University of California
Agriculture and Natural Resources
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Statewide Integrated Pest Management Program

Detecting and Identifying the Walnut Twig Beetle: Monitoring Guidelines for the Invasive Vector of Thousand Cankers Disease of Walnut

STEVEN J. SEYBOLD, USDA Forest Service, Pacific Southwest Research Station, Davis, Calif.;
PAUL L. DALLARA, Entomology, UC Davis; **STACY M. HISHINUMA**, Entomology, UC Davis;
MARY LOUISE FLINT, Entomology, UC Davis and UC Statewide IPM Program

Walnut twig beetle (WTB), *Pityophthorus juglandis*, (Figure 1) is a small native phloeophagous (phloem-feeding) insect that has recently been associated with the fungus *Geosmithia morbida* (Kolařik et al. 2011). This fungus and WTB are the principal agents involved in thousand cankers disease (TCD) (Seybold et al. 2010). This disease is fatal to walnut trees and is responsible for the gradual decline of several species of black walnut in the western United States during the past decade (Graves et al. 2009; Flint et al. 2010; Tisserat et al. 2011). Walnut and butternut appear to be the only hosts (Utley et al. 2009). The disease has spread widely in the western United States and has now been detected in eastern states—including Tennessee (June 2010), Virginia (May 2011), and Pennsylvania (August 2011)—threatening the highly valuable native timber stands of eastern black walnut, *Juglans nigra* (Newton and Fowler 2009). Populations of WTB have been invariably associated with the fungus: this type of dieback of walnut has been found only where the beetle is present. Thus, capturing and identifying the minute WTB is the key to early detection of TCD in new areas.

Photo by S. Valley, Oregon Department of Agriculture
Figure 1. Adult female WTB, lateral profile.

This publication provides detailed guidelines for using pheromone-baited traps to detect and monitor WTB. A two-page guide for field use, *Quick Guide: Installing, Maintaining, and Servicing Walnut Twig Beetle Pheromone Baited Traps*, is also available at http://www.ipm.ucdavis.edu/thousandcankers. The purposes of this trapping are to detect an incipient population of WTB or delimit a known population of WTB where it has been recently discovered.

S. J. Seybold, USDA Forest Service
Figure 2. Four-unit funnel trap.

The trap and guidelines described here were developed in Northern California walnut orchard ecosystems with high population densities of WTB. Subsequently, however, the trapping methodology has been field tested and demonstrated in a variety of urban and wildland landscapes in Southern California, Idaho, Tennessee, Utah, and Virginia with low to intermediate population densities of WTB. The system uses a small multiple-funnel trap (Figure 2) baited with the male-produced aggregation pheromone (Seybold et al. 2011). The trap captures both sexes of the WTB, while attracting few other insect species, including only limited numbers of other small bark or ambrosia beetles (Coleoptera: Scolytidae) (Table 1), making detection of WTB easier.

The baited traps have been used primarily to detect WTB populations. Little information is available on how the traps could be used to assess population levels. If WTB is detected in traps, a survey of nearby walnut trees is warranted to assess the extent of beetle infestation and other TCD symptoms (Graves et al. 2009).

TRAPPING STRATEGY

A primary consideration when selecting locations for traps and choosing a density of traps on the landscape is whether the objective is to detect an incipient population or delimit a known population. A higher density of traps would be used if the extent of an introduced population is to be assessed. If the goal is to detect a new population of WTB over a large land area (e.g., an entire state), only a much lower density of traps would be economically feasible. Whatever the overall goal, traps must be placed near walnut trees. WTB is completely dependent on walnut trees as hosts, and the emerging adult males (and soon thereafter the females) colonize branches of all sizes, but generally not those smaller than 1/2 to 3/4 inch (1.5 to 2 cm) in diameter. Unlike many other species of "twig" beetles (*Pityophthorus*), WTB will even colonize the main stem of trees in advanced stages of decline. It is never solely a twig-infesting beetle, even in its putative native range and host (*J. major*) in Arizona and New Mexico, where it also colonizes the larger branches and main stem of trees.

Table 1. Scolytidae besides WTB detected in pheromone-baited survey traps in California, Idaho, Tennessee, Utah, and Virginia (2010-2012).[1]

Name	Location	Relative abundance[2]
Ambrosiodmus tachygraphus	VA	Very low
Cyclorhipidion pelliculosus	VA	Very low
Dendrocranulus curcubitae	CA	Very low
Dryoxylon onoharaensis	VA	Low
Euwallacea validus	VA	Very low
Hylocurus hirtellus	CA	High
Hylocurus rudis	VA	Very low
Hypothenemus eruditus	CA, TN	Very low
Hypothenemus seriatus	VA	Very low
Monarthrum fasciatum	VA	Very low
Monarthrum scutellare	CA	Very low
Phloeotribus dentifrons	VA	Very low
Phloeotribus liminaris	TN, VA	High
Pityophthorus crinalis	VA	Very low
Pityophthorus pulicarius	VA	Very low
Pseudopityophthorus agricolae/pubipennis	CA	Very low
Pseudopityophthorus minutissimus/pruinosus	TN, VA	Very low
Scolytus multistriatus	TN	Low
Scolytus muticus	VA	Low
Scolytus rugulosus	CA, TN, VA	Low
Scolytus schevyrewi	ID, UT	Low
Xyleborinus saxeseni	CA, ID, UT, VA	High
Xyleborus affinis	VA	Low
Xyleborus atratus	VA	High
Xyleborus celsus	VA	Very low
Xyleborus impressus (=ferrugineus)	VA	Low
Xyleborus xylographus	VA	Low
Xylosandrus crassiusculus	VA	Low
Xylosandrus germanus	VA	Low
Xyloterinus politus	VA	Very low

[1]Researchers also expected to catch *Pityophthorus lautus* and *P. liquidambarus* in the survey traps, but these species have not been recovered to date.

