University of California
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DETECTING AND IDENTIFYING WALNUT TWIG BEETLE:

Monitoring Guidelines for the Invasive Vector of Thousand Cankers Disease of Walnut

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Walnut twig beetle (WTB), *Pityophthorus juglandis*, (Figure 1) is a small native phloeophagous (phloem-feeding) insect recently 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. 2013). Walnut and butternut are the primary hosts (Utley et al. 2013). 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). The disease has spread widely in the western United States and has been detected in eastern states—including Tennessee in June 2010, Virginia in May 2011, and Pennsylvania in August 2011—threatening the highly valuable native timber stands of eastern black walnut, *Juglans nigra* (Newton and Fowler 2009).

The beetle is now distributed discontinuously in the United States from eastern Pennsylvania to western Oregon and from northern Idaho to southern New Mexico in the West (Seybold et al. 2012a). It was trapped in southwestern Ohio in July 2012. 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 tiny beetle is the key to early detection of the disease in new areas.

This publication provides detailed guidelines for using pheromone-baited traps to detect and monitor WTB. A two-page guide for field use and instructional videos are also available at http://www.ipm.ucdavis.edu/thousandcankers. The purpose of this trapping is to detect an incipient population of WTB or delimit a known population of WTB where it has been recently discovered.

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 California, Idaho, Pennsylvania, 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. 2012b). The trap captures both sexes of the WTB while attracting few other insect species, including only low numbers of most other bark or ambrosia beetles (Coleoptera: Scolytidae) (Tables 1 and 2), making detection of WTB easier.

S. M. Hishinuma, UC Davis
Figure 1. Adult male WTB, lateral profile.

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

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 in 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 colonize even the main stem of trees in advanced stages of decline. It is never solely a twig-infesting beetle, even in its putative native host (*J. major*) and range (Arizona and New Mexico), where it also colonizes the larger branches and main stem of trees.

WHEN SHOULD I TRAP?

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

- Trapping for about six weeks from late August through mid-October or late April through mid-June
- Trapping for three weeks during May and June and three weeks during September and October

In California, WTB has been caught in pheromone-baited flight traps during every month although at extremely low

Table 1. Scolytidae other than WTB detected in pheromone-baited survey traps in Indiana, Missouri, Pennsylvania, Tennessee, and Virginia (2010-2012).[1]

Name	Location	Relative abundance[2]
Ambrosiodmus tachygraphus	VA	very low
Araptus dentifrons	MO	very low
Carphoborus bifurcus	TN	very low
Cyclorhipidion bodoanum	TN	very low
Cyclorhipidion pelliculosus	VA	very low
Dryocoetes granicollis	TN	very low
Dryoxylon onoharaensis	TN, VA	low
Euwallacea validus	PA, VA	very low
Hylastes porculus	VA	very low
Hylocurus bicornus	PA	very low
Hylocurus rudis	MO, TN, VA	low
Hylesinus aculeatus	PA	high
Hylesinus fasciatus	PA	very low
Hypothenemus eruditus	TN	very low
Hypothenemus seriatus	VA	very low
Ips avulsus	TN	very low
Ips grandicollis	MO	very low
Micrasis suturalis	TN	very low
Monarthrum fasciatum	MO, PA, VA	low
Monarthrum mali	MO, TN	very low
Phloeotribus dentifrons	VA	very low
Phloeotribus frontalis	MO, TN	very low
Phloeotribus liminaris	MO, PA, TN, VA	high
Pityogenes hopkinsi	PA, TN	very low
Pityophthorus crinalis	MO, PA, TN, VA	very low
Pityophthorus lautus	IN, MO, PA, TN	very low[3]
Pityophthorus puberulus	TN	very low
Pityophthorus pulicarius	VA	very low
Pseudopityophthorus minutissimus/pruinosus	TN, VA	very low
Scolytus multistriatus	MO, TN	low
Scolytus muticus	VA	low
Scolytus rugulosus	MO, TN, VA	low
Scolytus schevyrewi	MO	low
Xyleborinus saxeseni	MO, PA, TN, VA	high
Xyleborus affinis	TN, VA	low
Xyleborus atratus	PA, TN, VA	high
Xyleborus celsus	VA	very low
Xyleborus ferrugineus	TN, VA	low
Xyleborus impressus	TN, VA	low
Xyleborus xylographus	PA, VA	low
Xylosandrus crassiusculus	PA, TN, VA	low
Xylosandrus germanus	TN, VA	low
Xyloterinus politus	VA	very low

[1]Researchers also expected to catch *Pityophthorus liquidambarus* in the survey traps, but this species has 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 (5-15 specimens), and high (>15 specimens).

[3]Relative abundance of this species in Indiana was extremely high in one instance when a survey trap was placed near a typical host (*Cercus* sp.); otherwise, catches of this species have been quite low.

levels in December and January. In 2011 and 2012, WTB was trapped in December and January not only in California but also in Tennessee and Virginia. In more northern U.S. locations, winter trap catches are unlikely.

WHERE SHOULD I TRAP?

