California Black Oak Forest Health Challenges

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

Steven J. Seybold
USDA Forest Service
Pacific Southwest Research Station
Davis, CA
WESTERN FOREST INSECTS

R.L. Furniss and V.M. Carolin

Entomologists, Retired
Pacific Northwest Forest and Range Experiment Station
Forest Service

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FAMILY ASTEROLECANIIDAE—PIT SCALES

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

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

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

A bit of a “backwater”
Forest Pathogens on California Black Oak?

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

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

Figure 83. Anthracnose symptoms on California black oak.

Photo: Bruce Hagen, CDF.
How Times Have Changed

A Field Guide to Insects and Diseases of California Oaks

United States Department of Agriculture
Forest Service
Pacific Southwest Research Station
General Technical Report PSW-GTR-197
July 2006

Tedmund J. Swiecki
Elizabeth A. Bernhardt

Sudden Oak Death

Goldspotted oak borer
Forest Health Challenges to California Black Oak

I) Insects
   A) Phloem feeders: Oak bark (and ambrosia) beetles
   B) Phloem feeders: Goldspotted oak borer
   C) Defoliators: Fruit tree leafroller

II) Pathogens
   A) Stem cankers: Phytophthora ramorum and sudden oak death
   B) Root diseases: Armillaria mellea/gallica-Armillaria root rot
   C) Foliage (twig) diseases: Apiognomonia errabunda and oak anthracnose
# Impacts of Feeding Groups of Forest Insects

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<thead>
<tr>
<th>Herbivore guild</th>
<th>Potential impact on host growth and reproduction</th>
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<tbody>
<tr>
<td>Gall formers: leaves</td>
<td>Conophthorus spp.</td>
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<td>Cynipidae, Cecidionidae, Psyllidae</td>
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<td>Gall formers: twig/stems</td>
<td>Ips pini</td>
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<td>Adelgidae, Cynipidae</td>
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<td>Phloem/sapwood/pith borers: twig/stem/fruits</td>
<td>Ips paraconfusus</td>
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<td>Geometridae, Lasiochilidae, Lymantridae, Tortricidae</td>
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<td>Sap feeders: leaves/twig/branch</td>
<td>Ips latidens</td>
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<td>Aphididae, Coccidae, Diaspididae</td>
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<td>Phloem/sapwood/pith borers: twigs/branches/shoots</td>
<td>Pityogenes carinulatus</td>
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<td>Supraspididae, Cerambycidae, Curculionidae, Olethreutidae</td>
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<td>Root/sap feeders</td>
<td>Hylastes macer</td>
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<td>Cicadidae</td>
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<td>Root free feeders</td>
<td>Dendroctonus brevicomis</td>
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<td>Curculionidae, Scarabaeidae</td>
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<td>Folivores: middle-late season</td>
<td>Ips pini</td>
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<td>Arctiidae, Lymantriidae, Notodontidae, Saturniidae</td>
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<td>Folivores: both current and prior year's leaves</td>
<td>Ips paraconfusus</td>
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<td>Diprionidae, Lymantriidae</td>
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<td>Sap feeders: stem phloem/xylem</td>
<td>Pityogenes carinulatus</td>
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<td>Aphididae, Coccidae, Diaspididae</td>
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<td>Phloem/cambium/sapwood borers: root and root crown</td>
<td>Conophthorus spp.</td>
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<td>Supraspididae, Curculionidae, Scolytidae</td>
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<td>Phloem/cambium/sapwood borers: main stem</td>
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# GSOB: The Entomological Context in California
## Bark and Woodboring Insects Associated with Declining Oaks

