CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

Kuroshio and Polyphagous Shot Hole Borer in Southern California Wildlands

Associated Host Identification Guide

Contents

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All photos by CDFW staff unless otherwise noted.

Introduction

Shot hole borers (SHB) and *Fusarium* dieback (FD) represent an increasing threat to many plant species in southern California. Two similar species of invasive shot hole borer exist in southern California, the Polyphagous shot hole borer (PSHB) and the Kuroshio shot hole borer (KSHB) (*Euwallacea spp*). Shot hole borers are ambrosia beetles forming a symbiotic relationship with the fungi. PSHB symbionts are *Fusarium euwallaceae*, *Graphium euwallaceae*, and *Paracremonium pembeum,* while KSHB forms a symbiotic relationship with two novel species of *Fusarium* and *Graphium* (Cooperband et al. 2016) (Lynch et al. 2016) (Eskalen, Stouthamer 2015). These fungi clog the host's vascular tissue leading to branch dieback and eventually tree death. The beetles are not pathogenic in their native habitats in Southeast Asia, preferring instead to infect stressed trees (Hulcr and Dunn 2011). The two shot hole borer species found in southern California differ primarily in the fungal species they associate with but can be treated the same for the sake of management.

SHB infestations begin when females burrow natal galleries into the host, introduce symbiotic fungi, and lay eggs. Females are capable of producing haploid male offspring in the absence of mating while mated females produce diploid female offspring. Eggs mature into adults in six weeks. Beetle emergence occurs over a period of weeks during the spring and summer. Dispersal of females to other hosts is primarily wind-driven, but is also likely facilitated by firewood and green waste movement. Males are incapable of flight; they remain on the host tree but may enter other natal galleries (Umeda, Eskalen, and Paine 2016). Beetle dispersal can occur over large distances if winds allow.

The loss of wildland trees, particularly in riparian areas, poses a threat to numerous threatened and endangered species such as the least Bell's vireo (*Vireo bellii pusillus*). Destroyed forests give way to invasive species such as giant reed (*Arundo donax*) and castor bean (*Ricinus communis*) (Boland 2016). Specifics of this emerging threat are poorly understood and while research is ongoing this guide is intended as an identification aid for land managers in areas where SHB may not yet be discovered.

Willow stands destroyed by KSHB in the Tijuana River Valley. Note castor bean (Ricinus communis) in foreground – an invasive species

Identifying Shot Hole Borer in the Field

Entry/Exit hole in willow (Salix sp.)

Male (Left) and Female (Right) shot hole borers. *Eskalen et al., Jan. 2016*

Entry holes for PSHB and KSHB are perfectly circular and are roughly the size of the tip of a ball point pen (~0.85 mm). Males are flightless and remain in the tree on which they were born. Females emerge when temperatures rise above 68° Fahrenheit. Emerging females will fly to a new host or recolonize the tree they emerged from. Excessive recolonization can lead to the destruction of the tree's structural integrity. Early-stage infestations may require some effort to see, as symptoms may not be readily apparent. At bare minimum, you will encounter some entry holes with staining beneath the bark. Both KSHB and PSHB are mildly attracted to Querciverol lures; neither are known to use aggregation or sex pheromones. Within a host species, the females prefer healthy mature trees with access to plenty of water. These factors make SHB an unconventional and unpredictable pest.

This is intended to be a guide to California native and invasive host trees likely to be found in wildland settings. Also included is known host status, associated SHB symptoms, and photos to aid in identification. This guide should not be treated as an exhaustive list of potentially affected species; the list of known hosts is growing and any tree that exhibits general SHB symptoms should be documented. Though the known host list for KSHB is shorter than that PSHB, they are expected to have a similar host range.

Glossary

Bleeding: Leaking sap and fluids from the entry/exit wound. The fluids can leave stains or dry into a white or yellow powder. (*Fig. 1*)

Frass: Waste pushed out of SHB galleries, often looks like plugs of sawdust or a ring of sawdust around the base of the tree. (*Fig. 2*)

Fusarium Dieback: Dark discoloration of the sapwood around the entry/exit wound leading to isolated leaf and branch dieback. Often it will appear that only one section of the tree is affected. (*Fig. 3*)

Gumming: Thick gummy sap exuded from the entry/exit wound. (*Fig. 4*)

Not a Preferred Host: Based on survey data from infested landscapes with a sample size of greater than 7/species, species that are not preferred host have less than 5% of their population infected with SHB.