There will be a high probability of detection if the trap is placed close to, but never in, healthy or declining walnut trees and positioned near the larger branches of these trees (Figures 3 and 4). For instance, during a demonstration trial in Utah, a trap placed near a pecan tree for most of the summer and fall did not catch any WTB. The nearest source of WTB in this instance may have been English walnut trees growing within a 1-mile radius of the trap—apparently too far away for beetles to find the trap. High population densities of WTB may be associated with declining walnut trees, so placing 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 or adjacent to walnut orchards; or in wildland forest habitats. Look for riparian areas where walnut trees often grow in higher densities, then place traps about 9 to 15 feet from the main stem of the tree, 5 to 10 feet away from live branches, and about 9 feet above 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. If host material is accumulated from various sources, a trace-back analysis might be necessary to establish the actual origin of the infested host material.

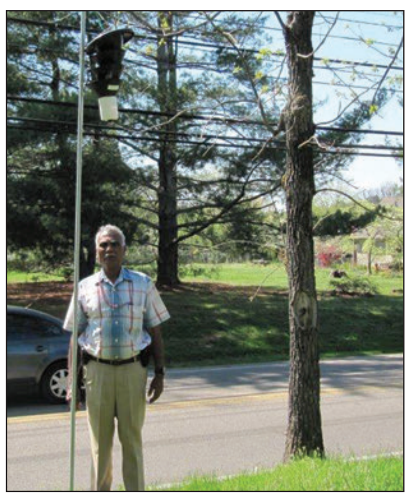
Table 2. Scolytidae other than WTB detected in pheromone-baited survey traps in Arizona, California, Idaho, Nevada, and Utah (2010-2012).

Name	Location	Relative abundance[2]
Cyclorhipidion bodoanum	CA	very low
Dendrocranulus curcubitae	CA	low
Gnathotrichus pilosus	CA	very low
Hylastes asperatus	AZ	very low
Hylastes gracilis	CA	very low
Hylesinus californicus	UT	low
Hylocurus hirtellus	CA	very low[2]
Hylurgops subcostulatus subcostulatus	AZ	very low
Hylurgus ligniperda	CA	very low
Hypothenemus californicus/eruditus	CA	very low[3]
Ips pini	UT	very low
Monarthrum scutellare	CA	very low
Phloeosinus cristatus	CA	very low
Phloeosinus scopulorum neomexicanus	AZ	very low
Phloeotribus pruni	AZ	low
Pityophthorus confertus confertus	NV, UT	very low
Pseudopityophthorus agricolae/pubipennis	CA	very low
Scolytus multistriatus	CA	very low
Scolytus rugulosus	CA	low
Scolytus schevyrewi	CA, ID, NV, UT	low
Xyleborinus saxeseni	CA, ID, NV, UT	high[3]
Xyleborus dispar	UT	very low

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

[2]This species can be locally abundant in coastal Northern California.

[3]These relative abundances have increased dramatically and undesirably when antifreeze with ethanol has been used in the trap cups.



J. Keener, Tennessee Dept. 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.

Research data are not available regarding 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.

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Figure 5. A 2- by 4-inch bubble cap formulation of WTB lure from Contech Enterprises Inc.

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 cleanup. 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. The vagaries of various commercial formulations of adhesive and the difficulties inherent in cleaning and processing the trap catches for identification make sticky-coated traps more difficult to use. These obstacles are not an issue with funnel trapping.

The Lure

The lure (Figure 5) is a proprietary formulation of the male-produced aggregation pheromone of WTB in a passive slow-release device. This small plastic bubble cap has been tested in California and Tennessee during studies of the effect of pheromone release rate and in California during a test of lure longevity. The active ingredient, when released at a higher rate in a previous formulation, was effective in Idaho, Nevada, Pennsylvania, Tennessee, Utah, and Virginia in trapping surveys. In 2012, traps baited with the lure detected WTB to establish new county records in Tennessee and Virginia as well as in Butler County, Ohio. The lure is attached directly to the trap inside the funnel column. (See Putting it All Together and Figure 9.) The vendor for the lures is Contech Enterprises Inc., http://www.contech-inc.com. When ordering, specify the walnut twig beetle lure.

The Trap Cup and Propylene Glycol Trapping Agent

Captured beetles fall into a white trap cup that is attached with a bayonet-type fitting to the lowest funnel. The preferred version of the wet cup has a solid molded-plastic bottom. Because of potential leakage, it is less preferable to use a cup with a bottom drain hole plugged with a No. 5 rubber stopper. 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 WTB, check to make sure the mesh size on this overflow hole is fine enough to prevent the loss of specimens.

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

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 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, ethyl alcohol, isopropyl alcohol, or a corrosion inhibitor package. Ethanol will attract ambrosia beetles, complicating trap catch processing and positive identification of WTB. There is no evidence that ethanol attracts WTB; rather, preliminary evidence indicates it may reduce trap catches. For large-scale use and to eliminate completely the potential for ethanol contamination, food-grade propylene glycol (99.5% pure) can be purchased from chemical supply companies and diluted with water to a 25 to 30% solution. *Do not use automobile antifreeze*, even if it is pink, as it typically contains ethylene glycol.