[2]Relative abundance was based on the catches in about 20 survey traps per state during one flight season: very low (<5 specimens), low (5 to 15 specimens), and high (>15 specimens).

WHEN SHOULD I TRAP?

Ideally, pheromone-baited WTB traps would be deployed from April through November when ambient air temperatures exceed 65°F (18-19°C). Depending on available resources, more targeted detection protocols may include:

- Trapping for about six weeks between late June and August. Programs in southern states might begin in April or May.
- Trapping for two weeks in midspring, two weeks in July, and two weeks in early fall.

These recommendations will be updated as full-season monitoring data become available in states with low-density populations. In California, WTB have been caught in pheromone-baited traps every month except December. In 2012, WTB was trapped in pheromone-baited traps in January, not only in California, but also in Tennessee and Virginia. In more northern U.S. locations, winter trap catches are unlikely to occur.

WHERE SHOULD I TRAP?

There will be a high probability of detection if the trap is placed close to healthy or declining walnut trees and positioned near the larger branches of these trees (Figures 3 and 4). During a demonstration trial in Utah, a trap near a pecan tree for most of the summer and fall did not catch any WTB, although English walnut trees were within a one-mile radius of the trap. High population densities of WTB may be associated with declining walnut trees, so placement of traps near dying trees would increase the likelihood of detecting the beetle.

Traps may be deployed in residential areas (particularly in older neighborhoods), parks, and arboreta; along rural roads; in walnut orchards; or in wildland forest habitats. At these locations, look for riparian areas where walnut trees often grow in higher densities. Place traps about 15 to 20 feet from the main stem of the tree, 5 to 10 feet away from live branches, and about 9 feet from the ground (Figures 3 and 4). Placing baited traps closer than the recommended distance may result in WTB infesting an uninfested branch or the main stem. Avoid placing traps near yard sprinklers and heavily trafficked locations.

Other locations where populations of WTB may be found include green waste facilities, firewood lots, or hardwood mills where walnut stems and branches might be brought for storage or processing. These sites concentrate potential WTB host material from many sources, so traps placed at these locations may have a higher probability of capturing the beetle. In these sites, where host material is accumulated from various sources, a “trace back” analysis might be necessary to establish the actual origin of the infested host material.

Research data are not available on the optimal trap density necessary to detect an incipient population of WTB. The current detection recommendation is to deploy one trap near each target walnut tree and then determine the number of target trees according to the budget of the detection agency. If trees are absent near log storage facilities or firewood lots, then place one or more traps near piles of walnut branches, stems, or cut slabs, but on the property perimeter and away from heavy equipment pathways.

J. Keener, Tennessee Department of Agriculture

Figure 3. Placement of a four-unit funnel trap in a residential yard near a small black walnut in Knoxville, Tenn.

P. L. Dallara, UC Davis

Figure 4. Placement of a four-unit funnel trap in a residential yard near a large black walnut in North Ogden, Utah.

WHAT DO I NEED TO GET STARTED?

The Trap

The recommended detection system begins with a black plastic multiple-funnel (Lindgren) trap (wet cup option) (Figure 2), which is commercially available from several vendors (e.g., Contech Enterprises Inc., Synergy Semiochemicals). These traps have been used for many years for trapping bark- and wood-boring insects in forest and urban habitats and are familiar to those across the United States who have participated in Cooperative Agricultural Pest Survey and Early Detection Rapid Response programs. Thus, many detection agencies may already have a large supply of the traps. For convenience and to minimize cost, use the four-unit funnel trap, but those with a larger number of funnels will also capture WTB.

Various sticky-coated and other barrier-type traps do not rival the funnel trap for ease, convenience, and consistency. Specimens caught in funnel traps are ready for immediate evaluation under the microscope and require little clean up. Bycatches (i.e., catches of other bark and ambrosia beetles, aphids, flies, thrips, and wasps) have been minimal in funnel traps baited with WTB pheromone. Color does not appear to influence the response of WTB, so the standard black plastic funnel trap is a good choice. Although certain sticky-coated traps may catch more insects than funnel traps, the vagaries of various commercial formulations of adhesive and the difficulties inherent in cleaning and processing the trap catches for identification make them more difficult to use. These obstacles are not an issue with funnel trapping.

The Bait

S. M. Hishinuma, UC Davis

Figure 5. Pouch formulation of WTB bait from Contech Enterprises Inc.