Preferred Host: Based on survey data from infested landscapes with a sample size of greater than 7/species, preferred hosts are species with greater than 75% of their population infected with SHB for native species, and greater than 10% for invasive species.

Staining: "Watermark" like stains around the entry/exit wound. These stains can be lighter or darker than the surrounding bark. (*Fig. 5, Fig. 6*)

Fig. 1 Bleeding with staining

Fig. 2 Frass (Boland 2016)

Fig. 3 Fusarium causing staining of sapwood

Fig. 4 Gumming (Boland 2016)

Fig. 5 Heavy staining

Fig.6 "Watermark" staining (Courtesy of OC Parks)

Acacia spp.

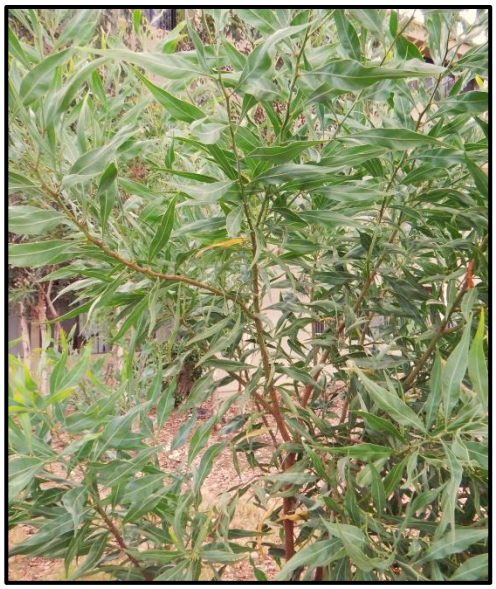
Wattles

Native/Invasive

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Yes	Unknown

Associated Symptoms: Staining, gumming

Diverse genus. Host status of native *Acacia greggii* is unknown. All other species are not native to California.



A. longifolia

A. melanoxylon (©2016 Zoya Akulova)

A. greggii (©2005 Stan Shebs)

***A. dealbata* leaves** (©2016 Zoya Akulova)

Acer negundo

Preferred Host

Box elder

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: *Fusarium* dieback, staining, bleeding, frass, often fatal

(©2016 Zoya Akulova)

Acer macrophyllum

Preferred Host

Bigleaf maple

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: *Fusarium* dieback, staining

(©2016 Steve Matson)

Aesculus californica

California buckeye **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: *Fusarium* dieback

(©2007 Eugene Zelenko)

(©2008 David Baron)

Ailanthus altissima

Tree of heaven **Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Yes	Unknown

Associated Symptoms: Unreported

(Richard Gardner, UMES, Bugwood.org)

(Richard Gardner, UMES, Bugwood.org)

Alnus rhombifolia

Preferred Host

White alder

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: Staining

Bleeding and staining caused by PSHB

Ambrosia monogyra

Singlewhorl burrobrush **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Unknown	Yes	Unknown	Unknown

Associated Symptoms: Unreported, not a preferred host

(©2014 Keir Morse)

(©2014 Keir Morse)

Arundo donax

Giant reed **Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Unknown	Yes	Unknown	Unknown

Associated Symptoms: Unreported




(©2009 Peter Forster)

Baccharis pilularis

Coyote bush

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Unknown	Yes	Unknown	Unknown

Associated Symptoms: Not a preferred host

Entry hole on *B. pilularis* stem

Baccharis salicifolia

Mulefat **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: Staining, gumming. Mulefat will sprout from the crown after its stalks are damaged; immature stalks suffer fewer beetle attacks.

(©2013 Keir Morse)

Entry/exit holes and gumming (2016 John Boland)

Cercis occidentalis

Western redbud **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Unreported

(©2004 Stan Shebs)

Eucalyptus spp.

Gum trees **Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Unknown

Associated Symptoms: Unreported. Diverse genus; leaves and bark characteristics vary.