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 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, so 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, and do not install poles near overhead electrical or telephone cables. 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.

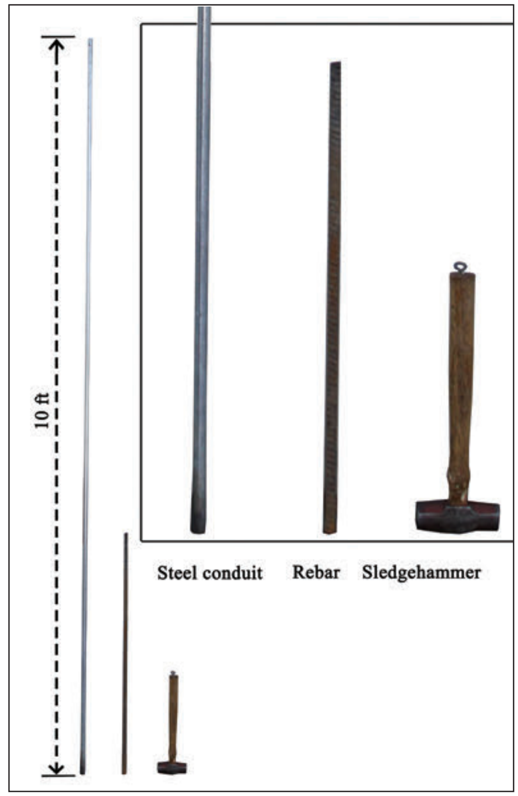

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Figure 7. Materials for suspending traps: steel conduit (EMT), rebar, and a sledgehammer.

Recently manufactured funnel traps come with an eyebolt attachment in the top of the trap (Figures 8 and 9). 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 so it can be wound around the pole and reattached to the trap. (See 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 3.

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

PUTTING IT ALL TOGETHER

Assembling the Trapping System

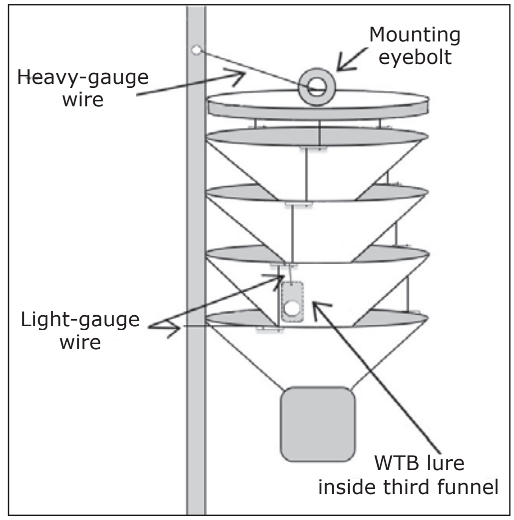
Once a specific location for trapping has been selected, use a small sledgehammer to drive the stake into the ground about 1 foot or more, depending upon the soil type, to provide a stable base for the pole. Leather or fabric gloves should be worn when handling and installing rebar. Avoid placing traps near overhead electrical or telephone cables and 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 the foliage and branches do not impede the flight of incoming beetles and so incoming WTB do not attack live branches.

Once the stake is in place, wire the eyebolt in 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 lure so it hangs in the middle of the trap (Figure 9). The most effective odor plume is thought to be produced when the lure is inside the funnel column. For a four-unit funnel trap, attach the lure 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, hang the lure from the strut above the sixth funnel.

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 approximately 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.



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 the lure, 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.

Table 3. Equipment/Supply Checklist.

To install the trap
Four-unit black plastic multiple-funnel (Lindgren) trap with wet cup
Lure (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
Sledgehammer
10 feet of 1/2-inch thin-walled galvanized steel conduit (EMT)
Leather or fabric gloves
To maintain and service the trap
Quart-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
Sledgehammer
Wire cutters or fencing pliers
Replacement lures, if necessary

MAINTAINING THE TRAPPING SYSTEM

Maintenance for the trapping system is fairly simple. Check traps periodically during routine servicing and specifically following major weather events (e.g., heavy rains, high winds, and so forth) 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 collected and placed in a freezer as soon as possible. (See Servicing the Traps.) Highly diluted antifreeze will cause specimens to decay rapidly, and in some cases the specimens will fragment, possibly preventing accurate identification of WTB.

Another aspect of maintenance is periodic replacement of the lures. The lure sleeve is loaded with enough material to last about two months when exposed to a constant temperature of 86ºF, but the actual longevity of the lure will depend on the mean ambient temperature during the service period. Conservatively, if temperatures are moderate (i.e., not continuously 86ºF for an entire 24-hour period), lures would need to be replaced every three months or longer during the service period. Therefore, lures could be left in the field longer during the spring and fall and replaced more frequently between June and September. Order enough lures 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.

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

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

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Figure 11. Paint strainer.

Servicing the Traps

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-sized zipper lock plastic bags, fresh antifreeze, some 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 such as 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.