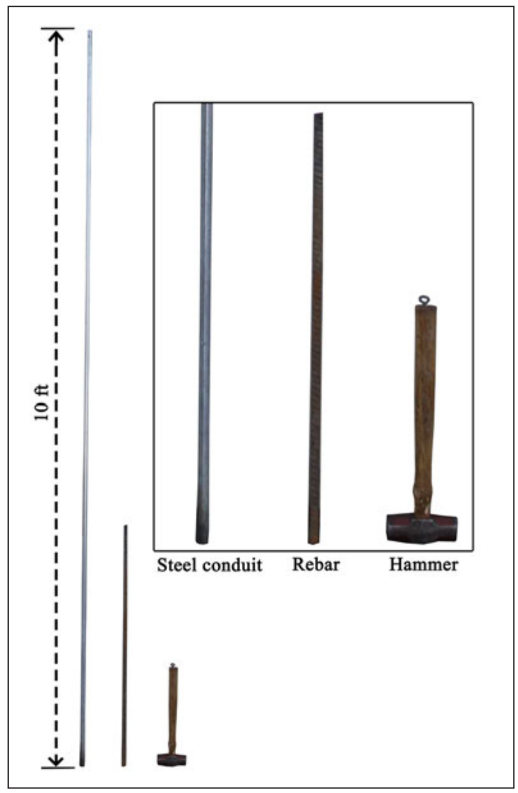
The bait (Figure 5) is a proprietary formulation of the male-produced aggregation pheromone of the WTB in a passive slow-release device. This small plastic pouch has been tested in California during studies of the effect of pheromone release rate, trap placement and trap type, and seasonal and diurnal flight behavior of the WTB. The attractant has been used in Idaho, Tennessee, Utah, and Virginia in trapping transects. Baited traps have detected WTB in new counties in Tennessee and Virginia and have proved that WTB is capable of flying into late November and in January in these two eastern states. The bait is attached directly to the trap inside the funnel column. (See the section Putting it All Together.) The vendor for the baits is Contech Enterprises Inc., http://www.contech-inc.com/. When ordering, specify the walnut twig beetle bait.

S. M. Hishinuma, UC Davis

Figure 6. Pouring antifreeze from the bottle into the trap cup.

The Trap Cup and Propylene Glycol Trapping Agent

Captured beetles fall into a white trap cup that is mounted with a "bayonet" fitting to the lowest funnel. The preferred version of the wet cup has a solid molded-plastic bottom. Because of potential leakage, a cup that has been modified from the usual design by replacing the metal sieve in the bottom drain hole with a No. 5 rubber stopper is less preferred. Request a "wet cup" or "wet trap" version when ordering traps from the manufacturer. Research in other bark beetle systems suggests that wet cup trapping retains more target insects than dry cup trapping; it also preserves the specimens better for later identification and curation in museum or survey collections. Some wet cups have a screened overflow hole located in the upper side of the trap cup. Because of the small size of the WTB, check to make sure the mesh size on this overflow hole is fine enough to prevent the loss of specimens.



S. M. Hishinuma, UC Davis

Figure 7. Materials for suspending traps: steel conduit (EMT), rebar, and a sledgehammer.

Add 1 to 2 inches of recreational vehicle or marine antifreeze to the bottom of the cup to immobilize insects (Figure 6). This antifreeze solution, available from many vendors, is usually pink and consists of propylene glycol dissolved in water. Read the antifreeze label to ensure that the product contains propylene glycol, which has very low toxicity, and **not** ethylene glycol, which is highly toxic to wildlife, and that the product does not contain ethanol or ethyl alcohol. Ethanol will attract ambrosia beetles that will complicate trap catch processing and positive identification of the WTB. There is no evidence that ethanol attracts WTB. *Do not use automobile antifreeze*, even if it is pink, as it typically contains ethylene glycol. For large-scale uses and to eliminate the potential for ethanol contamination, food-grade propylene glycol (99.5% pure) can be purchased from chemical supply companies and diluted with water in a 25 to 30% solution.

Materials for Suspending the Trap

Since traps should not be placed on trees, the recommended method of installation is on poles. For consistency, users should suspend traps from the top of a 10-foot length of 1/2-inch thin-walled galvanized steel conduit (EMT) (Figure 7), available at most hardware stores for only a few dollars. These conduit poles slip over a 3- to 4-foot length of 1/2-inch rebar used as a stake. The conduit poles have about a 3/4-inch outer diameter and a 1/2-inch inner diameter: make sure they fit over the rebar before taking them out in the field. Do not install poles or service traps during periods of potential lightning storms. Preliminary research in California suggests that baited traps suspended 10 feet or even higher above the ground will capture more beetles than traps placed at head height.

Funnel traps purchased during the last few years come with an eyebolt attachment in the top of the trap (Figure 8). When used to secure the trap to the pole, the eyebolt attachment provides wind stability. A strong heavy-gauge (12-gauge or thicker) wire can be attached to this eyebolt and threaded through a 3/16-inch or larger hole drilled through both walls of the pole, about 1 1/2 inches from the top. Cut the wire long enough to be wound around the pole and reattached to the trap. (See the section Putting it All Together.) Older traps without such an attachment can be modified by installing a 1/4-inch eyebolt, fender washers, and a locknut in the top of the trap.

For a complete list of materials, see Table 2.

PUTTING IT ALL TOGETHER

Assembling the Trapping System

Once a specific location for trapping has been selected, use a small sledgehammer to drive the stake into the ground about 1 foot or more, depending upon the soil type, to provide a stable base for the pole. Leather or fabric gloves should be worn when handling and installing rebar. Be cautious of underground irrigation lines or other buried objects, and do not place the trap near an automatic sprinkler that might flood the trap cup or knock the trap over. Try to position the trap 5 to 10 feet from the lower foliage of the target walnut tree, so that the flight of incoming beetles is not impeded and live branches are not attacked by dispersing WTB.

Once the stake is in place, wire the top of the trap to the top of the pole with heavy-gauge wire (Figure 9). Make sure that the funnels of the trap are fully extended, then use light-gauge wire (e.g., 16-gauge) or zip ties to fasten the lowest strut or the molded plastic tabs at the bottom of the funnel to a location further down on the pole (Figure 9). This will keep the trap vertical, reducing the risk of wind damage. Some of the newer traps have holes in the side of the lid that can be wired to the pole as well. When installed, the lid of the trap should be about 8 to 9 inches from the top of the pole.