***E. camaldulensis* flower** (©2005 Brent Miller)

Bark of *E. rudis*

***E. rudis* foliage**

***E. globulus* leaves** (©2016 Zoya Akulova)

***E. globulus* trunk**

Frangula californica

California coffeeberry **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Gumming

(©2012 Jean Pawek)

Fraxinus dipetala

California ash, flowering ash **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Unreported

(©2010 Michael O'Brien)

(©2009 Keir Morse)

Smmflowers.org /National Park Service

Fraxinus velutina

Arizona ash, Velvet ash

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Staining

Juglans californica

California black walnut **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Yes	Unknown

Associated Symptoms: Unreported

(©2016 Zoya Akulova)

(©2011 Robert A. Hamilton)

Lyonothamnus floribundus

Catalina ironwood **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Unreported

Nicotiana glauca

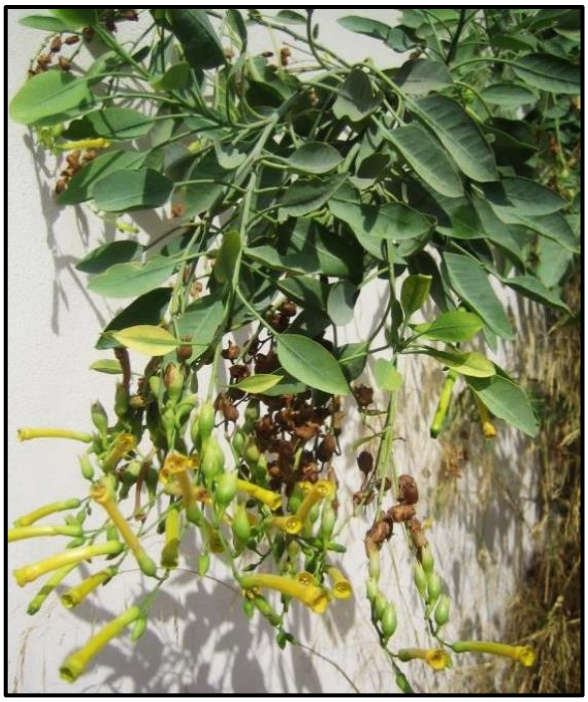
Preferred Host

Tree tobacco

Invasive

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Unknown	Yes	Unknown	Unknown

Associated Symptoms: Unreported



Parkinsonia spp.

Palo verde

Native/Invasive

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: *Fusarium* dieback, staining, frass. Both native and non-native species may be encountered in wildlands.

(©2011 Zoya Akulova)

Platanus racemosa

Preferred Host

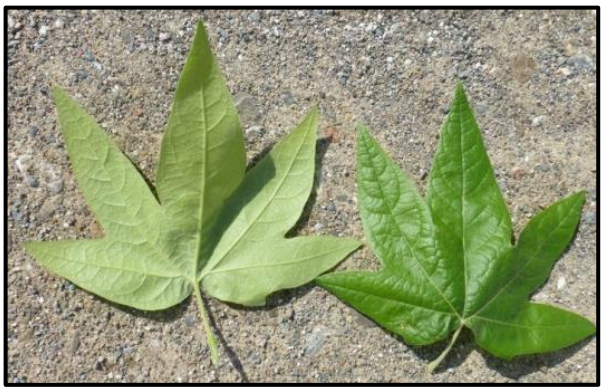
California sycamore

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: *Fusarium* dieback, staining, often fatal

Active gallery entrance/exit on California sycamore



(©2016 Zoya Akulova)

Active and abandoned entry/exit holes on trunk

Populus fremontii

Preferred Host

Fremont cottonwood

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: *Fusarium* dieback, staining

Trunk Staining

Populus trichocarpa

Preferred Host

Black cottonwood

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: Unreported

(©2008 Keir Morse)

Prosopis spp.