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-sized

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

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, reattach the cup, and reinstall the trap.

Plastic bags containing individual catches should be completely sealed, grouped, and 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.

IDENTIFYING WTB

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 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 45 other bark and ambrosia beetle species were trapped (Tables 1 and 2). To minimize the extent of this bycatch, use antifreeze without ethanol in the trap cup.

S. M. Hishinuma, UC Davis

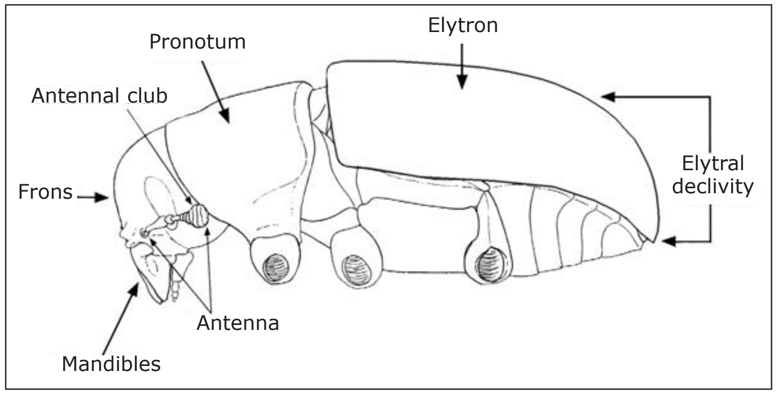
Figure 15. Sorting a funnel trap catch in the lab at a dissecting microscope.

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, especially to confirm new state or county records. Prior to reading this section the user should become acquainted with some of the general features of the external morphology of bark and ambrosia beetles (Figure 16). Some basic identification guidelines for WTB follow:

- WTB is 1.5 to 2 millimeters long, has a relatively narrow body (about three times longer than wide), and has a reddish-brown to brown cuticle (outer “skin”) (Figure 17).
- The frons 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 17B), whereas the male frons has very sparse setae, sometimes consisting of a narrow brush of short setae immediately above the mandibles (Figure 17A).
- The anterior half of the pronotum is sloped upward from the frons (Figures 17A and B), reaches an apex before the midpoint (Figures 17A and B), and features four to six concentric arcs of asperities (ridges) (Figure 18). These arcs of ridges may be discontinuous and overlapping, especially near the median. Small teeth line the anterior edge of the pronotum (Figure 18).
- The elytra (hardened forewings) have closely spaced punctures and sparse, short setae. The elytral apex is rounded (Figure 17), and the declivity (depression at the rear end) is very shallow and often shiny.
- The female declivity is smooth (Figure 17B), whereas the male declivity features rows of minute granules on the first and third interstrial spaces (Figure 17C).

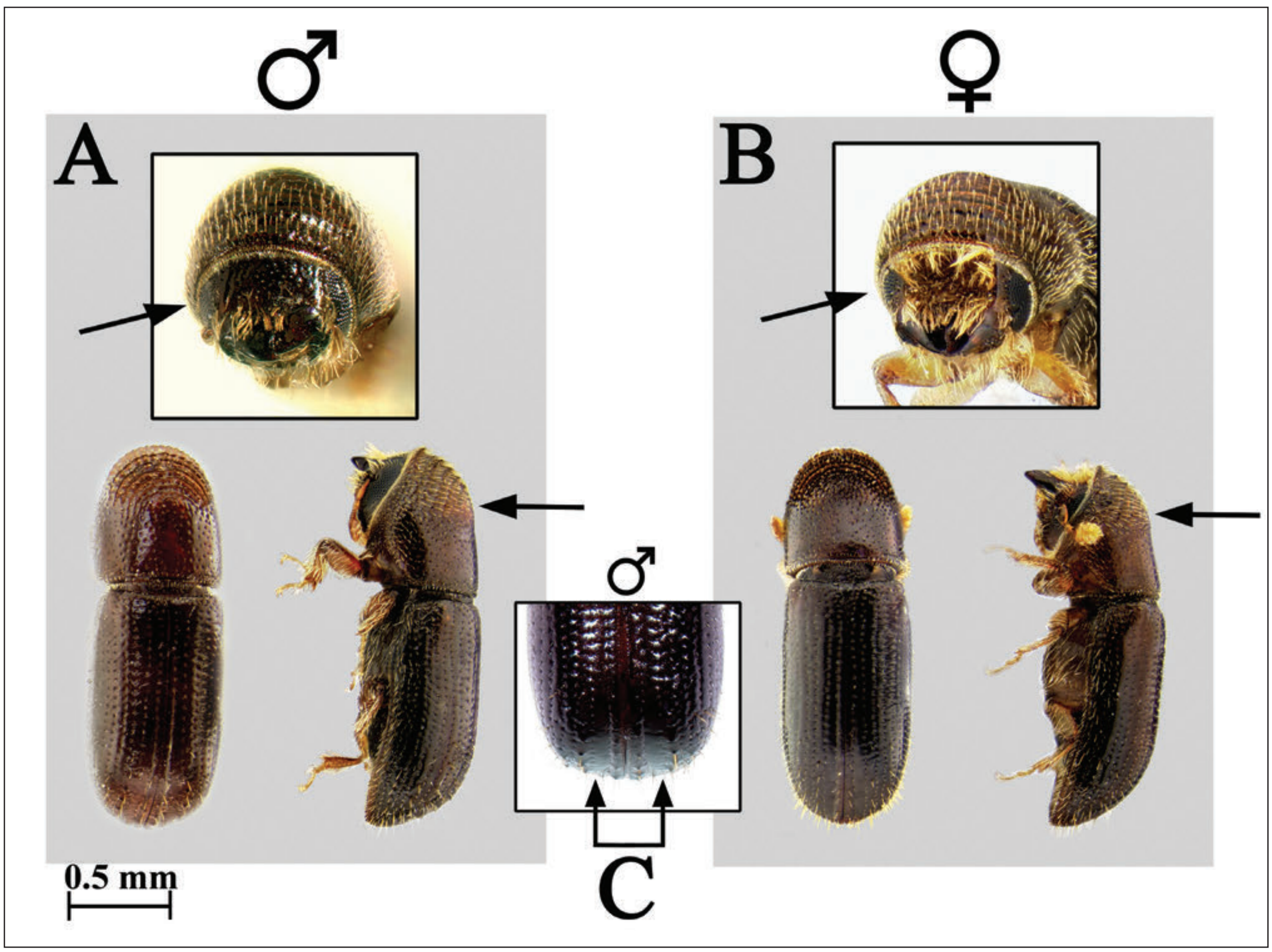
The bark beetle that is most likely to be confused with WTB is *Pityophthorus lautus*, (Figure 19), a native species that colonizes eastern hardwoods:

