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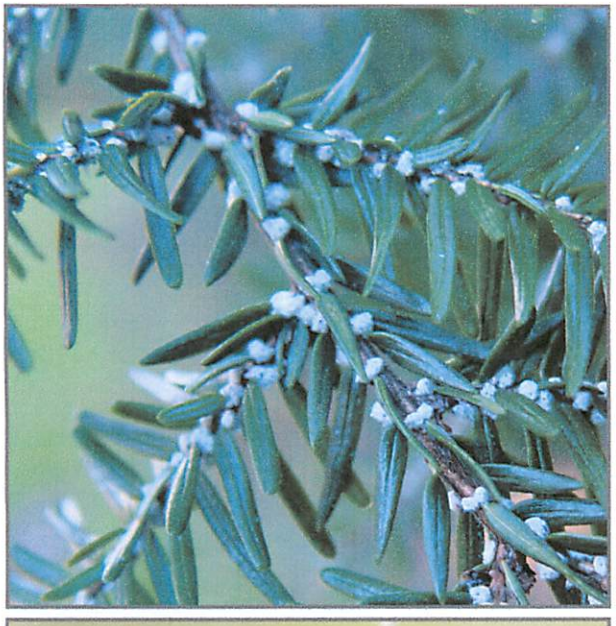
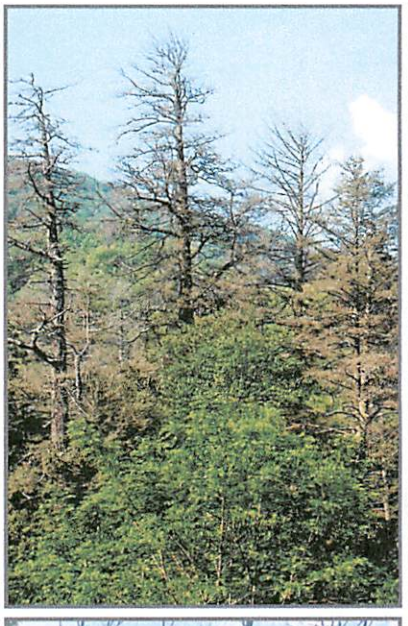
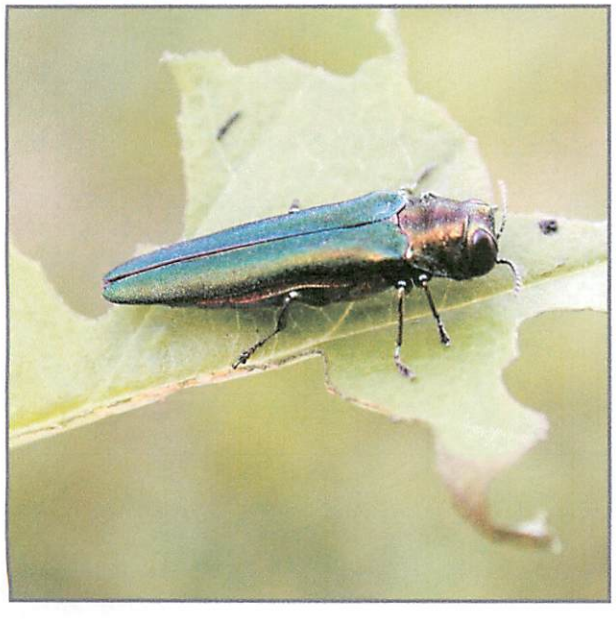
The Use of Classical Biological Control to Preserve Forests in North America

Edited by Roy Van Driesche and Richard Reardon







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XXXI Walnut Twig Beetle

(*Pityophthorus juglandis* Blackman) (Coleoptera: Curculionidae: Scolytinae)

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DESCRIPTION OF PEST

Taxonomy

The walnut twig beetle, *Pityophthorus juglandis* Blackman (Scolytini: Pityophthorina), was initially described by Blackman (1928) from specimens collected on black walnut (*Juglans nigra* L.) in Lone Mountain, New Mexico, and Paradise, Arizona (Blackman, 1928; Cranshaw, 2011; LaBonte and Rabaglia, 2012). There are no synonyms in the literature.

