GSOB ≠ SOD: Tree Mortality from the Goldspotted Oak Borer in Oak Woodlands of Southern California[1]

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Abstract

A new threat to oaks (*Quercus* spp.) in California was identified in June 2008 following years of misdiagnosis. The goldspotted oak borer (GSOB), *Agrilus coxalis auroguttatus* Schaeffer (Coleoptera: Buprestidae), is aggressively attacking and killing three species of oaks in oak woodlands in San Diego County. About 20,000 coast live oaks (*Quercus agrifolia*), California black oaks (*Q. kelloggii*), and canyon live oaks (*Q. chrysolepis*) have died in a 4903 km^2 area centered on the Descanso Ranger District, Cleveland National Forest and Cuyamaca Rancho State Park. Oak mortality has been continuous for the past 8 years and occurs on all land ownerships.

The goldspotted oak borer was first collected in California in 2004. Although the collection history for this species is very limited (68 pinned specimens or records from 26 museum and private collections surveyed), early records date back to 1889 and 1905 in southern Mexico and southeastern Arizona, respectively, where there have been no reports of damage or mortality to oaks. In fact, prior to 2008, the biology and hosts of GSOB were unknown. Previous collection history for GSOB, the pattern of oak mortality in California since 2002, an expanding level of infestation, and geographical separation of oak stands in southeastern Arizona and southern California strongly suggest that GSOB was introduced into San Diego County. Although molecular genetic analyses of the populations of GSOB are pending, the proximity of Arizona and California and the morphological similarity of specimens from the Arizona and California populations both imply that GSOB was introduced into San Diego County from Arizona. Firewood movement represents the most likely pathway into California, however, in support of an alternative hypothesis of origin, there are anecdotal reports of oak firewood brought into this area of San Diego County from Mexico for 20 years.

Larval GSOB kill native oaks by feeding primarily on the wood surface at the interface of the xylem and phloem. Larvae feed in a meandering pattern on the wood surface and galleries typically have a dark appearance when bark is first removed. Larval feeding can reach high densities and cause areas of the cambium to die, eventually leading to tree mortality. Oaks infested with GSOB can be identified by thinning crowns, D-shaped adult exit holes, woodpecker foraging, and dark black or red staining on the bole or larger branches. Evidence of colonization by other insects is absent in GSOB-infested trees until trees have declined severely (for example, when bark has cracked around areas of dead cambium). Studies are currently underway to assess GSOB biology, enhance survey and monitoring techniques, determine the distribution of GSOB in southern California, record its impact to native oak stands, manage its populations through insecticide and firewood treatments, and determine

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whether there is a relationship between physiological stress of oaks and mortality by GSOB. Data on the physiological host range, freezing tolerance, optimal developmental temperatures, and dispersal capacity are being gathered to utilize in a risk assessment.

We hypothesize that elevated oak mortality in southern California has occurred because of an absence of evolved host resistance in native oaks and/or an absence of natural enemies found in GSOB's native range. Observations in California suggest that GSOB tends to prefer coast live oak and California black oak more than canyon live oak; Engelmann oak (*Q. engelmannii*) has not been found with GSOB injury. Preliminary observations from Arizona and California suggest that GSOB may confine its attacks to red oak species (subgenus *Quercus*, section *Lobatae*). We hypothesize that phloem thickness, bark structure, and host chemistry may influence susceptibility to GSOB. The native distributions of the three California hosts of GSOB extend north through most of the state along the coastal foothills and along the Sierra Nevada. Thus, this new pest to oaks has the potential to impact more northern regions in California, and the prospect of GSOB and SOD acting simultaneously on coast live oak in California presents a severe threat to this key oak species.

Introduction

Since 2002, aerial survey data have revealed extensive oak mortality on federal, state, tribal, and private lands in San Diego County, California. About 20,000 coast live oaks (*Quercus agrifolia*), California black oaks (*Q. kelloggii*), and canyon live oaks (*Q. chrysolepis*) have died in a 4903 km^2 area centered on the Descanso Ranger District, Cleveland National Forest and Cuyamaca Rancho State Park. Drought was considered the principal cause of this tree mortality for many years, and various pathogens have been suspected, but never confirmed. In 2008, the goldspotted oak borer (GSOB), *Agrilus coxalis auroguttatus* Schaeffer (Coleoptera: Buprestidae), was linked to the continuing oak mortality (Coleman and Seybold 2008a).

