective at detecting beetle populations.

Clear panel sticky traps placed at breast height on the main stem of declining oaks can also be used to capture GSOB adults. Felling live host oaks and leaving a high stump (approximately 4 feet tall) can serve as a trap "tree" for GSOB. Girdling live oak trees has not been very effective at attracting GSOB even at sites with high beetle population densities (>50% infestation). These methods can be useful for detecting GSOB, but are not efficacious tools for preventing or suppressing infestations. Goldspotted oak borer adults have responded to host bark and foliage volatiles in electroantennographic detection analyses in the laboratory; however, a lure to improve GSOB adult trap catches has not yet been developed. Like most *Agrilus* spp. studied so far, GSOB does not respond to ethanol-baited traps. However, additional research will be necessary to determine whether ethanol may be a semiochemical utilized by GSOB in the context of other host- or beetle-produced signals.

Although the traps described here have been useful for researchers or managers to detect movement of GSOB into new areas, they are not sensitive enough to guide management decisions. Land managers should focus their monitoring efforts on surveying for GSOB emergence holes on oak trees and ground-checking declining and recently killed oaks as indicated from aerial survey data.

1- CROWN RATING (1-5)



1: Full, healthy crown (0% leaf loss); 2: Minor twig dieback and/or light thinning (10-25% leaf loss); 3: Moderate twig dieback and thinning (25-50% leaf loss); 4:Severe dieback to larger branches (>50% leaf loss); 5: Tree is dead, no living foliage.

2- EMERGENCE HOLE RATING (1-3)

1: Less than ten D-shaped emergence holes on the lower main stem (<8 feet). 2: Ten to 25 emergence holes. 3: Greater than 25 emergence holes.

3- BARK STAINING RATING (1-4)

1: One to five areas of staining on the lower main stem (<8 feet). 2: Six to ten stained areas. 3: Greater than 10 areas stained areas. 4: Bark cracking evident.

4- WOODPECKER FORAGING (+/-)

Present or absent on the main stem or larger branches

Figure 11. A health rating system developed to determine the degree of goldspotted oak borer injury and assist with management decisions (modified from Hishinuma et al. *2011). The health rating system includes the degree of crown thinning and dieback; the density of D-shaped emergence holes and areas of bark staining; and presence/absence of woodpecker foraging.*

Figure 12. A purple prism panel flight-intercept trap hung at 9-10 feet on a metal conduit pole adjacent to the crown of a coast live oak for monitoring the flight of goldspotted oak borer adults.

Insecticide Treatments

A contact insecticide applied to the main stem and to the larger branches (>8 inches in diameter) is the best option for preventing GSOB injury to high-value oaks. To reduce the amount of spray drift and the impact to non-target arthropods, treating the entire crown is not suggested and likely not feasible for ground applications to large oaks. Contact spray applications should occur in May prior to the adult flight period in southern California and be re-applied annually by a certified pesticide applicator (Table 1C). These preventive insecticides should only be applied after evidence of GSOB has been found in the immediate area (<½ mile). Contact sprays or systemic insecticides (see below) should not be applied to GSOB-infested oaks with a crown injury rating of "3" or greater and an emergence hole rating of "3" (>25 emergence holes, see Figure 11) because they have already experienced high levels of injury. In these instances, insecticide treatments may have limited benefit in preventing tree mortality. Trees with >120 GSOB emergence holes on the lower stem (<8 feet) will likely die in the next few years. Preventive contact sprays of a carbamate (Sevin) or a pyrethroid (bifenthrin and permethrin) insecticide have killed GSOB adults in laboratory assays of treated foliage one month and one year post-application.

Systemic insecticides applied as a trunk injection or a basal spray may kill larvae feeding in the phloem and outer xylem, but they may also target adults when they feed on the foliage. These materials should also be applied by a certified pesticide applicator. Systemic insecticides such as neonicotinoids (*e.g.*, imidacloprid) or emamectin benzoate were effective at killing adults in laboratory leaf-feeding bioassays when leaves were collected from coast live oaks and smaller diameter California black oaks that had been injected in December and/or February and assayed 3 or 5 months later. In the field, systemic treatments with imidacloprid or emamectin benzoate slowed the rate of growth of GSOB populations on large diameter coast live oaks. However, studies to evaluate protection of trees from GSOB with systemic insecticides are still in progress. Insecticide uptake was greater in smaller diameter California black oaks than coast live oaks with stem-injected applications. Systemic treatments applied as trunk injections to oaks should be applied from November to February when treatment can be followed by seasonal precipitation, which facilitates translocation of the active ingredient in the vascular system (Table 1D).