- *P. lautus* is 1.2 to 1.7 millimeters long (typically shorter than WTB) and is about 2.6 times longer than wide. It is similar in color to WTB (Figure 19E).
- The frons of both male and female *P. lautus* contains very sparse setae (Figure 19C), both sexes are very similar in appearance, and neither sex has the pronounced round brush of golden setae present in female WTB (Figure 19A).
- The anterior half of the pronotum features broken concentric arcs of asperities, similar to WTB. When viewed from above, the pronotum of *P. lautus* is somewhat triangular with a more pronounced taper toward the head than in the pronotum of WTB (Figure 19B).
- The elytral declivity is different from that of WTB (Figures 19D and 19F). The area between the first and third interstrial spaces is more depressed in *P. lautus* (Figure 19F, white arrows) than in WTB (Figure 19D), and the interstriae of *P. lautus* do not feature granules (Figure 19F).



Adapted from Hopkins 1909 by S. M. Hishinuma

Figure 16. Lateral view of a scolytid beetle (without legs) showing general features of the external morphology.

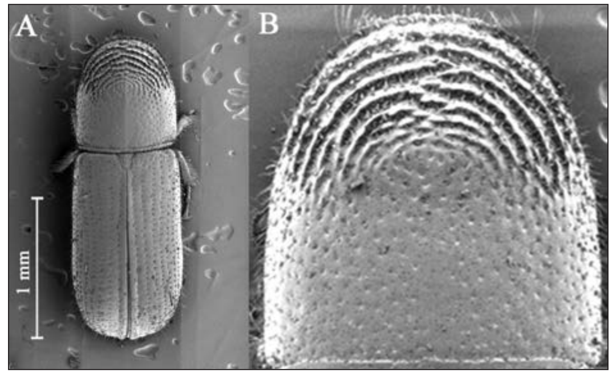


S. M. Hishinuma, UC Davis and A. D. Graves, USDA Forest Service

Figure 17. Comparison of morphological characters of male (A) and female (B) WTB. Arrows indicate the degree of pubescence on the male and female frons; the apex, which occurs before the midpoint on the anterior half of the pronotum of males and females; and granules on the male elytral declivity (C).

Some of the other bark and ambrosia beetles that have been trapped along with WTB provide useful contrasts for identification (Figure 20 and Tables 1 and 2):

- The fruit-tree pinhole borer, *Xyleborinus saxeseni*, is perhaps the most common ambrosia beetle trapped in WTB pheromone-baited traps (Figures 20 and 21).
- All scolytids have a clubbed elbowed antenna. In WTB the club is entire, whereas in *X. saxeseni* it is truncated (cut off at the tip) (Figure 21). In *Phloeotribus liminaris* the clubbed antenna is pseudolamellate (layerlike) (Figure 20 inset).
- The pattern of asperities on the pronotum of *X. saxeseni* (Figure 21) is relatively random when contrasted with the concentric arc pattern in WTB (Figures 17-21), *P. lautus* (Figure 19), and *P. crinalis* (Figure 20).
- 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 21).



A. D. Graves, USDA Forest Service

Figure 18. Scanning electron micrograph of the dorsal profile of a female WTB (A) and close up showing pronotal asperities (B).