In Blackman's revision of the genus *Pityophthorus* Eichhoff, he included species that (1) possessed numerous setae on body surfaces or were glabrous, (2) had several asperities (short cuticular protuberances) on the pronotum, (3) had elytra that partially covered the metepisternum, and (4) had clubbed antennae with five segments. This genus includes more than 100 species found throughout the United States (Arnett et al., 2002). Most species in this genus infest conifers, while only a few attack hardwoods. Because of the many species present in North America and their small size, LaBonte and Rabaglia (2012) provided a pictorial key to aid in identifying the key characteristics of *P. juglandis*.

Adults of walnut twig beetle are 1.5–1.9 mm long and may be distinguished from other species by the possession of 4 to 6 usually medially broken, concentric rows of asperities on the pronotum, and the acute declivity at the posterior of the elytra, with minute granules (Blackman, 1928; Bright, 1981) (Fig. 1). While specimens of *Pityophthorus lautus* Eichhoff are occasionally found on black walnut in eastern Tennessee, this species may be distinguished from *P. juglandis* by its possession of fused asperities on all but the first two lines on the pronotum (Blackman, 1928) and the more convex declivity on the posterior of the elytra. Because *P. juglandis* is known to infest only species of *Juglans*, the common name designated for this species is the walnut twig beetle (WTB).

Distribution

The WTB was collected in New Mexico as early as 1896 (Blackman, 1928) and by 1992 its distribution was known to include New Mexico, Arizona, southern California, and Chihuahua, Mexico (Wood and Bright, 1992). Excluding records from California, the earliest reported range of WTB appears to overlap the northern range of Arizona walnut (*Juglans major* Torr. [A. Heller]) (Cranshaw, 2011) (Fig. 2). The earliest records of WTB in California are from 1959 in Los Angeles County and were associated with eastern black walnut (*Juglans nigra* L.) and southern California walnut (*Juglans californica* S. Watson). Records from the Central Valley region date from the 1970s (Bright and Stark, 1973; Cranshaw, 2011).

The reported range of WTB has increased substantially since 1992, with the addition of new records from Colorado, Utah, Nevada, Idaho, Oregon, and Washington (Cranshaw, 2011; Seybold et al., 2011), which were associated primarily with unusual mortality of *J. nigra* and other *Juglans* species.

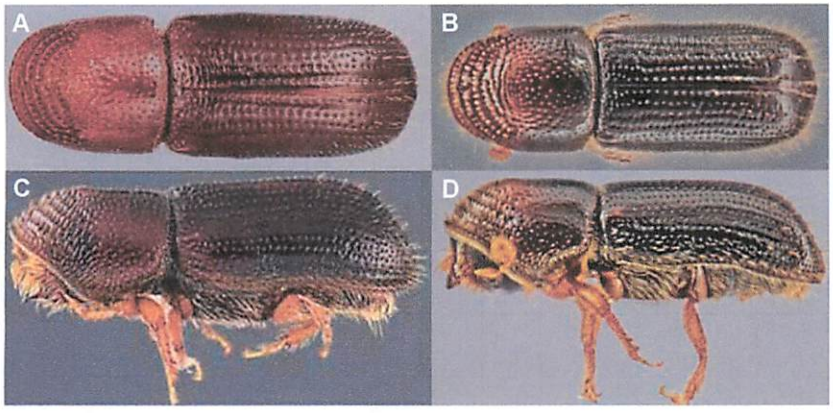

Figure 1 Adults of walnut twig beetle (*Pityophthorus juglandis*): A) female, dorsal view, B) male, dorsal view, C) female, lateral view, D) male, lateral view. Steve Valley, Oregon Department of Agriculture, Agriculture Plant Division, Salem, Oregon, USA.

