Forest Health Protection
Pacific Southwest Region

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To: Forest Supervisor, Cleveland National Forest
Subject: New insect evidence in continuing oak mortality

Forest Health Protection Staff Specialists (Tom Coleman, Entomologist and Paul Zambino, Pathologist) surveyed the Descanso Ranger District on May 28, 2008 with Gloria Silva, Russ Lajoie and Lisa Young to assess the ongoing oak decline and mortality prevalent in eastern San Diego County. Since 2002, oak mortality has occurred throughout the Descanso District, and had been attributed principally to drought. Recent observations documented significant injury caused by insects to healthy and declining oaks. A wood-boring species not previously reported attacking oaks was found feeding extensively on coast live (*Quercus agrifolia*) and California black oak (*Q. kelloggii*).

Background

Oak mortality has occurred on the Descanso Ranger District since 2002. Over six years, an estimated 15,790 oaks have died across 16,118 ac on the District (Appendix 1). Coast live oak and California black oak are the primary species affected. Coast live oak is a dominant canopy species found in foothills, valleys, and canyons of southern oak woodlands. California black oak is co-dominant with Jeffrey pine (*Pinus jeffreyii*) in higher latitudes along Laguna Mountain.

Figure 1. Oak mortality in the Descanso Ranger District, Cleveland National Forest

Previous surveys of the area resulted in no significant findings related to pathogens or insects. For many years, drought was attributed as the cause of the observed mortality. The region has experienced below average rainfall intermittently over the last six years. During our recent survey we discovered extensive insect-caused injury on what appear to be healthy oaks.

Observations

Oaks were assessed around Pine Valley (N 32.83235°, W 116. 51995°; 3,720 ft), Noble Canyon Trailhead (N 32.85136°, W 116.52222°; 3,601 ft) and Laguna Mountain (N 32.85755°, W 116.46422°, 5469 ft). At least 200 trees were surveyed for causes of decline and mortality across the three localities. Thirteen fixed-radius plots ($^{1}/_{10}$ acre) were established surrounding oaks to assess forest stand composition, total tree density (acre) and basal area (ft^2/ac) across the three sites.

Mean total basal area across the three sites is 153 ft^2/ac; mean oak basal area is 106 ft^2/ac. The average number of trees per acre is 68; the average number of oaks per acre is 52. Sixty-seven percent of the oaks (35 TPA) were found with external or internal evidence of aggressive insect attack. Currently, there is an average of seven dead oaks per acre (~13% mortality).

Agrilus coxalis was the primary insect found attacking oaks in the District. *A. coxalis* is a flatheaded wood-borer (Family: Buprestidae). The species was confirmed on June 26, 2008 when adults were first collected. *A. coxalis* larvae were recovered from coast live and California black oak. Larvae are white in color with an elongated, slender shape (Figure 2). They are legless and have two spines at the tip of the abdomen. Mature larvae were up to $^7/_8$ of an inch long. Larvae appear to feed primary on the surface of the sapwood where feeding galleries can be extensive (Figure 3). Larval galleries can be $^1/_8$" wide, black in color and packed with frass. Most larvae were recovered from the outer bark, probably preparing to pupate. Pupae were found only in the outer bark (Figure 4). Areas with extensive larval feeding are frequently strip killed. These areas are commonly soaked with water, which is expelled when bark is cut. Callus tissue was found on several trees and may signify a mechanism for host defense.

A. coxalis adults were reared from pupae collected in the bark and cut logs of coast live oak. Adults were also caught on purple panel flight traps. Adults are bullet-shaped, and a dull metallic green in color, with three prominent golden yellow spots on each fore-wing (Figure 5). The adult can be identified by these distinctive gold markings. Adults collected were an average $^3/_8$" in length and about $^1/_{16}$" wide. Eggs of *A. coxalis* have not been observed.

Figure 2. Mature larvae of *A. coxalis* removed from coast live oak.

Figure 3. Larval galleries of *A. coxalis* found on the sapwood of oaks.

Figure 4. Pupa of *A. coxalis* collected from the outer bark.

Figure 5. An adult *A. coxalis* with gold colored spots on forewings and body.

External evidence of *A. coxalis* is visible on the main bole and larger branches. Woodpecker foraging is very common, which uncovers larval feeding galleries in the outer bark (Figure 6). Fresh woodpecker feeding reveals the brick-red outer phloem. Staining is also common from the root collar of the bole to larger branches. Staining can appear as darkened spots or as red and black blistering which oozes from the bark (Figure 7). Underneath stained areas extensive larval galleries were found on the sapwood surface, which patch-killed the cambium. Significant levels of staining can occur on large diameter trees. Areas of staining can range from dime-size to half foot sections.