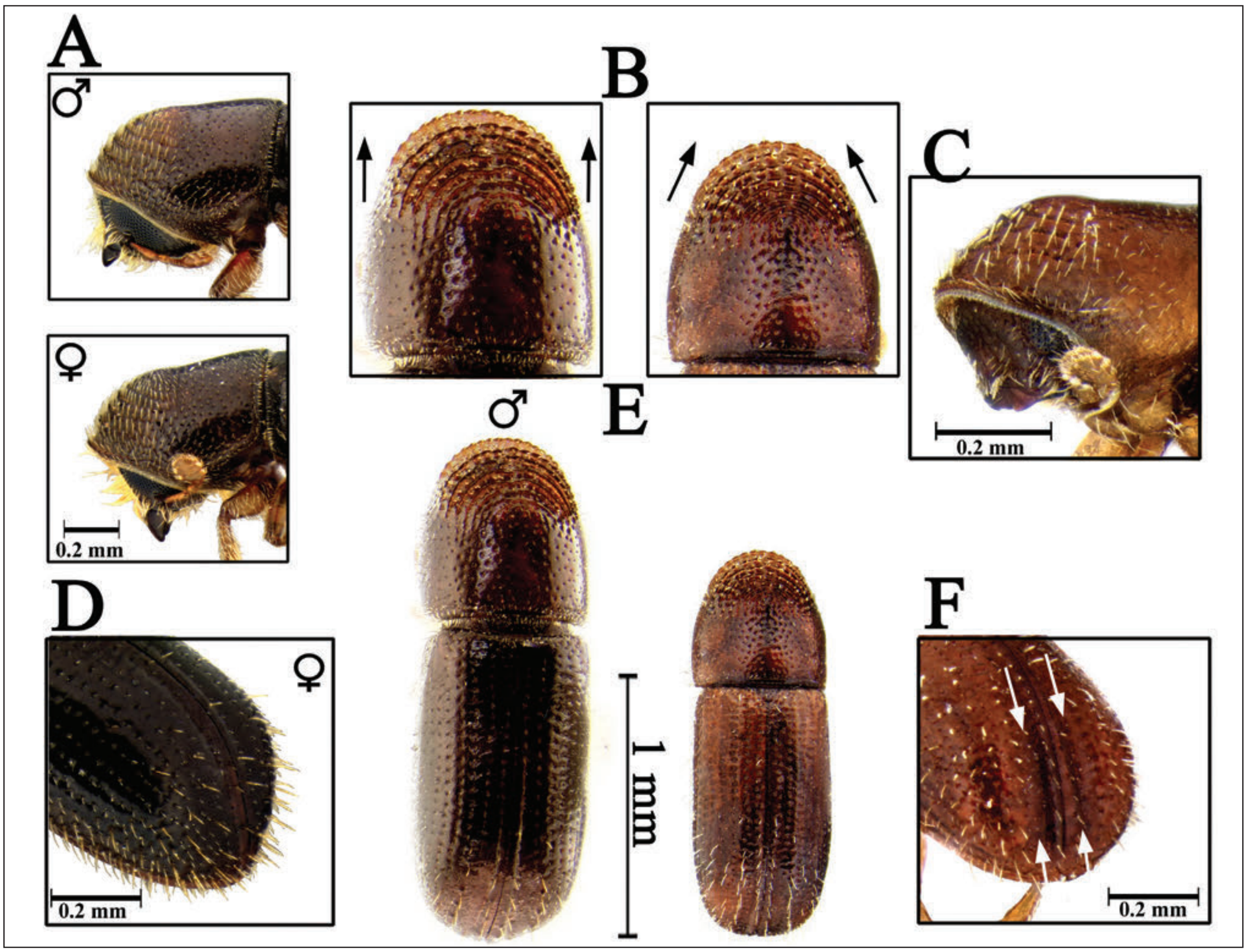


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Figure 19. Comparison of dorsal profiles (E) of male WTB and *Pityophthorus lautus*, showing the difference in body length. Close-up photographs of the heads illustrate the dense pubescence associated with female WTB (A) that is absent in both sexes of *P. lautus* (C). Close-up photographs of the dorsal view of the pronota (B) illustrate the more triangular and tapered shape in *P. lautus* (see arrows). Close-up photographs of the elytral declivity of female WTB (D) and *P. lautus* (F) illustrate the more deeply impressed surface of the declivity (white arrows) and absence of granules in *P. lautus*.

- The rounded elytral apex of WTB differs from the pointed elytral apex of *Hylocurus hirtellus*, *H. rudis*, and other *Hylocurus* spp. (Figures 20 and 22).
- 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 20).
- As their Latin names suggest, WTB and oak bark beetles are very similar in many other morphological characteristics.