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<tr>
<th>Species</th>
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<th>Significance</th>
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<td><em>Agrilus auroguttatus</em></td>
<td>Goldspotted oak borer, phloem and outer xylem of stems and branches</td>
<td>Highly significant, early</td>
</tr>
<tr>
<td><em>Pseudopityophthorus pubipennis/agrifoliae</em></td>
<td>Oak bark beetles, phloem of stems and branches</td>
<td>Moderately significant, can be early on seriously weakened trees</td>
</tr>
<tr>
<td><em>Monarthrum dentiger/scutellare</em></td>
<td>Oak ambrosia beetle, xylem of stems and branches</td>
<td>Moderately significant, late—stem breakage of SOD infected trees</td>
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<tr>
<td><em>Gnathotrichus pilosus</em></td>
<td>Oak ambrosia beetle, xylem of stems and branches</td>
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</tr>
<tr>
<td><em>Chrysobothris femorata/mali</em></td>
<td>Flatheaded borers, bark and outer xylem of stems and branches</td>
<td>Not significant, late, important for wood decomposition</td>
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<tr>
<td><em>Agrilus angelicus</em></td>
<td>Pacific oak twig girdler, xylem of small branches and twigs</td>
<td>Not significant, early, but attacks peripheral portions of tree</td>
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<tr>
<td><em>Scobicia declivis</em></td>
<td>Lead cable borer, xylem of stems and branches</td>
<td>Not significant, late, important for wood decomposition</td>
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<tr>
<td><em>Xylotrechus nauticus</em></td>
<td>Oak cordwood borer, phloem and xylem of stems and branches</td>
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<tr>
<td><em>Phymatodes lecontei/decussatus</em></td>
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Brown and Eads (1965) California Agricultural Experiment Station Bulletin 810;
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Western Oak Bark Beetles
*Pseudopythophthorus* spp.

**Distribution/Hosts**

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

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

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

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

Figure 60 (right). White ooze associated with oak bark beetle attack. Photo: Don Owen, CDF.
Figure 235.—Egg galleries of the western oak bark beetle (*Pseudopityophthorus pubipennis*).
Foamy Bark Canker = Mass Attack of Western Oak Bark Beetles + *Geosmithia pallida*

*Geosmithia* has been isolated from:

—Coast live oak
—Interior live oak

Likely will be isolated from California black oak
Oak Ambrosia Beetles

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

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

Figure 57. *Monarthrum scutellare* adult beetle.

Photo: Jack Kelly Clark, courtesy UC Statewide IPM Program
Oak Ambrosia Beetles

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

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

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

An Invasive Pest of Coast Live Oak, California Black Oak, and Canyon Live Oak in Southern California
Goldspotted Oak Borer
Take Home Messages

I) GSOB is not always associated with a pathogenic fungus.

II) GSOB appears to have originated from the Southwest (AZ/NM); so far it has only invaded southern California.

III) GSOB prefers to attack and kill large diameter red oaks (>18” dbh); it takes a long time (conservatively 3 to 5 yrs) to kill these trees.

IV) The key to limiting future expansion of the invaded range of GSOB is preventing the movement of infested firewood.
Goldspotted Oak Borer
Field Identification Guide

The goldspotted oak borer (GSOB), *Agrius cowperiatus* (Coleoptera: Buprestidae), is a flatheaded borer new to California that poses a significant threat to oak trees. The pest is native to southwestern Arizona, although a related species occurs in southern Mexico and northern Guatemala. GSOB was first collected and identified in California in 2004 in San Diego County but was not linked to extensive oak mortality until 2008. As of 2013, GSOB has killed an estimated 21,500 trees covering 1,893 square miles in San Diego County in forests, parks, and residential landscapes.

GSOB larva feed beneath the bark of certain oaks near the interface of the phloem and xylem, the nutrient and water conducting tissues of plants. The larvae damage both of these tissues as well as the cambium, a uniseriolar layer between the phloem and xylem that is responsible for the radial growth of the tree. Trees die after several years of injury inflicted by multiple generations of the beetle. Currently there are no effective tools for protecting trees once infestation occurs.

Identification

Capture of adult GSOB on sticky traps in infested areas of San Diego County and observations of immature life stages suggest that this pest completes one generation each year. Adults are about 0.4 inch long and 0.08 inch wide with a slender, bulbous-shaped body (Figure 2) and are agile fliers. They are primarily black with an iridescent green sheen and have six gold-spotted colorations on their forewings, hence the common name.

Eggs are extremely small (0.01 inch) dull colored, and rarely observed on trees. They likely lay singly or in clusters in bark cracks on the main stem and larger branches of oaks.

Larvae are white, legless, and about 0.1 inch long when mature (Figure 2). GSOB larvae can be distinguished from those of other wood boring beetles by C-shaped spiracles and two pincherlike spines on the end of their abdomen. Mature larvae can be found in a hairpin configuration in the outer bark (Figure 3) from early fall until early summer.