Mesquite **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: Staining

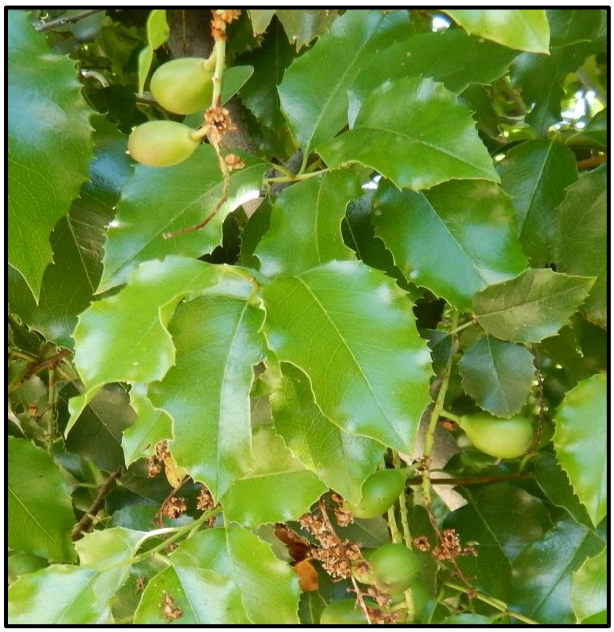
***P. glandulosa* leaves** (©2014 Keir Morse)

Prunus ilicifolia

Hollyleaf cherry **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Unreported



Pyracantha spp.

Firethorn **Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Unknown	Unknown	Unknown	Unknown

Associated Symptoms: Staining

Entry wounds (Courtesy of Orange County Parks)

Entry hole with staining (Courtesy of Orange County Parks)

Quercus agrifolia

Coast live oak **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: *Fusarium* dieback, staining, infection occurs mainly on branches

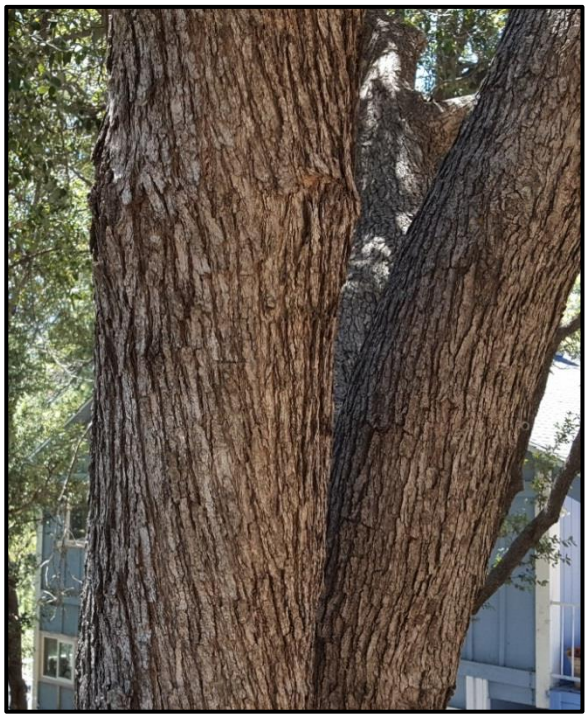
Entry holes along branch/trunk of *Q. agrifolia*

Quercus chrysolepis

Canyon live oak **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: *Fusarium* dieback



Quercus engelmannii

Engelmann oak **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: Staining, infection occurs mainly on branches (difficult to see).

(©2015 Keir Morse)