D-shaped exit holes from *A. coxalis* were found on the bole. Exit holes are approximately $^{1}/_{16}$ of an inch in width. No trees smaller than 5" DBH have been observed with external symptoms.

Oaks with woodpecker attacks, staining and exit holes also possess thinning crowns. Crowns appear to progressively thin and dieback as health declines. Trees with visible insect-caused injury have premature leaf drop, twig dieback and branch die-off. Coast live oak crowns with extensive thinning appear gray when compared to the dark green color of healthier crowns (Figures 8 and 9). A large amount of foliage is retained on coast live oak until tree mortality occurs and foliage turns brown. Coast live oak with *A. coxalis* attacks can still flush new foliage in the spring. California black oak does not appear to retain foliage for longer durations due to leaf abscission in the fall.

Figure 6. Woodpecker foraging uncovers larval galleries of *A. coxalis* on coast live oak.

Figure 7. Black staining along the bole of coast live oak. Bark was removed at the base of the tree to show strip killed cambium.

Figure 8. Dull green and gray crowns of living oaks in Pine Valley, CA.

Figure 9. Twig die-back commonly observed in declining oaks with *A. coxalis* attacks.

Evidence of ambrosia beetles, bark beetles (*Pseudopityopthorus* spp.), lead cable borer (*Scobicia declivis*) and longhorned beetles (Family: Cerambycidae) were found on dead oaks. Ambrosia beetles expel fine white boring dust when constructing galleries into the sapwood. Pinhole-size galleries with black staining can differentiate ambrosia galleries from other insect galleries. Lead cable borer and longhorned beetles produce winding larval galleries that can penetrate into the sapwood. *Pseudopityophthorus* spp. bark beetles are found in smaller branches in the crown and produce galleries which are perpendicular to the grain of the wood. Removing the bark can uncover evidence of these insects on dead trees. These insects are not playing a role in the oak mortality.

<u>Discussion and Recommendations</u>

A. coxalis was first found in southern California on the Cuyamaca Rancho State Park in 2004 as part of a survey for exotic wood-boring beetles by the California Department of Food and Agriculture. Very little information is known about the life history of this species. The host species and larval habitat were unknown until this recent discovery. The species has been collected previously in Arizona, Guatemala, and Mexico. No report of attack, injury or mortality from this insect has ever been reported from these areas. There is no approved common name for this insect, but "gold-spotted oak borer" has been proposed and agreed upon by several entomologists in California. The common name will be submitted officially to the Entomological Society of America for approval. Additional information is being prepared for the public to alert them of this new insect and its signs and symptoms of attack and infestation.

The presence of *A. coxalis* in southern California is either a range expansion or an introduction. If *A. coxalis* was introduced, it is not known when or how this species arrived in southern California. *A. coxalis* may have been introduced prior to 2002, since oak mortality was first mapped that year and oak mortality occurs over a few years. The point of establishment may have occurred around Descanso, CA because the first hardwood mortality was mapped in that area. The current distribution of this insect in southern California is also not known. As of July 2008, evidence of *A. coxalis* attacks or collections of adults and larvae have been confirmed in the areas of Pine Valley, Guatay, Descanso, Laguna Mountain and Cuyamaca Rancho State Park. Dying oaks can be seen in Alpine, Campo and Viejas, but insect attacks have not been confirmed in these areas yet. Other regions of hardwood mortality in the Palomar District have been mapped during aerial surveys; initial ground surveys did not find *A. coxalis* in this area. The distribution of coast live and California black oak both extend further north in the Descanso and Palomar Districts and many others areas in California (Figure 10). There is a high potential for this insect to spread to these areas.

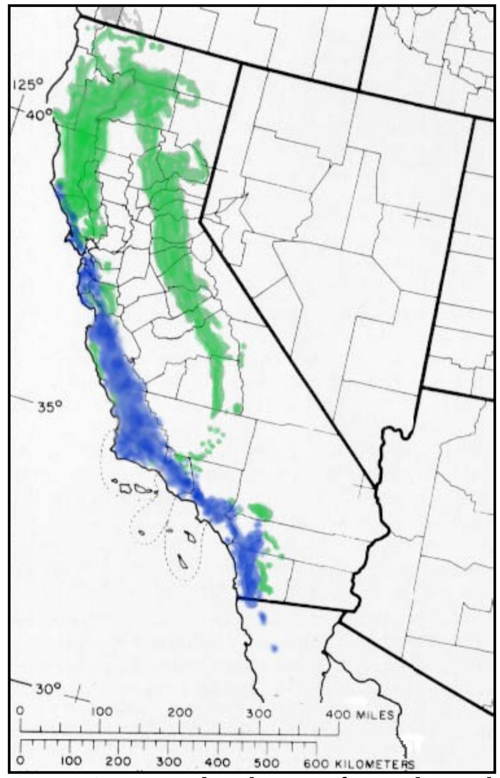

Figure 10. Native distribution of coast live oak (blue) and California black oak (green) in California.