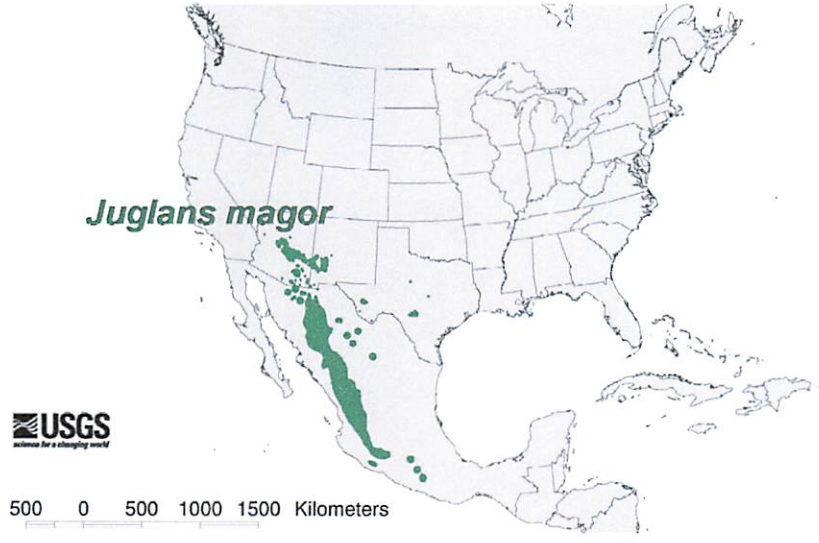

Figure 2 Native range of Arizona walnut, *Juglans major*, in North America. US Geological Survey. http://www.thousandcankers.com/media/images/juglmajo.pdf

Juglans nigra is native to the eastern United States, but has been planted widely in western states for ornamental and commercial use. Unusual *J. nigra* mortality in Colorado and other western U.S. states was eventually determined to be caused by aggressive attacks of the WTB and associated cankers caused by a fungal symbiont, *Geosmithia morbida* Kolařík, Freland, Utley, and Tisserat (Tisserat et al., 2009; Kolařík et al., 2011). This insect-pathogen complex causes a disease known as "thousand cankers disease" due to the large number of cankers formed in association with WTB attacks and tunnels in the bark (Tisserat et al., 2009). The origin of *G. morbida* and the reason for WTB's presumed recent invasion of new geographic areas and hosts are uncertain. Recently, thousand cankers disease and the WTB were detected within the native range of *J. nigra* in the eastern United States (Grant et al., 2011), and as of 2012 there were known infestations in eastern Tennessee, Virginia, and eastern Pennsylvania (Seybold et al., 2011). Eastern black walnut is widely distributed in the eastern half of the coterminous United States, and continued expansion of the distribution of WTB is anticipated and would be very damaging.

Damage

Type Before the early 2000s, WTB was not reported in association with any *Juglans* decline or mortality, and the fungal symbiont *G. morbida*, which causes thousand cankers disease, was unknown (Tisserat et al., 2009). In *J. nigra*,

thousand cankers disease is characterized by progressive decline and mortality that takes 2 to 4 years after the onset of symptoms, although some diseased trees may live several years longer. Early symptoms include yellowing and thinning of leaves in the upper crown and eventual twig and branch dieback. Early attacks by WTB may be detected by the extremely small circular entrance holes in the bark of small diameter branches. Careful removal of thin layers of bark reveal shallow beetle galleries surrounded by diffuse brown to black cankers in the phloem (Fig. 3). Although infection with *G. morbida* is not systemic and cankers remain localized (within 4 cm) around beetle galleries or other attack points, if beetle density is high, attacks are so abundant that cankers coalesce. Eventually, the cankers extend into the cambium, girdling and killing branches. As the disease progresses, attacks by the WTB and associated cankers occur in larger branches, limbs, and trunks, causing crown dieback and death (Tisserat et al., 2009; Tisserat and Cranshaw, 2011) (Fig 4).

Figure 3 Walnut twig beetle galleries and associated cankers caused by *Geosmithia morbida* in a small-diameter black walnut (*Juglans nigra*) branch. Photo by Albert Mayfield, USDA Forest Service, Southern Research Station, Asheville, North Carolina, USA.

Figure 4 Black walnut with branch and crown dieback caused by thousand cankers disease. Photo by Albert Mayfield, USDA Forest Service, Southern Research Station, Asheville, North Carolina, USA.