Next, attach the bait so it hangs in the middle of the trap (Figure 9). The most effective odor plume is thought to be produced when the bait is inside the funnel column. For a four-unit funnel trap, attach the bait to the funnel strut so it rests on the inside surface of the third funnel, but not so low that it blocks the central axis/interior hole of the trap. That cylindrical space should be kept clear so the beetles can fall down freely into the trap cup. When using 12-unit traps, users should hang the bait from the strut above the sixth funnel.

S. M. Hishinuma, UC Davis

Figure 8. Lid from a four-unit funnel trap showing the eyebolt and heavy-gauge wire.

Table 2. Equipment/Supply Checklist.

To install the trap
Four-unit black plastic multiple-funnel (Lindgren) trap with wet cup
Bait (male-produced WTB aggregation pheromone in a slow-release device)
Heavy-gauge wire and light-gauge wire or zip ties
Wire cutters or fencing pliers
Propylene glycol-based antifreeze, marine or RV (no ethyl alcohol, ethanol, or ethylene glycol)
3- to 4-foot length of 1/2-inch rebar
Drill and 3/16-inch drill bit
Heavy hammer
10 feet of 1/2-inch thin-walled galvanized steel conduit (EMT)
Leather or fabric gloves
To maintain and service the trap
Quart- or sandwich-sized zipper lock plastic bags
Replacement antifreeze
Laser-printed or penciled slips of paper for labels (no ink)
Conical paper paint strainers with nylon mesh inserts, one per trap catch
Secondary container (e.g., a large yogurt container) to catch antifreeze during filtration
Plastic container with cap for waste antifreeze
Plastic funnel
Gallon-sized zipper lock plastic bags
Plastic cooler with frozen blue ice for transporting trap catches and baits
Spare wire
Heavy hammer
Wire cutters or fencing pliers
Replacement baits, if necessary

Once the trap is baited, add antifreeze to the trap cup to a depth of about 1 to 2 inches (Figure 6) and reattach it to the trap. Finally, place the pole, with the trap attached, over the stake (Figure 10). Check the trap to ensure it is fairly vertical and all funnels are fully separated.

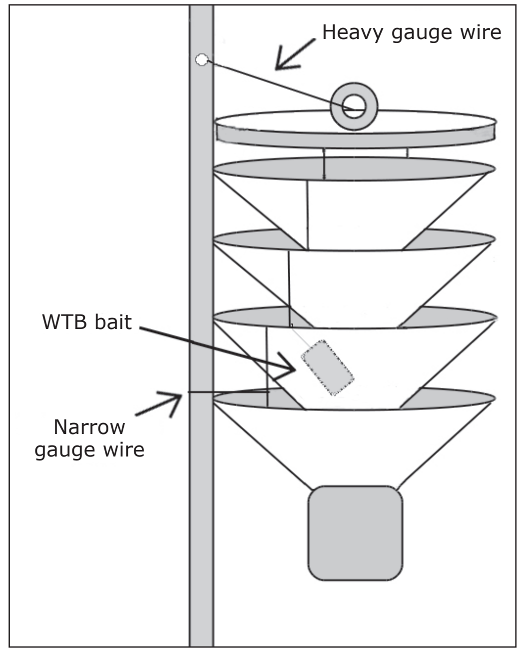
For more information, see the video clip *Installing Walnut Twig Beetle Traps* at http://www.ipm.ucdavis.edu/thousandcankers.

Maintaining the Trapping System

Maintenance of the trapping system is fairly simple. Check traps periodically during routine servicing and specifically following major weather events (e.g., heavy rains, high winds, etc.), to make sure the trap is upright and undamaged and that rain has not diluted the antifreeze or caused the liquid in the trap cup to overflow; if the cup has accumulated rainwater or irrigation water, it should be emptied and the trap catch removed as soon as possible. (See the section Servicing the Traps.) Diluted antifreeze will cause specimens to decay rapidly, and in some cases the specimens will fragment, possibly preventing the accurate identification of WTB.

Another aspect of maintenance is periodic replacement of the baits. The bait pouches are loaded with enough material to last about two months when exposed to a constant temperature of 86°F, but the actual longevity of the bait will depend on the mean ambient temperature during the service period. Thus, conservatively, if temperatures are moderate, baits might need to be replaced every two months during the service period. However, baits could be left in the field longer during the spring and fall, and replaced more frequently between June and September. Order enough baits in the spring to accommodate three to four changes during the trapping season, depending on regional mean temperatures and the duration of the detection survey.

For more information, see the video clip *Maintaining Walnut Twig Beetle Traps* at http://www.ipm.ucdavis.edu/thousandcankers.



J. A. King, UC Davis

Figure 9. Schematic of a four-unit funnel trap showing the attachment between the eyebolt and pole with heavy-gauge wire, attachment and placement of bait, and attachment of the lowest funnel strut to the pole with light-gauge wire.

S. J. Seybold, USDA Forest Service

Figure 10. A four-unit funnel trap in place at the top of a pole.

Servicing the Traps

S. M. Hishinuma, UC Davis

Figure 11. Paint strainer.

Traps should be serviced every 7 to 14 days. Do not service traps during periods of potential lightning storms. Materials necessary for servicing include a supply of quart- or sandwich-sized zipper lock plastic bags, fresh antifreeze, some prepared laser-printed (or penciled) slips of paper for labels, conical paper paint strainers with nylon mesh inserts, a secondary container to catch the antifreeze during filtration, and a plastic container with a cap for waste antifreeze. Paint strainers (Figure 11) can be obtained from paint or hardware stores or in bulk from other vendors (e.g., http://www.toolrage.com, Astro Pneumatic product No. AST-4583). The mesh portion of the filter should be constructed of nylon, not cotton, and a medium to fine mesh size (e.g., 226 to 190 microns) should be used to allow liquid to flow easily through the filter. Do not use mesh sizes larger than 226 microns, as WTB may slip through the filter.