Pupae are also found in the outer bark from late spring to early summer; they resemble the adults in size and shape but are primarily white and soft bodied (Figure 4). When adult beetles emerge from the pupal cell in the bark, they make a diagnostic D-shaped emergence hole, see External Symptoms below. Adult GSOB feed on oak foliage and make notches along leaf margins (Figure 5), but tree mortality results from larval feeding. This pest is known to kill three species of native oaks in California; for more information, see the sidebar Which Oak Species Are Attacked? on Page 5.

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


The goldspotted oak borer (*GSOB*) was first detected in 2004 in San Diego Co., California by the California Department of Food and Agriculture during a survey for exotic wood borers. In 2008, it was found in the same county, attacking coast live oak, *Quercus agrifolia*, canyon live oak, *Q. chrysolepis*, and California black oak, *Q. kelloggii*, on the Cleveland National Forest. GSOB is playing a major role in on-going oak mortality on federal, state, private, and Native American lands in southern California. GSOB larvae feed under the bark primarily at the interface of the sapwood and phloem on the main stem and larger branches. Larvae kill patches and strips of phloem and cambium, resulting in limb and branch die back and, eventually, tree death. Although the exact origin of the California population is unknown, GSOB has been previously collected in Arizona, Mexico, and Guatemala. Because of host distribution, GSOB has the potential to spread further north in California and cause similar tree mortality. Since very little published information is available on this insect, additional research is needed to determine the life cycle, behavior, and management strategies. The movement of infested firewood likely represents a significant pathway for introducing GSOB into non-infested areas.

**Identification**

Adults are about 10 mm long and 2 mm wide (Fig. 1). They are bullet-shaped and can be identified by the six golden-yellow spots on the dark green forewings. Mature larvae are about 18 mm long and 3 mm wide. They are legless, white, and have a long slender appearance (Fig. 2). The larvae possess two pincher-like spines at the tip of the abdomen. Pupae are found in the outer bark and resemble adults, but are commonly white in color. Eggs are probably laid in bark crevices like other *Agrilus* spp., but have not been observed by the authors.

**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-
GSOB: Awareness Began in May/June 2008

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

**THE PAN-PACIFIC ENTOMOLOGIST**


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

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

**INTRODUCTION**

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

Several evergreen and deciduous oaks are dominant or co-dominant canopy species in southern oak woodlands of California. *Quercus agrifolia* is commonly found below 1200 m in coastal foothills, valleys, and canyons. *Quercus engelmannii* is found inland in foothills below 1200 m. Canyon live oak, *Quercus chrysolepis* Liebm., is widely distributed in canyons, moist slopes, and flats below 2000 m. On the CNF, *Quercus kelloggii* is found further upslope (1219—1826 m) in co-dominant canopy positions with Jeffrey pine, *Pinus jeffreyi* Grev. & Balf. (Pinaceae).

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

2008

Research on GSOB biology and detection efforts begin

2009

GSOB found in Idyllwild (Riverside Co.)

2010

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

2011

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

2012

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

2013

GSOB found in Green Valley (Los Angeles Co.)

2014

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

2015

GSOB research: insecticides, fuel impacts
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).

Goldspotted Oak Borer: Connections to California Black Oak

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

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

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

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

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

III) GSOB adults have a preference for feeding on the foliage of California black oak
Adults feed on foliage; larvae feed on phloem
GSOB mature larva

Tom Coleman
May 2008

4 mm
High density larval mining by GSOB in oak phloem
Sap stain on outer bark of several oak species
Symptoms: Woodpeckering and Bleeding Wounds
D-Shaped Emergence Holes and Galleries Beneath the Bark
Table 1. Common Borers on Southern California Oaks and their Emergence Holes.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Emergence hole</th>
<th>Injury location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beetles (Coleoptera)</strong></td>
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<tr>
<td>Bostrichidae (false powderpost beetles)</td>
<td><em>Scobicia decivis</em> (lead cable borer)</td>
<td>round</td>
<td>Common on smaller branches less than 5 inches in diameter.</td>
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<tr>
<td>Buprestidae (flatheaded borers)</td>
<td><em>Agrius auroguttatus</em></td>
<td>D-shape</td>
<td>Located primarily on the lower trunk. Can reach high densities.</td>
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<td></td>
<td><em>Chrysobothris</em> species (appletree and related borers)</td>
<td>oblong/ crescent</td>
<td>Common on the trunk and larger branches.</td>
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<tr>
<td>Cerambycidae (roundheaded borers)</td>
<td><em>Xylotrechus nauticus</em> (oak cordwood borer)</td>
<td>oval</td>
<td>Common on the main trunk, especially around wounds from mechanical damage or fire.</td>
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<tr>
<td>Scolytidae (bark and ambrosia beetles)</td>
<td><em>Monarthrum</em> species, <em>Gnathothrichus pilosus</em> and <em>Xyleborinus saxeseni</em> (ambrosia beetles)</td>
<td>round</td>
<td>Frequently on the main stem.</td>
</tr>
<tr>
<td></td>
<td><em>Pseudopityophthorus</em> species (western oak bark beetle)</td>
<td>round</td>
<td>Most common on smaller branches.</td>
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<tr>
<td><strong>Moths (Lepidoptera)</strong></td>
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<tr>
<td>Sesiliidae (clearwing moths)</td>
<td><em>Synanthedon resplendens</em> (western sycamore borer)</td>
<td>round</td>
<td>In bark cracks near deteriorated bark and phloem.</td>
</tr>
</tbody>
</table>