Goldspotted oak borer larvae feed primarily at the interface of the phloem and xylem (Coleman and Seybold 2008b). Larval galleries are meandering and dark-colored. Pupation occurs in the outer bark. Infested trees can be identified by woodpecker foraging on the outer bark, crown thinning and die back, D-shaped adult emergence holes, and dark-colored staining on the bark. Bark staining signifies extensive injury from larval feeding, which eventually girdles trees and leads to their death. GSOB attacks oaks aggressively along the main stem and largest branches (>12 cm in diameter). No additional insect species are associated with early GSOB injury.

The phloem/wood borer was first collected in 2004 in California. An investigation of the collection history of GSOB (68 specimens or records from 26 collections) revealed that it was first recorded in the 1880s in Guatemala and southern Mexico, and then later in the early 1900s in southeastern Arizona, suggesting that GSOB is native to Central and North America (Coleman and Seybold 2009). No tree injury or mortality has ever been reported from GSOB in these native regions. Very little data on host of development, biology, and life cycle of GSOB were available prior to 2008.

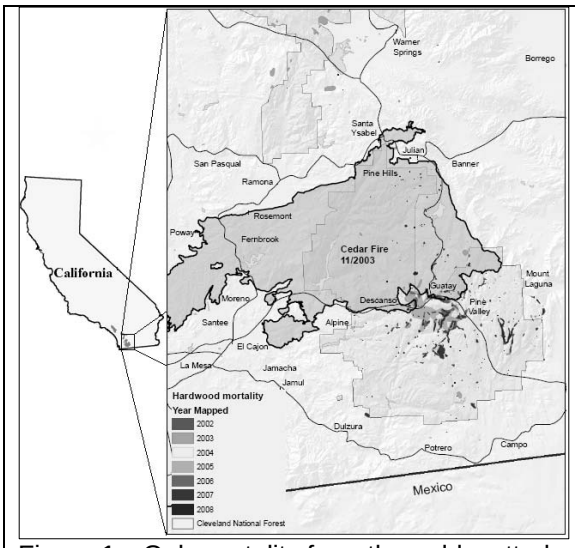

Figure 1—Oak mortality from the goldspotted oak borer in San Diego County, 2002 to 2008.

We hypothesize that GSOB arrived in southern California during the last 10 to 15 years as a consequence of an introduction on oak firewood. Oak mortality was initially detected on the Descanso Ranger District, Cleveland National Forest and at Cuyamaca Rancho State Park, so the GSOB infestation is believed to have originated in the vicinity of these two areas. In 2003, the majority of oak mortality was primarily surrounding the communities of Descanso and Guatay. In the following years (2004 to 2008), oak mortality has expanded outward from these communities (Fig. 1). As of summer 2009, mortality was not present at the U.S. and Mexican border (for example, the town of Campo), and GSOB infested trees along the border were first detected in 2009 and infestation rates are currently very low, suggesting a nascent infestation in this area that is spreading from the north. Increased levels of oak mortality have not been aerially mapped further south of the U.S. and Mexican border, but the spatial pattern of infestation on the U.S. side does not support a range expansion from Mexico. Confirmed oak hosts for GSOB in California have limited distributions in northern Baja California, Mexico and do not extend much further east in San Diego County. Thus, a continuous range expansion of GSOB from Arizona and/or Mexico is extremely unlikely. The Sonoran and Mohave Deserts geographically isolate the oak hosts and the California GSOB population from native GSOB populations in southeastern Arizona and Mexico. Because the zone of mortality is isolated by the Sonora and Mohave deserts to the east and by a band of healthy host type to the south and southeast, and because initial mortality was mapped away from the border, we conclude that the hypothesis of continuous range expansion is unlikely. The recent designation of subspecific status of the California population (Hespenheide and Bellamy 2009) based on its morphological similarity to the Arizona population, suggests that the tree-killing population of GSOB in California originated from Arizona.

Studies in 2009 and 2010 are assessing the current distribution of GSOB in southern California, determining effective survey techniques, investigating the impact of GSOB on forest stand dynamics, documenting adult emergence from firewood, developing management techniques for firewood, exploring the role of oak volatiles in attraction, assessing its risk to areas outside of its current distribution, and investigating the relationship between tree water stress and successful attack. This presentation compares the introduced GSOB population in California with native GSOB populations in Arizona.