The host range of this insect is unknown. Previous collection records are associated with oak species in Arizona and Mexico. Initial observations suggest oaks $\geq$10” DBH are favored by *A. coxalis*. Oaks <10” DBH are either not favored or unsuitable for development. Scrub oak species and Engelmann oak (*Q. engelmannii*) have not been observed with attacks, but Engelmann oak mortality has been aerially mapped. Observations of larval size and location suggest this species may complete one generation per year with adults emerging in late-spring and early-summer. Adult activity could extend to late-August based on previous collection records.

This insect is playing a major role in oak mortality. Tree mortality appears to occur when larval feeding reaches high densities and patch-kills much of the cambium. The exact reasons why *A. coxalis* is causing oak mortality in southern California and no where else are uncertain. The observed mortality could result from new host associations or the lack of natural enemies, which may be present in Arizona, Mexico and Guatemala.

Drought may be a contributing factor to oak mortality but it is not the sole cause. Stress from drought may be reducing the tree’s ability to properly defend itself from attack. *A. coxalis* is a playing a primary or secondary role in oak mortality and drought is a secondary factor. Other native *Agrilus* spp. often cause extensive tree mortality when trees become stressed either from drought, injury, thinning or soil compaction. Since *A. coxalis* is considered to be either a range expansion or introduction in southern California, it may be aggressively killing oaks with little assistance from drought. Additional work is required to determine the interactions of *A. coxalis* and drought.

Management alternatives

No research is available for *A. coxalis* concerning prevention and suppression tactics. Most data and research that is available is extrapolated from the prevention and suppression work for the emerald ash borer, *Agrilus planipennis,* (McCullough et al. 2003. Evaluation of Insecticides to Control Emerald Ash Borer Adults and Larvae. [http://www.emeraldashborer.info/Research.cfm], the bronze birch borer, *Agrilus anxius* (USDA Forest Service-Forest Insect and Disease Leaflet 168) and the twolined chestnut borer, *Agrilus bilineatus* (USDA Forest Service-Forest Insect and Disease Leaflet 111).

Cultural Control

Several options are available for handling and treating firewood. Additional studies are needed to determine the most effective approach for limiting beetle emergence and expansion. One or multiple management techniques discussed below should be used. Logs or firewood of oaks from infested areas that still possess bark should not be removed from the area. Wood-boring insects are easily dispersed through logs and firewood. Transporting infested firewood can possibly introduce *A. coxalis* into additional areas. Green or freshly killed oaks have a high likelihood of possessing *A. coxalis*. Trees that have been dead for greater than one year may have a very minimal chance of possessing *A. coxalis* populations. However, it will be difficult to distinguish when oak trees died, or which logs or firewood came from what tree, so all cut logs should be treated in the same manner. *A. coxalis* may still be able to complete development in pieces of oak that contain bark. Some *Agrilus* spp. are not capable of surviving in wood once the cambium dies and turns brown, but there is currently no data to support this for *A. coxalis*. The District should restrict firewood permits for oaks until more data are collected. Additional public education materials should be posted and provided to spread awareness of this new insect.

Exposing cut wood to direct sunlight or covering wood with a tarp may be detrimental to *A. coxalis*. Exposing wood to direct sunlight is best suited for mid-summer when temperatures are high. If logs and firewood are covered, soil should cover the edges of the trap to limit beetle emergence. Removing bark has also been shown to kill most immature life stages of *Agrilus* spp. These management tactics are used for the bronze birch borer and twolined chestnut borer.

Chipping wood is the best way to ensure beetles will not survive in cut logs and firewood. All wood should be chipped to minimize the spread and population growth of *A. coxalis*. Research conducted with emerald ash borer found chipping ash wood into 1" pieces kills all beetles.

Sanitation cutting oaks may reduce *A. coxalis* population numbers in a localized area. Recently dead or dying oaks with heavy infestations should be cut prior to adult emergence in the early spring. Cuts logs should be handled appropriately to limit beetle emergence.

A. coxalis attacks oaks, but it is not known if all oaks are equally susceptible. Scrub oak species may be resistant to *A. coxalis* attacks. Plantings efforts should potentially utilize other native species found on site besides oaks if possible. Planting the native oak species and maintaining the sites at appropriate densities will help prevent loss of oaks to *A. coxalis*. Additional surveys and studies are needed to further assess other oak species susceptibility.