Extent Thousand cankers disease has been found in twelve states in the United States, nine in the West (Arizona, California, Colorado, Idaho, Nevada, New Mexico, Oregon, Utah, and Washington) and three in the East (Pennsylvania, Tennessee, and Virginia) (Seybold et al., 2011). Extensive mortality of black walnut (*J. nigra*) has been observed wherever WTB and thousand cankers disease occur (Tisserat and Cranshaw, 2011). *Geosmithia morbida* has been isolated from WTB galleries in Arizona walnut (*J. major*) in Arizona and New Mexico, but branch dieback and mortality characteristic of thousand cankers disease has not been observed in this species (Tisserat and Cranshaw, 2011). Walnut twig beetle has been widely recovered from dying/declining southern California walnut (*Juglans californica* S. Wats.) and northern California walnut (*Juglans hindsii* [Jeps.] Jeps. Ex R. E. Sm.) growing along roads and in natural habitats. Commercial orchards of English walnut (*Juglans regia* L.) have experienced infestationd of WTB but without significant damage or mortality. *Juglans regia* appears to have some level of resistance to development of thousand cankers disease, but WTB attacks and disease symptoms have been observed on some Paradox rootstocks (a hybrid between English and black walnut) in *J. regia* orchards (Tisserat and Cranshaw, 2011).

Concern is high over the potential impact of WTB and thousand cankers disease on eastern black walnut (*J. nigra*) in its native range. The beetle and associated disease are well established and causing substantial black walnut mortality in at least three eastern U.S. states. The WTB and associated pathogen can be moved to new areas via transportation of infested logs, firewood, or ornamental plants, and as of 2012, quarantines on the movement of walnut material have been enacted in many counties in Tennessee and Virginia and one county (Bucks) in Pennsylvania (Tennessee DAC, 2012; Virginia DACS, 2012; Pennsylvania DAC, 2012). Eastern black walnut is highly valued for lumber and veneer, and growing stock in the United States is estimated to be worth over half a trillion dollars (Newton et al., 2009). It is planted by landowners for timber and nut production and thus is an important agroforestry crop, especially in mid-western states such as Missouri. Although it comprises a small component of eastern hardwood forests, black walnut carries high economic, cultural, and ecological value due to its beautiful wood, mast production, medicinal qualities, and use as an ornamental (Newton et al., 2009).

Biology of Pest

Pityophthorus juglandis is a bisexual species with at least two overlapping generations per year. Attacks occur only on *Juglans* species. In east Tennessee, adults of the overwintering generation emerged and were collected from containerized bolts beginning in late April. Adult activity continued until early December (K. Nix, Univ. Tenn., unpublished data). Emergence of the adults appears to be temperature-dependent, and in the western United States adults may fly on warm days even during winter months (S. Seybold, USDA Forest Service, pers. comm. 2012). Both sexes produce an aggregation pheromone that attracts both sexes in flight (Seybold et al., 2010). Upon discovery of a suitable walnut tree, beetles attack the twigs, limbs, and trunk, where they bore holes through the bark to the outer cambial layer (Fig. 5A). The entrance tunnels are often located near cracks or in rough areas of the bark and extend from the surface to the cambial layer just underneath the bark (Cranshaw and Tisserat, 2008). Males initiate colonization and development of the brood chambers on walnut branches (Graves et al., 2010). This