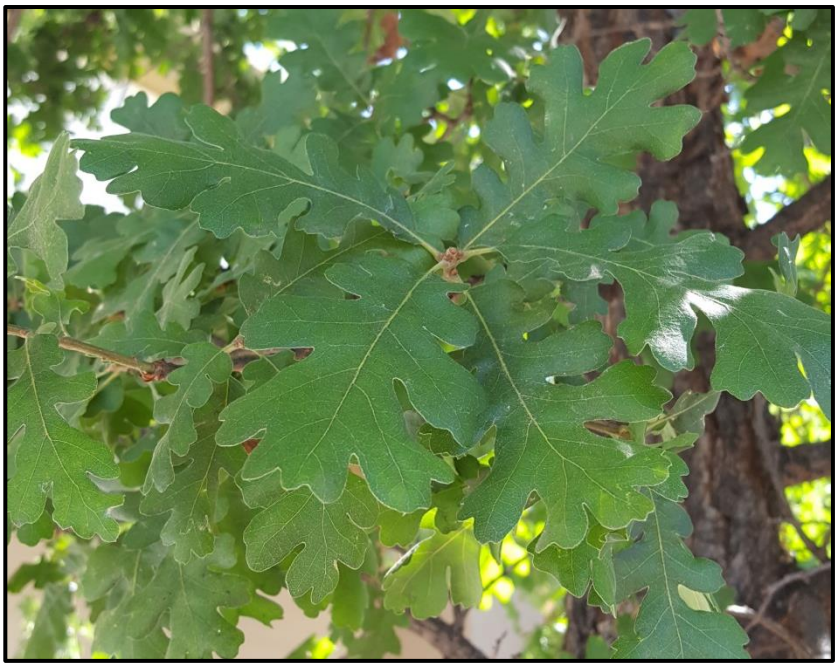
Quercus lobata

Valley white oak

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	No	Yes	No

Associated Symptoms: *Fusarium* dieback, staining



Ricinus communis

Preferred Host

Castor bean

Invasive

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: *Fusarium* dieback, staining

Entry/exit holes (2016 John Boland)

(©2013 Keir Morse)

Robinia psuedoacacia

Black locust **Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: Unreported

Salix exigua

Narrowleaf willow, sandbar willow **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Unknown	Yes	Unknown	Unknown

Associated Symptoms: Unreported, not a preferred host

Salix gooddingii

Black willow **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: Staining, frass, Black willow will sprout from the crown after the tree is damaged; immature sprouts suffer fewer attacks from beetles.

(© 2008 Stan Shebs)

Entry wound

Salix laevigata

Preferred Host

Red willow

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: Staining, frass. Red willow will sprout from the crown after the tree is damaged; immature sprouts suffer fewer attacks from beetles.

(©2017 Zoya Akulova)

Trunk staining

Salix lasiolepis

Preferred Host

Arroyo willow

Native

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Yes

Associated Symptoms: *Fusarium* dieback, staining, frass, Arroyo Willow will sprout from the crown after the tree is damaged; immature sprouts suffer fewer attacks from beetles.

Heavy staining of Arroyo Willow trunk

Entry holes and staining on trunk

Sambucus mexicana

Mexican elderberry **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Unreported, not a preferred host.




Mexican Elderberry leaves and flowers (©2015 Barry Breckling)

Schinus terebinthifolius

Preferred Host

Brazilian peppertree

Invasive

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Unknown	Unknown

Associated Symptoms: *Fusarium* dieback, staining

***S. terebinthifolius* drupes** (Everglades NPS)

Tamarix spp.

Saltcedar, tamarisk **Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Yes	Yes	Unknown

Associated Symptoms: Unreported

Triadica sebifera

Chinese tallow **Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Yes	Unknown

Associated Symptoms: *Fusarium* dieback, staining

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(©2016 Ron Vanderhoff)

(James H. Miller, USDA Forest Service, Bugwood.org)

Umbellularia californica

California bay-laurel, Oregon myrtle, pepperwood **Native**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: *Fusarium* dieback, staining

Washingtonia spp.

Fan palms **Native/Invasive**

PSHB Host	KSHB Host	PSHB Reproductive Host	KSHB Reproductive Host
Yes	Unknown	Unknown	Unknown

Associated Symptoms: Gumming, staining

W. robusta (Mexican fan palm) invasive in coastal areas; native *W. filifera* (California fan palm) in desert washes, creeks

W. filifera (National Park Service)

W. filifera* is stouter with grayer leaves than *W. robusta. (©2008 Luigi Rignanese)

W. robusta (Infratec/Wikimedia Commons)

Appendix – Key to Identifying Willows

Quick Willow Identification for southern California

- **Step 1**: Is the leaf at least 10 x longer than wide? If so, you have found *S. exigua*, sandbar or narrowleaf willow. If not, go to Step 2.
- **Step 2**: Is the leaf the same color above and below? If so, you have found *S. gooddingii*, black willow.
- **Step 3**: Is the distal half of the leaf as wide or wider in every portion than the proximal half of the leaf? (The distal portion is closest to the tip of the leaf, farthest from the stem; the proximal portion is closest to the stem.) If so, you have found *S. lasiolepis*, the extremely common arroyo willow.
- **Step 4**: Are the buds in the axils of the upper leaves obviously sharply-pointed; and is the leaf stalk (petiole) smooth, without "bumps" (glands)? If so, you have found *S. laevigata*, red willow
- **Step 5**: Are the buds in the axils of the upper leaves obviously rounded at the tip; and does the leaf stalk (petiole) have "bumps" (glands)? If so, you have found *S. lucida* var. *lasiandra*, shining willow.

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