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

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

Crown thinning

Bark staining

D-shaped exit holes

Woodpecker foraging
Oak Health Rating System
Based on Symptoms of Injury from GSOb

– Crown condition (3 or greater)

– Number/density of emergence holes (3)

– Bark staining

– Presence/absence of woodpecker damage


dfield-identification-guide.pdf
GSOB injury and symptoms

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

- White bars: uninfested
- Black bars: infested

- Larger size-classes preferred by GSOb

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


COLLECTION HISTORY AND COMPARISON OF THE INTERACTIONS OF THE GOLDSPOTTED OAK BORER, Agrilus auricatus Sparrecker (Coleoptera: Buprestidae), with Host OAKS in SOUTHERN CALIFORNIA AND SOUTHEASTERN ARIZONA, U.S.A.

TOM W. COLEMAN
USDA Forest Service, Forest Health Protection
620 S. Tuppinasse Ave., Arc, California 92408, U.S.A.
swcoleman@fs.fed.us

AND

STEVEN J. SEYBOLD
USDA Forest Service, Pacific Southwest Research Station
Chemical Ecology of Forest Insects
720 Olive Dr., Suite 7, Davis, CA 95616, U.S.A.
sseybold@gmail.com

ABSTRACT

An invasive population of the goldspotted oak borer, Agrilus auricatus Sparrecker (Coleoptera: Buprestidae), is colonizing and killing three species of oaks in San Diego Co., California. However, the interactions of A. auricatus with oaks in its native range in southeastern Arizona have not been recorded. We present a complete inventory of the North American collection records of A. auricatus and Agrilus coxalis Waterhouse from the literature and from a survey of the holdings of 27 museums and personal collections. We also discuss the relationship between this collection history and the behavior of A. auricatus as an intraspecifically invasive species. Surveys of native populations of oaks in oak forests from the mountains of southeastern Arizona recorded injury patterns on Emory oak, Quercus emoryi, and silver oak, Quercus hypoleucoides A. Camus, similar to those observed on other "red" oaks in California. No damage was observed on "white" oaks in Arizona, and observed only rarely on a white oak, Quercus engelmannii Greene, in California. In Arizona, adult emergence was confirmed from hickory, native to Arizona, and from native to the adult stage for species identification. Nonetheless, our observations of damage and the presence of larvae in the same location and condition in the oak bark, we would expect for A. auricatus suggest that Q. hypoleucoides is also a host. Two hymenopteran parasitoids, California eloquentis Gibson (Hymenoptera) and Ambrosia cupressana Cresson (Hymenoptera), and two lycoperdoid wasps (Pogonosintha and Ectropis) emerged from, or were collected in southeastern Arizonia from, Q. emoryi and Q. coxalis. Based on these surveys, we conclude that A. auricatus is an invasive species in California and the Arizona and California populations, the spatial dynamics of the pattern of infestation in California, the geographic isolation of hosts in California from native populations of the borer, and the proximity of San Diego Co. to southeastern Arizona, we hypothesize that A. auricatus was introduced to California from Arizona or the north of the Mexican states of Baja California, Chiituma, or Sonora, and that the introduction most likely occurred on oak fronds. Further, we hypothesize that the oak mortality in southern California is occurring from this invasive, species because the borer is filling a vacant niche by colonizing and developing in non-colonized trees with low host resistance in the absence of a diverse and coevolved insect complex.