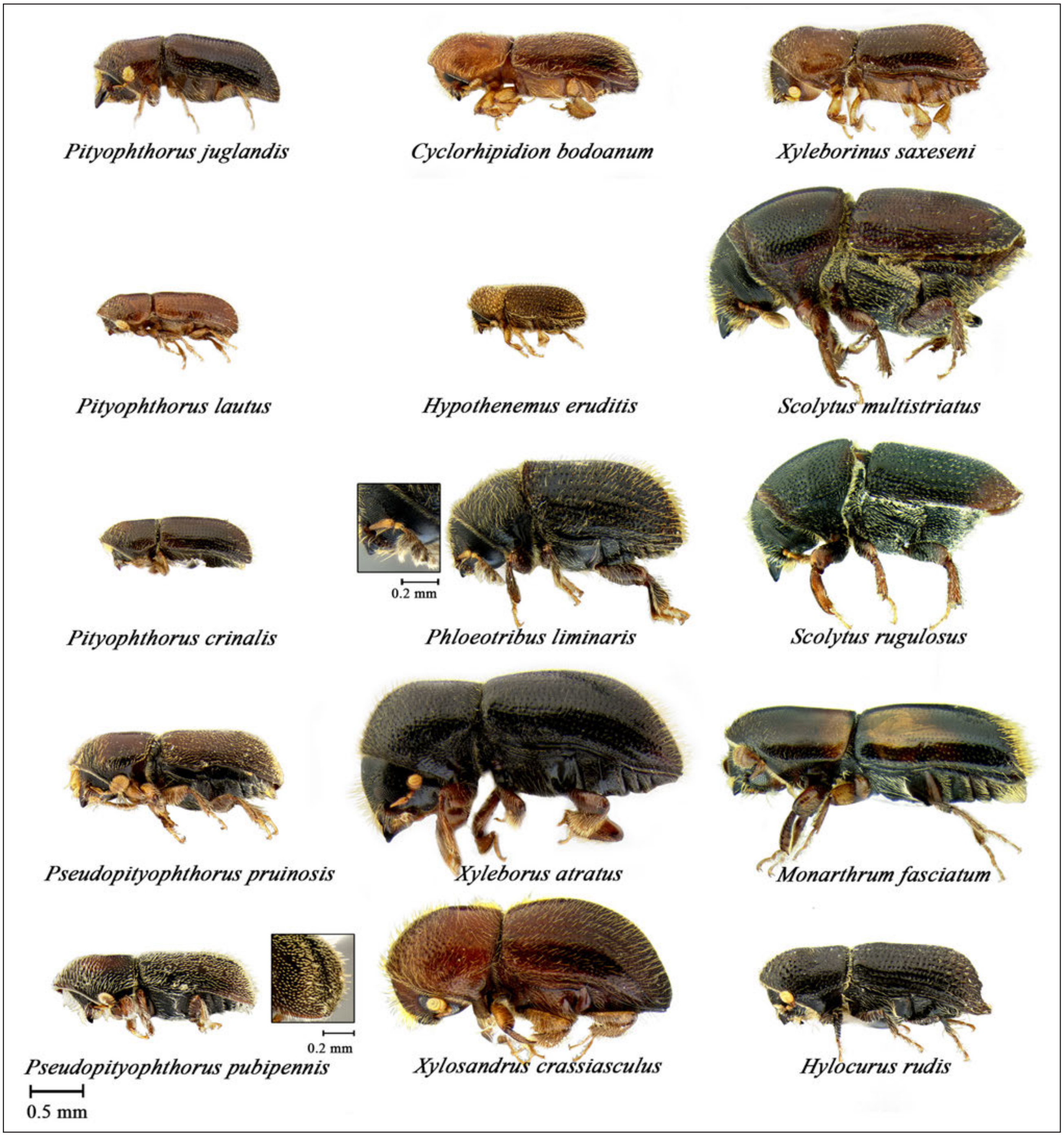

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Figure 20. Comparison of lateral profiles of female WTB, *Pityophthorus lautus*, *Pityophthorus crinalis*, *Pseudopityophthorus pruinosus*, *Pseudopityophthorus pubipennis*, *Cyclorhipidion bodoanum*, *Hypothenemus eruditus*, *Phloeotribus liminaris*, *Xylosandrus atratus*, *Xylosandrus crassiusculus*, female *Xyleborinus saxeseni*, *Scolytus multistriatus*, *Scolytus rugulosus*, *Monarthrum fasciatum*, and *Hylocurus rudis*.