Detach the trap cup and pour the contents through the paint strainer, catching the liquid in a second container (e.g., a large yogurt container) (Figure 12). A plastic funnel can be used to support the paint strainer. Because the beetles are so small, they may get lodged around the cork or any indentations in the bottom of the cup. To be sure all beetles are collected, wash the cup several times with the same antifreeze before discarding the liquid. Carefully transfer all contents within the cup including leaves and other vegetation (Figure 13); nothing should be discarded in the field until the contents have been examined under a microscope.

Once all of the trap cup contents have been transferred into the paper paint strainer and the excess antifreeze has been drained completely, fold the filter and place it along with a paper label into a quart- or sandwich-sized zipper lock plastic bag (Figure 14). Labels should include information about the trap location, start and end dates of the trapping period, and the name of the collector. Label information should be laser printed or written in pencil, as antifreeze will dissolve most ink. Collect the filtered antifreeze in the capped plastic container for later disposal. Next, check the trap for broken parts, make sure the mounting eyebolt is snug, and clear spider webs and other debris from the funnels and cup. Finally, add new antifreeze to the cup and reinstall the trap.

Plastic bags containing individual catches should be completely sealed, grouped, placed into a gallon-sized zipper lock bag, transported in a plastic cooler in the field, then frozen in the lab for a minimum of 72 hours to ensure all insects are dead. Because the insects are easily crushed, do not stack objects on bagged catches. After freezer treatment, catches may be shipped for processing in a corrugated cardboard shipping container (e.g., a FedEx medium box) to prevent damage to specimens. For long-term storage, keep samples in a freezer or transfer to 70% ethanol.

For more information, see the video clip *Maintaining Walnut Twig Beetle Traps* at http://www.ipm.ucdavis.edu/thousandcankers.

S. M. Hishinuma, UC Davis

Figure 12. Pouring trap catch contents in propylene glycol antifreeze through a paint strainer.

S. M. Hishinuma, UC Davis

Figure 13. Trap catch in antifreeze in a trap cup.

IDENTIFYING WTB

S. M. Hishinuma, UC Davis

Figure 14. Folded paint strainer and paper label in a quart-sized zipper lock bag.

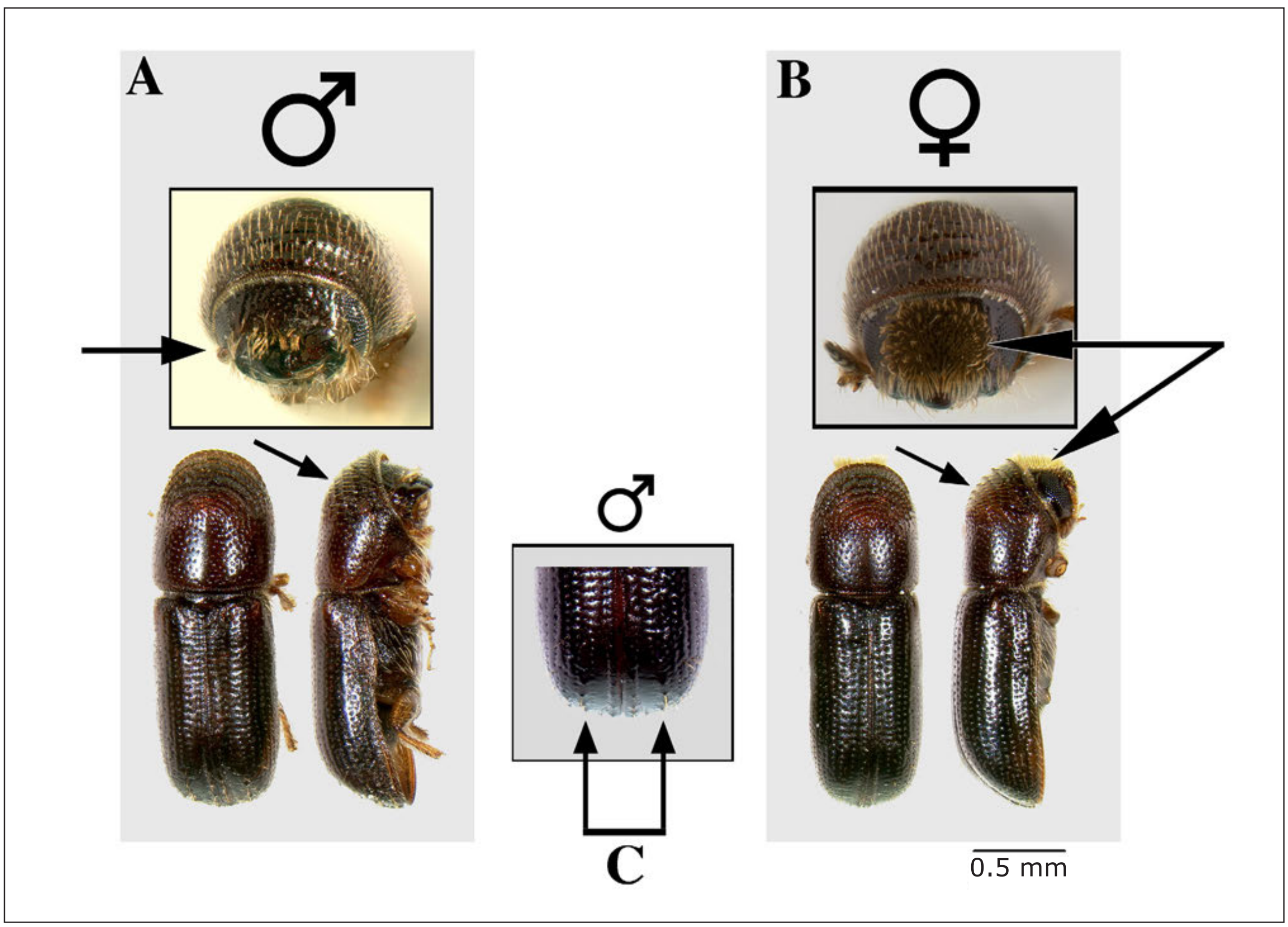
Trap catches will include other insects and arthropods as well as vegetative debris funneled into the cup (Figure 13). Use a stereo dissecting microscope (40X to 60X magnification) to sort through this material to find and identify the WTB (Figure 15). Be sure to examine vegetative debris and large insects carefully for any hidden or attached WTB. In demonstration trials in the eastern and western United States, thousands of WTB have been trapped in WTB pheromone-baited survey traps, whereas low numbers of about 30 other bark and ambrosia beetle species were trapped (Table 1). To minimize the extent of this bycatch, use antifreeze without ethanol in the trap cup.