Prevention and Suppression

Thinning trees is a common prevention method to reduce forest insect pests. High stand densities can reduce tree health and increase susceptibility to insect attack. Reducing oak stand density may improve individual tree health and increase host trees defenses. Harvesting should target those of poor vigor first and should result in proper spacing and species composition. Mulching, watering, soil aerations and fertilizing oaks may further increase oak health and reduce *A. coxalis*-caused impacts in high-value trees.

Spraying with an insecticide can possibly save uninfested trees. High-value trees with no visible symptoms (staining, thinning crown, adult exit holes, and woodpecker foraging) can be sprayed as a preventive measure. Insecticides should be sprayed on the stem of the tree, larger branches (> 5"), and the foliage. Spraying with carbaryl may provide adequate control. Spraying the trunk, branches and foliage in the spring or early summer may kill adult beetles and recently hatched larvae on the stem. Spraying the foliage may be crucial for reducing attacks.

A single spray may provide effective control throughout the summer. Oak saplings do not appear to be preferred or suitable hosts for beetles so do not require immediate spraying. Preventive treatments should be re-applied every year for the best results. Spraying does not inflict additional wounds to trees and the insecticide is effective immediately, which are benefits, and it may be the best treatment to reduce additional attacks from *A. coxalis* in low-vigor, unhealthy trees. However, topical insecticides will not impact larvae already present under the bark, so should be used in conjunction with a systemic insecticide if the tree is suspected to be infested.

Figure 11. A soil injector used to deliver a systemic insecticide to trees via the roots.

Systemic insecticides might be utilized to target *A. coxalis* life stages under the bark and those that feed on leaf tissue. Imidacloprid is a systemic insecticide that can be soil-injected (Figure 11), basally drenched or trunk-injected using a variety of methods. Soil-injections and basal drenches should be applied immediately adjacent to the root collar of trees for best results. Soil-injections do not injure the tree cambium, whereas trunk-injections may cause minor wounding and eventually girdle trees after repeated treatments. Treating trees for other *Agrilus* spp. in May and July both reduced beetle populations within trees, but treating earlier in the year was more effective (McCullough et al 2003). Treating trees early in the year may kill both adults and larvae; late treatments may only target young larvae in the tree. Systemic treatments should be re-applied every year until additional research is collected. Soil- and stem-injections should be applied at least two to four weeks before *A. coxalis* adults are active (~ mid-May) to allow translocation through the tree. Soil- and stem-injections may not provide adequate suppression in low-vigor trees because the compound will not be adequately transported throughout the tree. Systemic insecticides and whole-tree spraying can be used in unison to prevent attacks and kill life stages under the bark. Prevention and suppression involving insecticides are feasible for high-value shade and ornamental trees and critical habitat on a small-scale. Treating trees with an insecticide does not guarantee protection. Prevention and suppression are typically not cost effective on a landscape level. Follow all directions, restrictions, registered uses and read all precautions on insecticide labels before use. Insecticides should be applied by certified applicators. Consult a county agricultural extension agent for additional insecticide information.

No Management

Not using any prevention and suppression tactics might result in increased oak mortality. A high percentage of trees are currently showing signs of beetle attack (~67%) and many will likely succumb to insect attack within a few years. Mortality has been continually mapped aerially over the past six years, this trend will probably continue. If the public is not made aware of this problem, the species may spread to other areas by transporting oak logs and firewood.

Conclusion

A. coxalis is an important insect involved in the ongoing oak mortality and is a new concern in the oak forests of California. The oak mortality observed in southern California represents a unique situation that has not been reported in the native regions of this insect. Although adults were previously collected in Arizona, Mexico and Guatemala, no record of *A. coxalis* attacking oaks has ever been reported. This is the first record to verify the hosts and larval habitat of *A. coxalis.*

FHP personnel will continue to determine the life history, current distribution, suitable hosts, and suppression tactics for *A. coxalis* in California (Figure 12). High-value oak trees should be treated with insecticide to prevent or suppress *A. coxalis* populations. This insect may continue to be a long-term problem in this area and in other parts of California. Infested wood should not be moved off-site and should be treated using methods described in this report. If you have additional questions please contact me at 909.382.2871 or twcoleman@fs.fed.us.

Figure 12. A purple panel trap used to assess *A.coxalis* populations.

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Appendix A. Map of hardwood mortality from Forest Health Monitoring Aerial Surveys 2002-2007 Yellow colors represent mortality from 2002-2005; red and orange colors represent the most recent mortality in 2006-2007.