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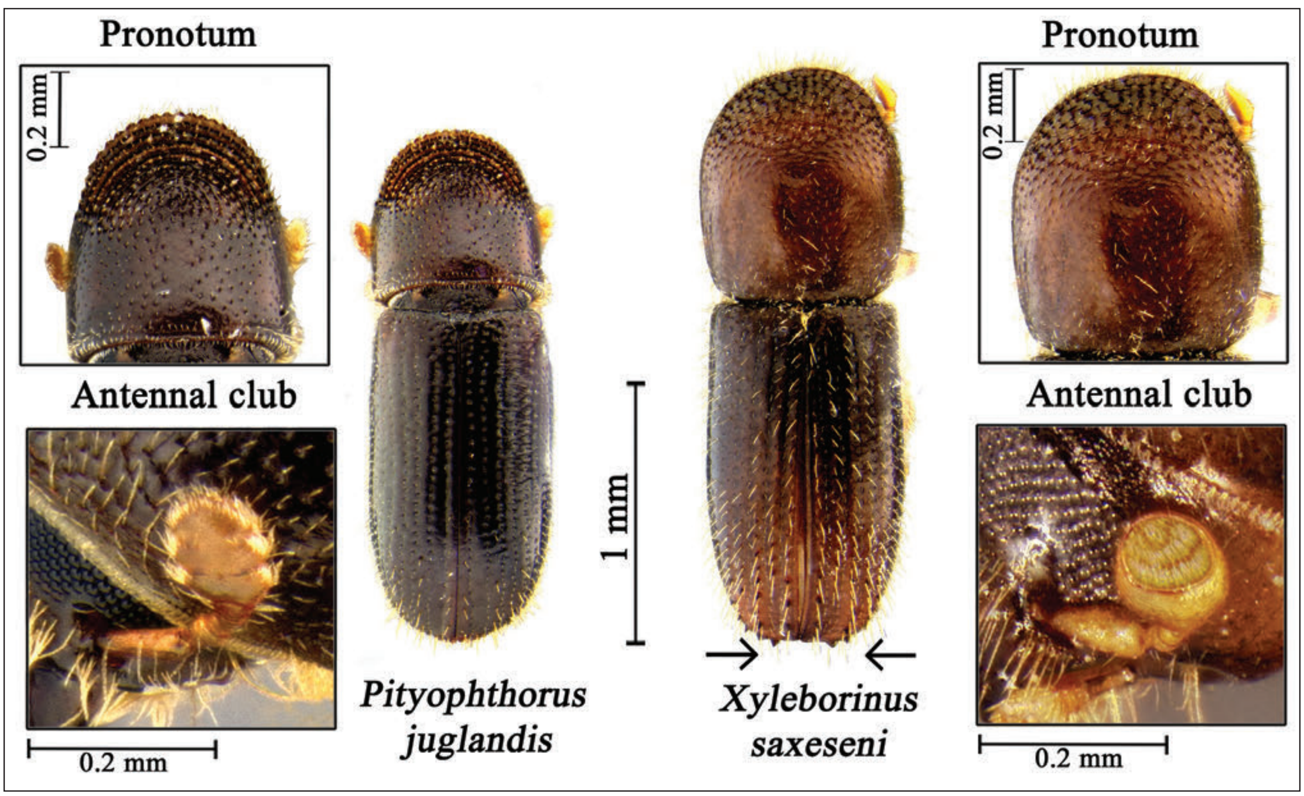

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Figure 21. Comparison of dorsal profiles, close up of pronota, and antennal clubs of female WTB and female *Xyleborinus saxeseni*. Arrows indicate spines in the elytral declivity and the truncated antennal club of X. saxeseni.

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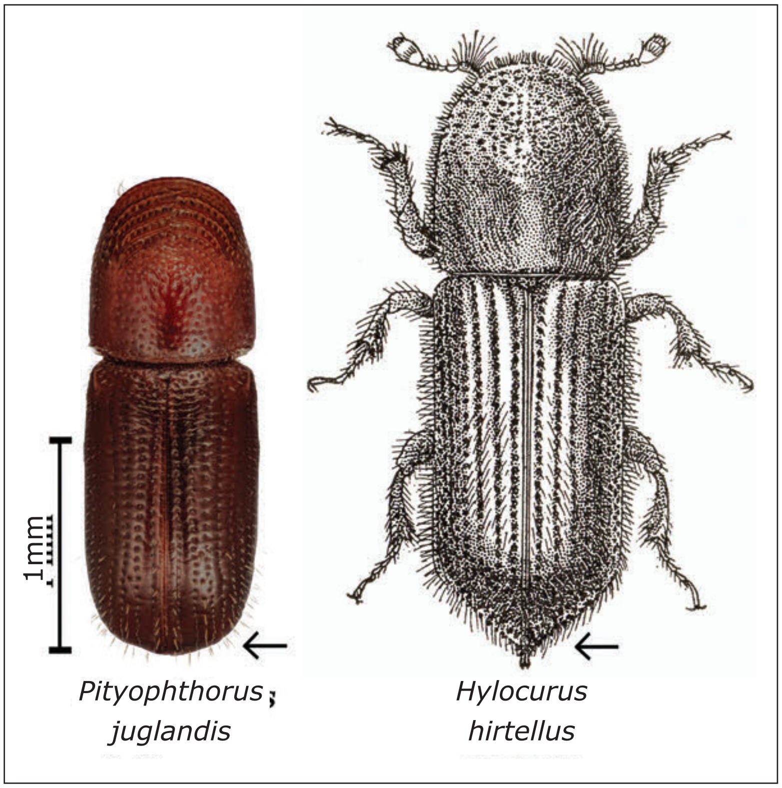

Figure 22. Comparison of dorsal profiles of WTB (S. Valley, Oregon Department of Agriculture) **and *Hylocurus hirtellus*** (engraving by E. C. Van Dyke in Doane et al. 1936, biology in Dallara et al. 2012) **showing differences in the apex of the elytra, indicated by arrows.**

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