This guide will not provide the morphological details necessary to allow a user to distinguish all other species of *Pityophthorus* from WTB. If the user is not sufficiently familiar with the distinctive morphology of the WTB, expert identification should be sought to confirm new state or county records. Some basic identification guidelines follow:

- WTB is 1.5 to 2.0 mm long, has a relatively narrow body (about three times longer than wide), and has a reddish-brown to brown cuticle (outer "skin") (Figure 16).
- The frons (face) of the female WTB contains a round brush of golden setae (short hairs) that are no longer than half the distance between the eyes (Figure 16B), whereas the male frons has very sparse setae, sometimes consisting of a "moustache" of short setae above the mandibles (teeth) (Figure 16A).
- The anterior half of the pronotum (upper back) is sloped upward from the frons (Figures 16A and B), reaches an apex before the midpoint (Figures 16A and B), and features four to six concentric arcs of asperities (ridges) (Figure 17). These arcs of ridges may be discontinuous and overlapping, especially near the median. Small teeth line the anterior edge of the pronotum (Figure 17).
- The elytra (hardened forewings) have closely spaced punctures and sparse, short setae. The elytral apex is rounded (Figure 16), and the declivity (depression at the rear end) is very shallow and often shiny.
- The female declivity is smooth (Figure 16B), whereas the male declivity features rows of minute granules on interstriae one and three (Figure 16C).

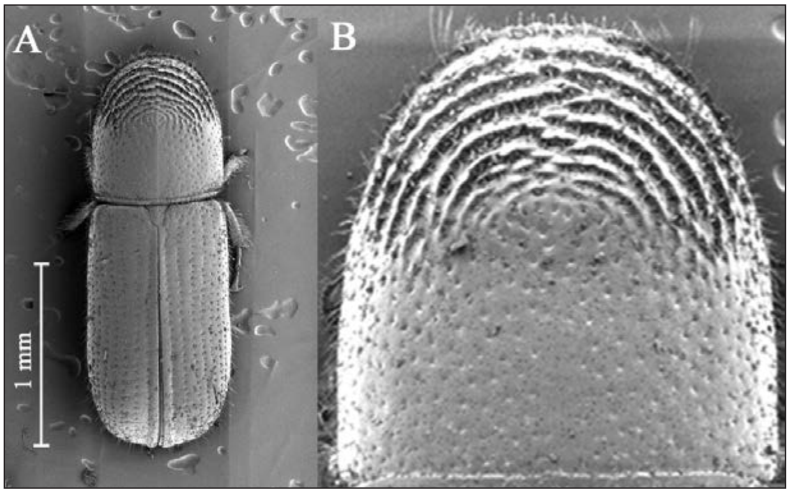
S. M. Hishinuma, UC Davis

Figure 15. Sorting a funnel trap catch in the lab at a dissecting microscope.



A. D. Graves, USDA Forest Service

Figure 16. Comparison of morphological characters of male (A) and female (B) WTB. Arrows indicate the degree of pubescence (hair cover) on the male and female frons (face) and apex before the midpoint on the anterior half of the pronotum (upper back) as well as granules on the male elytral declivity (C).



A. D. Graves, USDA Forest Service

Figure 17. Scanning electron micrograph of the dorsal profile of a female WTB (A) and close up showing pronotal asperities (B).

Several of the other bark and ambrosia beetles that have been trapped along with WTB provide interesting contrasts for identification (Figure 18 and Table 1):

- The fruit-tree pinhole borer, *Xyleborinus saxeseni*, is perhaps the most common ambrosia beetle trapped in WTB pheromone-baited traps (Figure 19).
- All scolytids have a clubbed, elbowed antenna, but in WTB the club is entire, whereas in X. saxeseni it is truncated (cut off at the tip) (Figure 19). The pattern of asperities on the pronotum of X. saxeseni is relatively random when contrasted with the concentric arc pattern in WTB (Figure 19).
- Although the elytral declivity of male WTB has small granules, neither sex has true spines, which are present in that location on some ambrosia beetles (e.g., *X. saxeseni*) (Figure 19).
- The rounded elytral apex of WTB differs from the pointed elytral apex of *Hylocurus rudis* and other *Hylocurus* spp. (Figure 20).
- The sparse vestiture (collection of setae) on the wing covers of WTB contrasts with the bi-layered and heavy vestiture of oak bark beetles, *Pseudopityophthorus* spp. (Figure 18).
- As their Latin names suggest, WTB and oak bark beetles are very similar in many other morphological characteristics.