Key Words: Agrilus coxalis, Atascocita scansa, Canisuga elongata, firewood, intraspecific invasive species, oak mortality

Between 2002 and 2010, aerial survey data revealed an expanding pattern of extensive oak mortality on federal, state, and private lands in San Diego Co., California (CA). Approximately 21,535 acres of oak trees, Quercus agrifolia Nee (Fagaceae), California black oak, Quercus kelloggii Newberry, and canyon live oaks, Quercus chrysolepis Lieb., have died in a 4903 km² area centered on the Descanso Ranger District, Cleveland National Forest and Cuyamaca Rancho State Park (Fig. 1A). Until recently, this zone of oak mortality was not consi-

2012

Forest stand composition and impacts associated with Agrilus auricatus Sparrecker (Coleoptera: Buprestidae) and Agrilus coxalis Waterhouse in oak woodlands

Tom W. Coleman a,*, Andrew D. Graves b, Mark Hoddle c, Zachary Heath d, Yigen Chen e, Mary Louis Flint f, Steven J. Seybold b

a USDA Forest Service–Forest Health Protection, 632 S. Township Ave., Arc, California 92408, United States
b USDA Forest Service–Forest Health Protection, 333 Broadway Rd., SE, Albuquerque, NM 87102, United States
c Department of Entomology, University of California, Riverside, 530 University Ave., Riverside, CA 92521, United States
d USDA Forest Service–Forest Health Management, 1731 Research Pk. Dr., Bk, P.O. Box 556, United States

ABSTRACT

From 2002–2011, we assessed the impacts of the goldspotted oak borer, Agrilus auricatus Sparrecker, or its sibling species, Agrilus coxalis Waterhouse, at locations in southern California (infested: infected ICA and uninfested: UC), southeastern Arizona (AZ), and southwestern Mexico (MX). Our surveys examined forest composition of oak woodlands; the degree of injury and proportion of oak killed; extent of infestation; impact of infestation on oak mortality in San Diego Co. (ICA), by tree species of impact. At infested BAS, we estimated the proportion of infestation and the degree of injury, i.e., stem base of oak species at ICA sites, and red oaks greater than or equal to 18 cm in DBH; the oak mortality in any live trees and killed 13% of the oak component of the forest (vs. 14% killed and 25% dead in AZ, respectively). At survey plots near the predicted origin of the outbreak in CA, over 90% of the diameter of red oaks have been infested. Nearly 90% of the dead oaks surveyed across all ICA sites showed evidence of previous injury symptoms from A. auricatus. Aerial oak mortality patterns associated with A. auricatus have expanded – 34 km in nine years, but our analysis confirms that the outbreak appears to still be confined to San Diego Co. The distance of oak mortality from the predicted origin of the outbreak is explained by a variable in a compartmental computer model. The invasive population of A. auricatus is of significant consequence to the oak woodlands of California and should be managed accordingly, especially by removing infested trees.

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1. Introduction

Stem-infesting Agrilus spp. (Coleoptera: Buprestidae) phloem xylem borers have played key roles in historic cases of oak decline and mortality in the eastern USA and Europe (Nichols, 1968; Sten-ger et al., 1989; Hartmann and Blank, 1993; Fellers, 1998; Ozolins, 1998; Thomas et al., 2002). Damage from most Agrilus spp. is associated with oak trees already in decline. For example, in the eastern USA, the native twinned chestnut borer, Agrilus harveysi Weber, frequently attacks oaks weakened by high levels of defoliation from Leptographos, infection by Armillaria sp. (Fr) Staudt root rot, injury from frost, and drought (Chapman, 1943; Harris and Hauss, 1943; Knoll, 1972; Backlund, 1981; Smith, 1985; Tumer and Steffen, 1975; Wargo, 1977) and is typically regarded as a secondary pest on stressed oaks (Dunne et al., 1994; Haack and Clace, 1990; Neza and Alcayd, 2002). In Europe, the native oak splen-
GSOB larval hosts

California

Arizona

Mexico

Q. peduncularis

Q. conzatti

(A. coxalis)
GSOB Adult Feeding Assays

Dual-choice test for GSOB adult feeding behavior

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

Small leaf disks

Small branches with leaves
GSOB: Adult Feeding Preference

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

Chen et al. (2013) Entomologia Experimentalis et Applicata 149:57-66
GSOB: Adult Feeding Preference