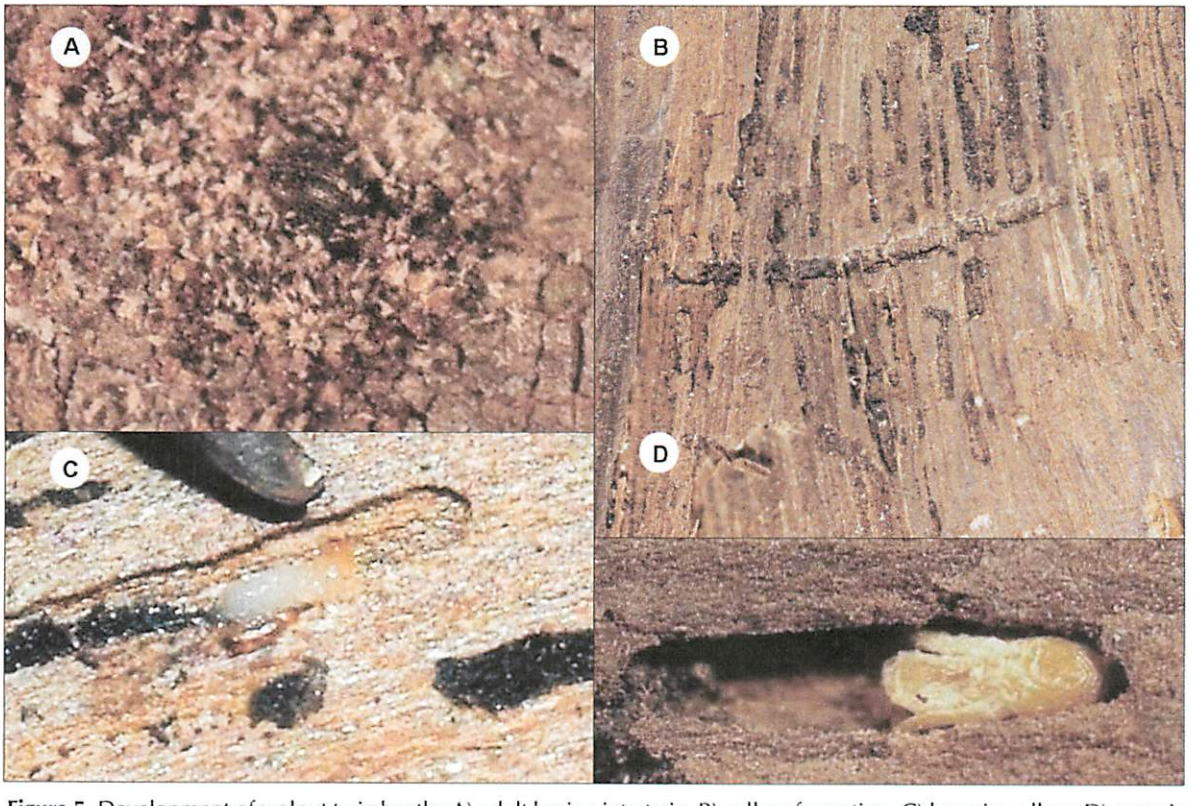

Figure 5 Development of walnut twig beetle: A) adult boring into twig, B) gallery formation, C) larva in gallery, D) pupa in gallery. Katheryne Nix, University of Tennessee, Knoxville, Tennessee, USA.

species appears to be polygynous, with one or two females observed within the same tunnel as the male.

Females lay minute, individual, cream-colored eggs. After egg hatch, the larvae begin to form single unbranched tunnels ~1.1– 1.3 cm long. The brood galleries are constructed against the grain within the area of the phloem and xylem surfaces (Graves et al., 2010), leaving an imprint on the upper cambial tissue and the underside of the bark (Fig. 5B). However, it appears the developing larvae construct their tunnels with the grain in infested black walnuts in eastern Tennessee. The larvae are white with reddish-brown heads and are found within the tunnels underneath the bark (Fig. 5C). The mature larvae create cells in which to pupate at the ends of their larval tunnels (Fig. 5D). By late July, most pupae have developed into adults. All stages of development, except the eggs, were documented to occur within the larval tunnels. By the end of larval development, the tunnels are packed with dark brown boring dust. The emerging adults either re-infest the host tree or fly to other host trees to mate and reproduce (Graves et al., 2010). This invasive species has the ability to increase rapidly in population size and spread over large areas in a relatively short period of time.

As they disperse and bore into new host trees, beetles carry the fungal conidia of *G. morbida* on their exoskeleton, often attached to the setae. The WTB is the only known vector of the thousand cankers pathogen. *Geosmithia morbida* was originally isolated and identified from branch and twig cankers surrounding the tunnels (Tisserat et al., 2009). The fungal growth occurs outside the tunnels in the region of the phloem and cambium, resulting in the development of many small cankers. As the cankers coalesce, the trunks and limbs become girdled by "thousands of cankers"—hence the common name of the disease (Cranshaw and Tisserat, 2008; Tisserat et al., 2009).