Methods and Results

In February 2009, we surveyed two mountain ranges, the Huachuca and Santa Rita Mountains, on the Coronado National Forest in southeastern Arizona (Cochise, Pima, and Santa Cruz Counties) for the presence of GSOB. Early collection records had documented several canyons in these mountains where GSOB had occurred. Aerially detected hardwood mortality is not available for this region, so comparison of long-term oak mortality between Arizona and California is not possible, but our observations suggested that oak mortality was occurring at latent levels in Arizona. The native oak component in these two ranges is primarily comprised of silverleaf oak (*Q. hypoleucoides*), Emory oak (*Q. emoryi*), Arizona white oak (*Q. arizonica*), gray oak (*Q. grisea*), and gamble oak, (*Q. gambelii*). None of these oaks occur in southern California. In Arizona, silverleaf, Emory, Arizona white, and gray oaks are found frequently interspersed in the same forest stand, whereas gamble oak is primarily restricted to higher elevations and was not observed during our survey.

During the detection survey, we observed D-shaped exit holes, meandering dark-colored larval galleries on the sapwood, and pupal cells in the outer bark of several silverleaf oaks and Emory oaks in canyons where previous GSOB specimens had been collected, as well as in new localities. Injury symptoms were similar to those discussed in Coleman and Seybold (2008). Callus tissue was also observed in areas where insect herbivory was present. Mature *Agrlius* sp. larvae were collected from the outer bark of an Emory oak that recently died at one location (Box Canyon) in the Santa Rita Mountains (Pima County) in February 2009. No visible external injury or signs of pathogen infection to the Emory oak were observed. It is believed the tree succumbed due to insect infestation, but predisposing factors may have been involved. The larvae from this original collection did not complete development, so we could not verify the species status of the adult, but we suspected that it was GSOB. The same tree was visited on 1 to 2 May 2009, at which time additional *Agrilus* larvae and pupae were collected. The outer bark of the Emory oak (47 cm diameter at breast height) from ~1.5 m and below to the root collar was removed, collected, and returned to the lab to monitor insect emergence. Bark samples were placed in emergence cages and monitored daily.

The goldspotted oak borer was the only phloem/wood borer that emerged from the bark samples. A total of 113 insects were reared from the bark samples, 102 GSOB, eight parasitoid wasps (Hymenoptera), one moth (Lepidoptera), and two other beetles (Coleoptera). Larvae of one parasitoid species were observed feeding on GSOB larvae in the bark. Of the 27 GSOB larvae and pupae encountered in the bark, four were parasitized (15 percent parasitism rate).

Discussion

Our preliminary observations in California suggest that GSOB tends to prefer coast live oak and California black oak (both "red" oaks, subgenus *Quercus*, section *Lobatae*) more than canyon live oak (an intermediate oak species, i.e., neither a red nor a white oak, subgenus *Quercus*, section *Quercus*) (Nixon 1993). There have been no observations of injury by GSOB to Engelmann oak (*Q. engelmannii*), a white oak species that occurs in San Diego County. During surveys in the Huachuca and Santa Rita Mountains of southeastern Arizona (Cochise, Pima, and Santa Cruz

Counties), we observed similar injury symptoms of GSOB on silverleaf oak and Emory oak (both thick-barked red oaks). On one particular Emory oak, we noted the characteristic injury symptoms and we reared GSOB adults from the outer bark collected at a location in the Santa Rita Mountains (Pima County). This is the first confirmed record of a host for GSOB in Arizona. We suspect that silverleaf oak is also a susceptible host to GSOB because of the injury symptoms that we observed. We found no evidence that the two native Arizona white oaks, Arizona white oak and gray oak, had injury symptoms from GSOB or any woodboring flatheaded borers (Buprestidae). We hypothesize that phloem thickness, bark structure, and host chemistry may influence susceptibility to GSOB. White oaks commonly have fibrous, furrowed bark and thin phloem, whereas red oaks have thick phloem. Additional observations and experiments involving host susceptibility are needed to test this hypothesis.

The native distributions of the three California hosts of GSOB extend north through most of the state along the coastal foothills and along the Sierra Nevada (Coleman and Seybold 2009). The buprestid is currently injuring and killing three oak species between 90 and 1830 m elevation in southern California. Previous collection records in its native region extend to 2195 m. Thus, this new pest to oaks has the potential to impact more northern regions in California, and the sobering possibility of GSOB and SOD impacting coast live oak in unison in the central and southern Coast Range is very worrisome for the future of this beloved California oak. Firewood movement represents a significant pathway for introducing GSOB into these regions and should be a major focus of management efforts in the state.

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