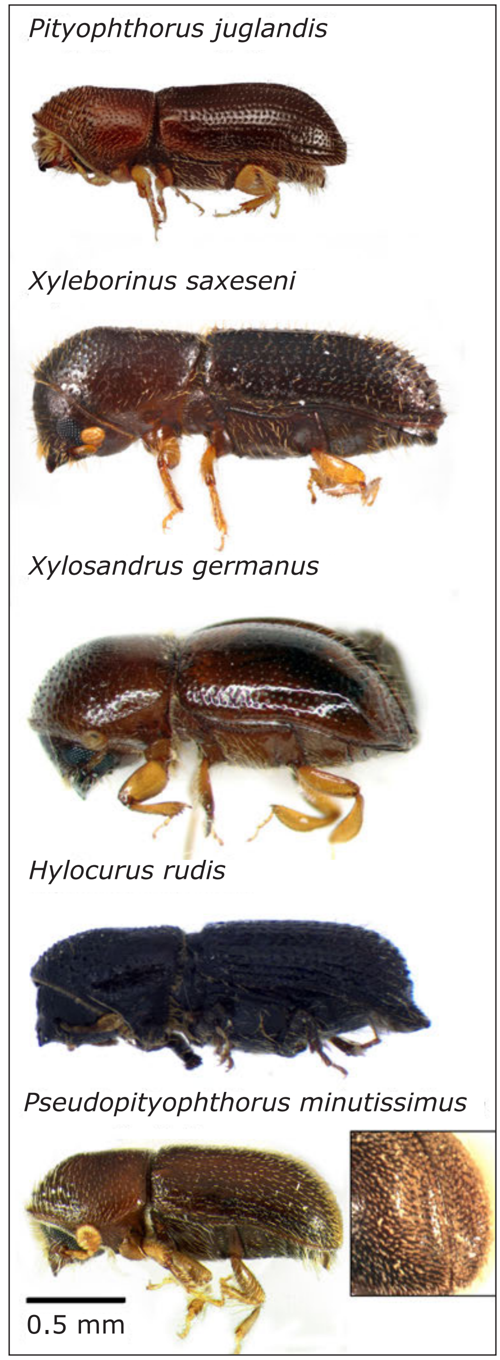


Figure 18. Comparison of lateral profiles of WTB, *Pityophthorus juglandis*, (S. Valley, Oregon Department of Agriculture)**, *Xyleborinus saxeseni*** (Pest and Diseases Library, Australia)**, *Xylosandrus germanus*** (Pennsylvania Department of Conservation and Natural Resources–Forestry Archive)**, *Hylocurus rudis*** (S. M. Hishinuma and A. Richards, UC Davis)**, and *Pseudopityophthorus minutissimus*** (Louisiana State Arthropod Museum) **with close up of *P. minutissimus* elytral declivity showing bi-layered and heavy collection of setae (vestiture)** (J. R. Baker and S. B. Bambara, North Carolina State University)**.**

ACKNOWLEDGEMENTS

The authors appreciate technical reviews of this document by J. H. Borden (Contech Enterprises Inc., Delta, BC, Canada), D. LeDoux and C. Wamsley (Missouri Department of Agriculture), J. Keener (Tennessee Department of Agriculture), B. Moltzan USDA Forest Service Forest Health Protection, Washington, D.C.), and A. S. Munson (USDA Forest Service Forest Health Protection, Ogden, Utah). The authors also thank D. E. Bright (Colorado State University, Fort Collins, Colo.) for the identification of scolytids other than WTB caught in survey traps and appreciate the support of the USDA Animal and Plant Health Inspection Service's Center for Plant Health Science and Technology program for discovering the male-produced aggregation pheromone and developing the detection tool.