Basal spray applications of a systemic insecticide (dinotefuran) to uninfested coast live oak and California black oak trunks resulted in high levels of active ingredient in foliage samples when applied in May just prior to adult flight. The active ingredient had declined dramatically when foliage was collected in September. Basal trunk applications to coast live and California black oaks yielded the greatest translocation of active ingredient in smaller diameter (<12 inches dbh) trees, but translocation was also detected in foliage at high levels one-month post application in large diameter (>40 inches dbh) trees. Although GSOB adults were not killed in laboratory leaf-feeding bioassays, the highest label rate was not used in these studies. Based on best current knowledge, we recommend that basal trunk applications of dinotefuran be applied annually, whereas trunk-injected applications of imidacloprid and emamectin benzoate be applied once every two years in southern California. Repeated stem injections can cause injury to the trunk, and treated trees should be monitored for bark cracking, staining, and crown thinning. Watering high-value oaks can facilitate insecticide uptake and alleviate drought stress during dry years. For high-value sites or individual trees, a combination of topical and systemic insecticide treatments may provide the most effective protection. However, this combined insecticidal approach has not been evaluated sufficiently to support this management action.

Mechanical Treatments

Grinding GSOB-infested wood to a particle size of <3 inches with a 3-inch-"minus" grinding screen is the most effective mechanical method for eliminating GSOB populations (Figure 13A). For greatest impact on GSOB population density and dispersal, grinding wood should occur before the emergence of adults in May, but the treatment can be applied year round to kill any of the life stages (Table 1E). Grinding wood is only practical for large-scale management projects, due to the specialized equipment required and the cost of the equipment. Chipping infested wood is not recommended as a management option because of the difficulty with treating large, dense pieces of oak stems with a standard chipper. Goldspotted oak borer does not attack the smaller stems and branches, which are often targeted in chipping operations. A more economical and feasible option for landowners with small quantities of wood is to either enclose or debark the infested wood (Figure 13B,C).

Figure 13. To manage wood infested with goldspotted oak borer, large quantities of wood can be ground with a tub grinder (A); small quantities of wood can be enclosed with plastic sheeting (B); or small quantities of wood can be debarked by landowners (C). If used for firewood, the wood should be burned locally.

Stacks of infested firewood can be enclosed with thick (6 mil), clear, UV resistant plastic sheeting and placed in a sunny location from the first of May to September (Table 1F). If the edges of the tarp are buried in the soil and the integrity of the tarp is maintained from May to September, emerging adults are not capable of escaping and will eventually die. Metal screening, tightly rolled and secured at the seams, can also be used to enclose wood. Debarking wood requires the manual separation of the bark and phloem from the wood prior to the emergence of GSOB adults. A log splitter, or other debarking tools, can remove outer bark in large pieces. This option can be very labor intensive and is only feasible for small quantities of wood. Goldspotted oak borers can survive in the bark and phloem shavings, so this material must be destroyed (*e.g.*, ground or burned) or tarped to eliminate all live beetles.

Cultural Treatments

Removing moderately- and severely-infested trees (*i.e.*, "brood" trees) may slow GSOB population growth at high-value sites. These infested trees should be felled and the wood managed by using one of the aforementioned mechanical treatments. Felling infested trees and the application of a preventive insecticide to any remaining uninfested or lightly infested (<10 emergence holes) large-diameter oaks may provide the best opportunity for maintaining high-value sites. However, no experimental data are available presently to support these combined management steps.

Limiting the movement of GSOB-infested wood into and within a community may be the most effective management method for reducing GSOB-associated tree mortality. In mountain communities, firewood is often a valuable commodity and sometimes the primary source of heating. To minimize movement or introduction of GSOB, the following simple and effective approaches for reducing GSOB-associated tree mortality are available: 1) educate community members to screen incoming firewood for evidence of GSOB; 2) allow wood from recently felled trees to season within the infested zone for longer than two years; and 3) keep infested material away from uninfested trees. Limiting the movement of firewood <50 miles from the location of harvest, (*e.g.*, "Buy it where you burn it" approach) is a best management practice for limiting the spread of GSOB and other subcortical invasive insects.