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

Chen et al. (2013) Entomologia Experimentalis et Applicata 149:57-66
GSOB: Risk to California?
GSOB Risk Assessment

Initial Risk Assessment, 2008/2009

Based on:

Range of Potential Hosts
GSOB Risk Assessment

Initial Risk Assessment, 2008/2009

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

Advanced Risk Assessment, 2015

Based on:

Temperature/Precipitation
Freeze Tolerance
Host Susceptibility
Dispersal Capacity

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

Yigen Chen
UC-Davis

Tom Coleman
USDA FS
San Bernardino
# Coordination of Life Cycle and Management Activities for GSOB

An IPM Framework

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## Treatments for Infested Wood

Yigen Chen  
UC-Davis

Tom Coleman  
USDA FS  
San Bernardino
Treatments: Management of Wood from Infested Areas

- Debarking
- Grinding
- Removal timing
- Solarization
2011: Survival and Management of GSOb in Firewood (Grinding, 3" Pieces)

www.dontmovefirewood.org

Season wood from recently killed trees for two years.
California Black Oak Defoliator: Fruit tree leafroller, *Archips argyrospila* (Tortricidae)

**Figure 11.** Fruit tree leafroller caterpillar hanging from silken thread.
California Black Oak Defoliator: 
Fruit tree leafroller, *Archips argyrospila* (Tortricidae)

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

Historical outbreaks on California black oak in the San Bernardino Mountains
1) 1951-1953
2) 1999-2003
California Black Oak Defoliators

**Defoliators**

**Black Oak Leaf Miner**  
*Eriocrania aurosparsella*  
Contributions by: Danny Cluck

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

**Fruittree Leaf Roller**  
*Archips argyrospila*  
Contributions by: Tom Coleman

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

New flatheaded wood borer in San Diego County

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

In September 2005 one of us (RJW) collected a large buprestid beetle at her home near Julian, San Diego Co., California and sent it to another of us (JPB) who identified it as *Chrysobothris costifrons* Waterhouse, 1887 (Fig. 1). The identification was confirmed by the third author. In October 2005, RJW collected another individual of the same species as it flew into her garage! She photographed it and posted the image on BugGuide (bugguide.net/node/show/371262; accessed 3 February 2015). Specimen label data are as follows: CALIFORNIA, San Diego Co., Julian, 5893 Mt. Meadow Rd. 33.0150° N, -116.6166° W, elev. 1268 m, 27-IX-2005, R. J. Wuyers [J. P. Basham Collection]; same locality, 25-X-2008, R. J. Wuyers, [R. J. Wuyers Collection]. The locality is 4.5 mi SSW of Julian. This species ranges in length from 15.2–19.8 mm (Westcott 1983).

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

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

**Figure 1.** *Chrysobothris costifrons* Waterhouse, adult male, 4.5 mi SSW Julian, California, U.S.A.
Forest Health Challenges to California Black Oak

I) Insects
   A) Phloem feeders: Oak bark (and ambrosia) beetles
   B) Phloem feeders: Goldspotted oak borer
   C) Defoliators: Fruit tree leafroller

II) Pathogens
   A) Stem cankers: Phytophthora ramorum and sudden oak death
   B) Root diseases: Armillaria mellea/gallica-Armillaria root rot
   C) Foliage (twig) diseases: Apiognomonia errabunda and oak anthracnose
Stem cankers:

*Phytophthora ramorum* and sudden oak death

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

Original map from M. Kelly, UC-Berkeley

Humboldt County

Marin County

Big Sur
Big Sur
S. Frankel
Oaks
Quercus agrifolia
Q. kelloggii
Q. parvula var. shrevei
Q. chrysolepis

Tanoak
Notholithocarpus densiflorus
Infections and lesions on leaves, twigs, and small stems of a variety of native species in coastal California forests.
Known Host Range of *Phytophthora ramorum*

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

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

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

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

- Mycelial fans
- Rhizomorphs
- Wet stringy white rot, sometimes with hard black plates (zone lines)
- Fruiting bodies
Dispersal

Rhizomorphs

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

Produce spores, not significant in disease development
Persistence

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

Gap started at a suppressed and infected black oak.