ANALYSIS OF RELATED NATIVE INSECTS IN THE UNITED STATES

Native Insects Related to the Pest (Nontarget Species)

Pityophthorus Eichhoff is a large, diversified, and widespread genus of bark beetles with over 200 species in North and Central America (Bright, 1981). Many of these species breed in the inner bark or pith of twigs and small branches, although some attack larger stems. Because most *Pityophthorus* colonize twigs of dead, dying, or injured hosts, they are of little economic importance, although some species are suspected vectors of the pitch canker fungus, *Fusarium circinatum* Nirenberg and O'Donnell, in pines (Storer et al., 2004, Sakamoto et al., 2007). There is a notable lack of published information on natural enemies of *Pityophthorus* species, perhaps historically due to their lack of importance as pests.

Of the 220 North and Central American *Pityophthorus* species treated by Bright (1981), 141 attack coniferous hosts and 101 of these utilize only pines (*Pinus* spp.). Other coniferous host genera include *Abies*, *Picea*, *Pseudotsuga*, and *Larix*. Of the remaining 79 species, 26 attack deciduous trees, 31 use vines or shrubs, and 22 have unknown or unrecorded hosts (Bright, 1981). There are three subgenera, *Hypopityophthorus*, *Gnatholeptus*, and *Pityophthorus*. The subgenus *Pityophthorus* contains most of the species and is further subdivided into various taxonomic groups. *Pityophthorus juglandis* is one of 13 species in Juglandis group, for which there is very limited information on biology and host associations, although most appear to be associated with non-coniferous shrubs and vines (Bright, 1981) (Table 1). *Pityophthorus lautus* Eichhoff, classified as part of the Lautus group, has been collected from a number of deciduous tree species in the eastern United States and is the only member of the genus besides *P. juglandis* reported to attack *Juglans* species (Bright, 1981) (Table 1). If potential biological control agents were identified for *P. juglandis*, *P. lautus* should be considered as a potential nontargethost species. Other potential nontarget *Pityophthora* might include additional species in the Juglandis and Lautus groups and others reported to attack non-coniferous hosts (Table 1). Presumably, compared to those that use conifers, natural enemies of *P. juglandis* would be more likely to affect nontargetinsects of deciduous species. Seybold et al. (2012) listed 30 species of bark beetles (Coleoptera: Curculionidae: Scolytinae) that were collected in pheromone-baited survey traps for WTB in California, Idaho, Tennessee, Utah, and Virginia, including two species of *Pityophthorus* (*P. crinalis* Blackman and *P. pulicarius* [Zimmermann]) and numerous other bark and ambrosia beetles. These and additional bark beetles that may be recovered from *Juglans* spp. or in pheromone traps for the WTB should also be considered as possible nontargetspecies in a biological control program.

Native Natural Enemies Affecting the Pest

Little has been recorded of the natural enemies of the WTB. Seybold (2010) listed three potential generalist predators, *Temnochila chlorodia* (Mannerheim) (Coleoptera:

Table 1 *Pityophthorus* species of North and Central America in the Juglandis and Lautus groups, and other species with non-coniferous host records in Bright (1981).