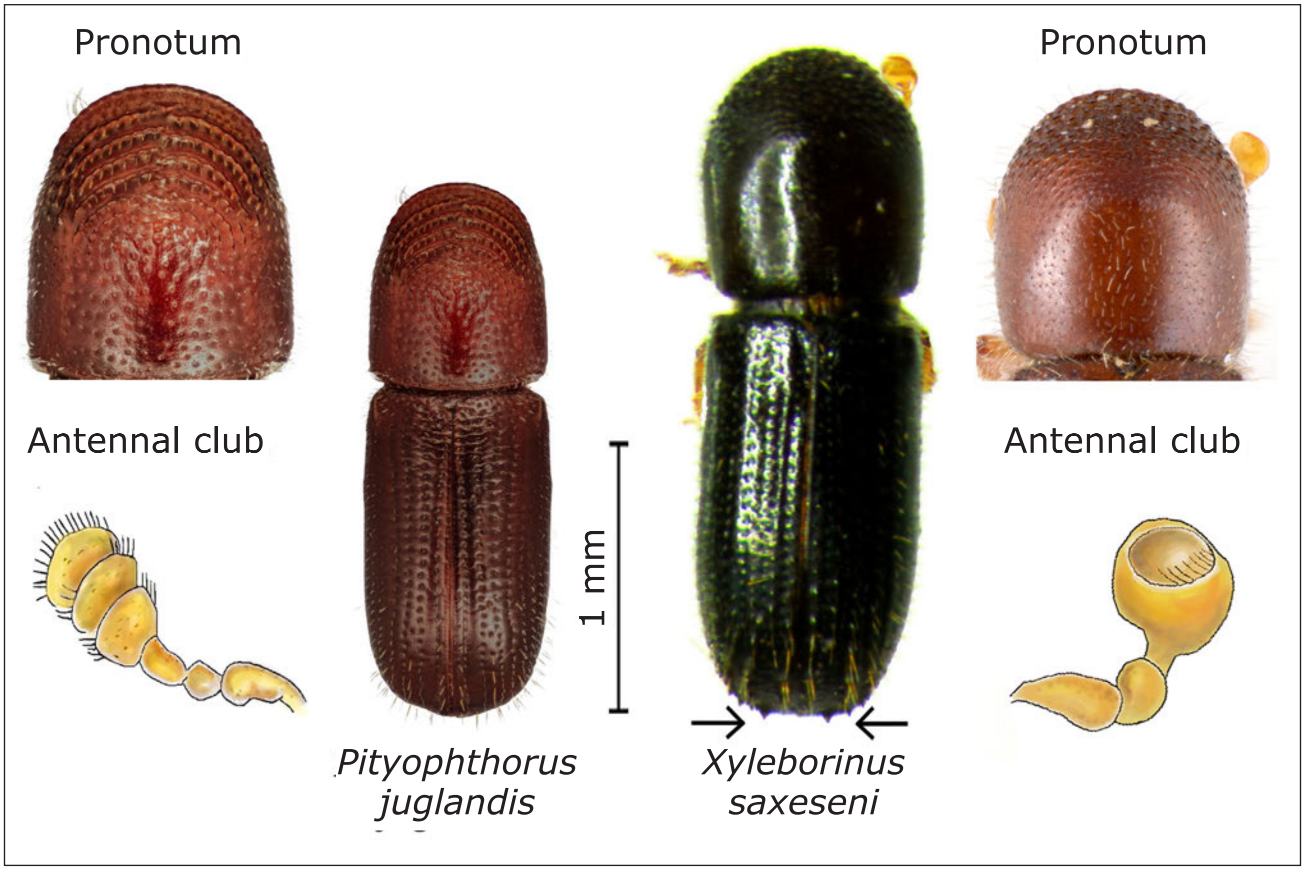


Figure 19. Comparison of dorsal profiles, close up of pronota, and antennal clubs of WTB, *Pityophthorus juglandis*, (S. Valley, Oregon Department of Agriculture, dorsum and pronotum; J.A. King, UC Davis, antennal club) **and *Xyleborinus saxeseni*** (S. M. Hishinuma and A. Richards, UC Davis, dorsum; Pest and Diseases Library, Australia, pronotum; J. A. King, UC Davis, antennal club)**. Arrows indicate spines in the elytral declivity of *X. saxeseni*.**

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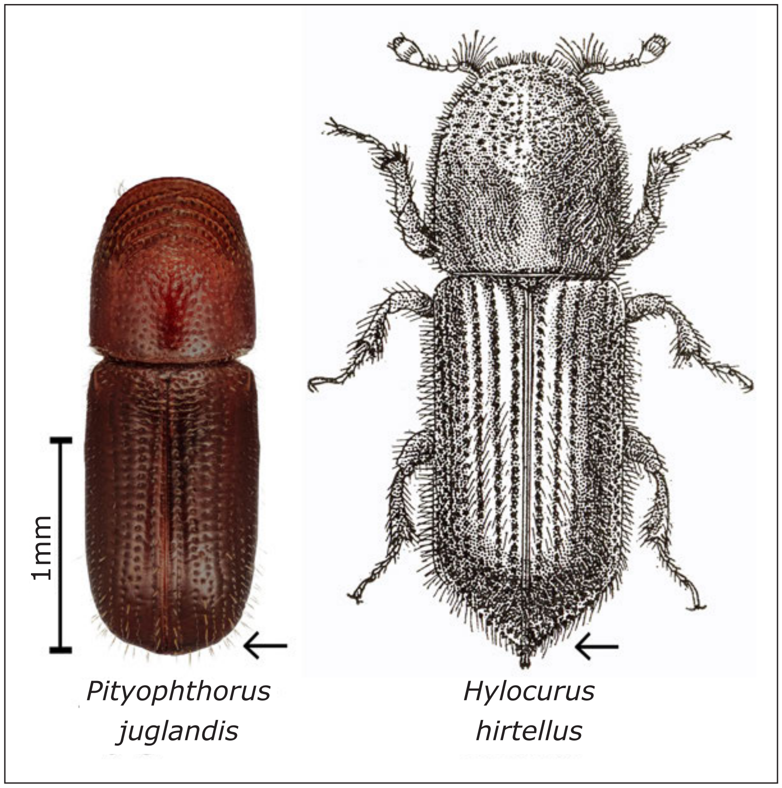

Figure 20. Comparison of dorsal profiles of WTB, *Pityophthorus juglandis*, (S. Valley, Oregon Department of Agriculture) **and *Hylocurus hirtellus*** (engraving by E. C. Van Dyke in Doane et al. 1936) **showing differences in the apex of the elytra, indicated by arrows.**

This publication is available online at http://www.ipm.ucdavis.edu/thousandcankers. Published April 30, 2012. Development of this publication was partly supported by USDA /Forest Service Agreement No. 10-JV-112721-092. Products mentioned in this guide are intended to provide the user with the specific information necessary to efficiently detect WTB but are not meant to be endorsements of specific products by the University of California or the USDA Forest Service.

Bibliographic citation: Seybold, S. J., P. L. Dallara, S. M. Hishinuma, and M. L. Flint. 2012. *Detecting and identifying the walnut twig beetle: Monitoring guidelines for the invasive vector of thousand cankers disease of walnut*. UC IPM Program, University of California Agriculture and Natural Resources. 11 pp. www.ipm.ucdavis.edu/thousandcankers.

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