All tree species may be killed.
Foliage (twig) diseases:

*Apiognomonia errabunda* and oak anthracnose

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

We would rather not see what will happen to oaks if GSOB and SOD join forces
Thank you for your Attention

Questions and Discussion?
Agrilus auroguttatus

GSOB’s native and introduced ranges

Coleman and Seybold (2008)
*Pan-Pacific Entomologist* 84: 288-300
Fig. 2. The four mountain ranges (Santa Catalina, Santa Rita, Huachuca, and Chiricahua) in the Coronado National Forest in southeastern Arizona where historical collections of *Agrilus auroguttatus* were made. General localities (X) are noted on the four mountain ranges, but a few exact localities (○) were available from collection labels.
Fig. 2. The four mountain ranges (Santa Catalina, Santa Rita, Huachuca, and Chiricahua) in the Coronado National Forest in southeastern Arizona where historical collections of *Agrilus auroguttatus* were made. General localities (X) are noted on the four mountain ranges, but a few exact localities (●) were available from collection labels.
mtDNA and nuclear DNA analyses suggest that the CA population is most similar to populations in southeastern AZ.
Likely transported to CA on firewood.
Population genetics of goldsplted oak borer, *Agrilus auroguttatus* Schaefler (Coleoptera: Buprestidae): investigating the origin of an invasive pest of native oaks in California

Vanessa M. Lopez · Paul F. Rugman-Jones · Tom W. Coleman · Mark S. Hoddle · Richard Stouthamer

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Abstract The goldsplted oak borer, *Agrilus auroguttatus* Schaefler, is an invasive woodborer in California USA that is native to oak woodlands across southern Arizona USA. Developing a classical biological control program for this pest in southern California is a high priority due to the continuing ecological and economic damage caused by this insect since its recent introduction into the area. In an attempt to determine the area of origin for this invasive beetle, analyses of the mitochondrial cytochrome oxidase I and ribosomal nuclear D2 domain of the 28S gene regions were undertaken and provided insight into the phylogeographic relationship between and within populations of *A. auroguttatus* in Arizona and California. The area of origin for the invasive population of goldspted oak borer in California was not determined conclusively, although our molecular data suggests the Dragoon Mountains in Cochise Co., Arizona as a possible source for the California population of *A. auroguttatus*. Results also confirmed that individuals collected from populations across southern Arizona and California are all *A. auroguttatus*, and are not part of a cryptic species complex comprised of the morphologically similar *A. consulis*. Future surveys for natural enemies of *A. auroguttatus* will focus on the Dragoon Mountains as a potential source for co-evolved enemies for use in a classical biological control program against this invasive woodborer in southern California.

Keywords *Agrilus auroguttatus* · Biological control · Cytochrome oxidase I · Phylogeography · Wood-borer

Introduction

The goldspted oak borer, *Agrilus auroguttatus* Schaefler, (Coleoptera: Buprestidae) is an invasive wood-boring beetle that aggressively attacks native oak trees in southern California, USA. Native to Arizona, this beetle was initially detected in the Docena Ranger District, Cleveland National Forest (IRD-CNFS), San Diego County, California, in 2004, but was likely introduced accidentally several years earlier through movement of infected oak firewood (Coleman and Seybold 2008c; Coleman et al. 2012a). Infestations of *A. auroguttatus* in southern California currently covers approximately 213,000 ha across San Diego, and Riverside Counties (Jones et al. 2013), and
~25,000 oaks
Have been killed by
GSOB within an area
of 212,460 ha in
San Diego Co.
(USDA FS, FHM 2013).

Aerial Detection of Southern California Oak Mortality
Time from infection to mortality

– *Armillaria* & Host Species

– Inoculum potential of the individual fungus
  • Larger resource base = more aggressive

– Health and age of the host
  • Young trees (less than 15 years old, especially in plantations) often girdled
  • Older trees can often contain the infection

– Environment
  • Moist conditions
In Managed Forests

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

• Especially aggressive and damaging in young trees

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

• Avoid off-site trees that may be stressed and pre-disposed

• Removal of inoculum = tree and root system removal
Landscape, Vineyards, Orchards

• Common in Urban settings

• Important disease of stone fruits, also infects citrus, walnuts, and grapes

• Most severe on sites previously occupied by hardwoods, especially oaks (reason for the common name “Oak Root Fungus”)
Control: Urban & Agricultural

• Avoid Overwatering
• Reduce wounding
• Removal of stumps/dead wood that can harbor the fungus
• If hot and dry, can removal of soil from the root collar can help infected hosts recover, may kill the fungus
Top 10 Interesting Facts about the 37-Acre Fungus

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

April 9, 1992