Natural Enemies

Three parasitoid wasp species and several generalist insect predators have been associated with GSOB in Arizona and California. The impact of these parasitoids and predators on GSOB populations is unknown in both regions, but low levels of GSOB mortality (<15%) have been attributed to some of these species. Low densities of natural enemies and low levels of host resistance may have contributed to the elevated levels of oak mortality by this indigenous exotic species in California. *Calosota elongata* Gibson (Hymenoptera: Eupelmidae), a newly described ectoparasitoid wasp, is only known from GSOB prepupae in Arizona and California (Figure 14A,B). *Calosota elongata* was likely introduced into California with the original GSOB population, but its known adventive distribution is limited to southeastern San Diego Co. in

California. A *Trichogramma* sp. wasp (Hymenoptera: Trichogrammatidae) was associated with GSOB eggs in Arizona, but was only found at low densities there and is believed to be a generalist parasitoid (Figure 14C). *Atanycolus simplex* (Hymenoptera: Braconidae) is a generalist larval parasitoid found in association with GSOB, but it also parasitizes other wood-boring insects throughout the USA (Figure 14D). The straw itch mite, *Pyemotes tritici* Lagrèze-Fossat and Montané (Acari: Pyemotidae), has been found on prepupae, pupae, and unemerged GSOB adults from Arizona and California and on Mexican GSOB in southern Mexico (Figure 14E). *Pyemotes tritici* has a cosmopolitan distribution and parasitizes species in several insect orders, including beetles (Coleoptera), moths (Lepidoptera), and ants (Hymenoptera). Snakeflies (Raphidioptera) and bark-gnawing beetles (Trogossitidae) have also been found feeding on GSOB larvae or in larval galleries. Though it has appeared to be locally extensive on highly infested trees, the impact of woodpecker feeding on GSOB has not been quantified. In general, the impact of insect and avian predators on GSOB population density is likely to be limited in California. *Calosota elongata* was considered a promising candidate for augmentative biological control in California. However, the difficulty of rearing GSOB populations on cut logs and at high densities in a laboratory setting makes an augmentative biological control program infeasible at this time.

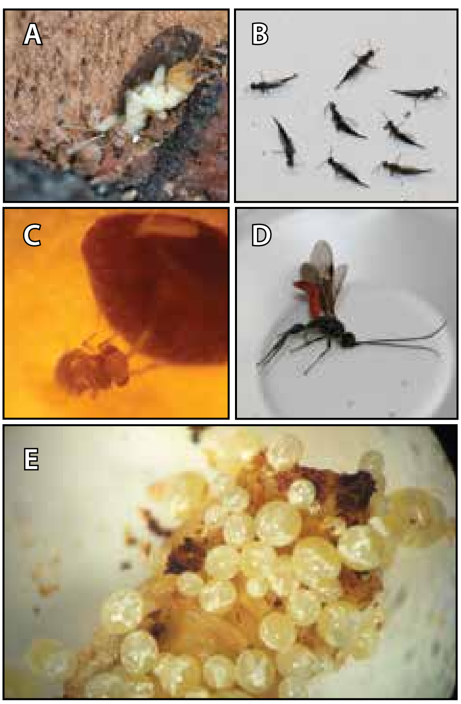


Figure 14. Natural enemies associated with goldspotted oak borer, include Calosota elongata *(A: parasitoid larvae feeding on a GSOB prepupa and B: adult parasitoids);* Trichogramma *sp. adult wasp on a GSOB egg (C);* Atanycolus simplex *adult wasp (D); and the straw itch mite,* Pyemotes tritici *on a GSOB prepua (E).*

Assistance

If you suspect that you have found signs of GSOB or symptoms of its damage on your property, or on municipal, state, or federal lands please contact a Pest Control Advisor, your local University Cooperative Extension Office, the County Agricultural Commissioner's Office, or your local USDA Forest Service, Forest Health Protection representative (http://www.fs.fed.us/foresthealth/). This publication and other Forest Insect and Disease Leaflets are available online (www.fs.usda.gov/goto/fhp/fidls).

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Figure 2: J. Moore (USDA Forest Service, Forest Health Protection); Figure 3: R. Venette (USDA Forest Service, Northern Research Station); Figure 14C: R. Lara (University of California, Riverside); All other figures by T.W. Coleman (USDA Forest Service, Forest Health Protection).

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