Pityophthorus species	Recorded Distribution	Recorded host plant species
Juglandis group		
P. burserae Wood	central Mexico	*Bursera* sp.
P. costabilis Wood	central Mexico	*Thevetia* sp.
P. costatulus Wood	southern Mexico	*Thevetia* sp.
P. detentus Wood	central Mexico	shrubs (*Rhus* sp.) and unknown vines
P. diligens Wood	central Mexico	unknown shrub
P. franseriae Wood	New Mexico; host occurs southwestern U.S.	probably *Ambrosia deltoidea* (Torr.) W.W.Payne
P. galeritus Wood	Costa Rica; host occurs Oaxaca to Panama	*Garcinia intermedia* (Pittier) Hammel
P. indigens Wood	Mexico	*Bursera* sp.
P. juglandis Blackman	southern California to New Mexico, south into northern Mexico	*Juglans* spp.
P. nanus Wood	southern Mexico	*Bursera* sp., *Pinus* sp.
P. pudicus Blackman	Jalisco, Mexico	*Sambucus* sp.; unknown shrubs
P. strictus Wood	Costa Rica; host occurs Oaxaca to Panama	*Garcinia intermedia* (Pittier) Hammel
P. tenax Wood	Guatemala	unknown
Lautus group		
P. *borrichiae* Wood	Florida	*Borrichia* spp.
P. *concentralis* Eichhoff	Cuba and Florida	*Metopium toxiferum* (L.) Krug & Urb.
P. *corruptus* Wood	central Mexico	*Rhus* spp. (*Toxicodendron*)
P. *crinalis* Blackman	eastern U.S.	*Rhus* spp. (*Toxicodendron*), *Quercus alba* L.
P. *lautus* Eichhoff	eastern North America	*Acer* spp., *Cercis* sp., *Hammamelis* spp., *Juglans* spp., *Quercus* spp., *Rhus* spp.
P. *liquidambaris* Blackman	southeastern U.S.	*Liquidambar styraciflua* L.
P. *molestus* Wood	Mexican distribution of sweetgum	*Liquidambar styraciflua* L.
P. *morosus* Wood	Chiapas and Veracruz, Mexico to Honduras	*Critonia daleoides* DC; unknown woody plants
P. *nemorolis* Wood	Honduras, Costa Rica, throughout Central America	*Aristolochia anguicida* Jacq.; unspecified vines
P. *paulus* Wood	central Mexico	*Baccharis* sp., unknown plants
P. *perexiguus* Wood	Costa Rica, Panama	unknown
P. *sambuci* Blackman	Jalisco, Mexico	*Sambucus* sp.
Other species with non-coniferous hosts		
P. alni Blackman	Veracruz and prob. elsewhere in southern Mexico	*Alnus* spp.
P. alnicolens Wood	southern Mexico	*Alnus* sp.
P. arceuthobii Wood	Durango, Mexico	*Arceuthobium globosum* Hawksw. & Wiens
P. attenuatus Blackman	Southern Mexico to El Salvador, prob. throughout Central America	*Quercus* sp., *Alnus* sp., unidentified shrubs
P. conspectus Wood	Costa Rica	prob. *Quercus* sp.
P. *coronarius* Blackman	Mexico	*Sambucus* sp. and prob. other shrubs

Table 1 *Pityophthorus* species of North and Central America in the Juglandis and Lautus groups, and other species with non-coniferous host records in Bright (1981), *continued.*

Pityophthorus species	Recorded Distribution	Recorded host plant species
P. debilis Wood	Probably throughout central Mexico	*Rhus* sp. amd *Mauria heterophylla* Kunth
P. exquisitus (Blackman)	Central Mexico; probably a larger area	*Sambucus* sp. and other unknown shrubs
P. guatemalensis Blanford	Durango, Mexico to Guatemala, possibly TX	*Quercus* spp.
P. hermosus Wood	Honduras, prob. throughout southern Mexico to Costa Rica	*Perymanium grande*[1] and *Critonia daleoides* DC.
P. hylocuroides Wood	Hidalgo, Mexico	*Rhus* sp.
P. medialis Wood	Costa Rica	*Quercus* spp.
P. melanurus Wood	Chiapas, Mexico	Quercus sp.
P. mendosus Wood	Costa Rica; probably throughout Central America	*Phosphoro* sp.[1]
P. *mexicanus* Blackman	Northern and central Mexico	*Parthenium argentatum* A.Gray
P. nebulosus Wood	Veracruz, Mexico	*Bursera* sp.
P. parilis Wood	Honduras	*Quercus* spp.
P. scitulus Wood	Costa Rica, Panama	*Quercus* spp.
P. *scriptor* Blackman	Southeastern U.S., west to Texas and Oklahoma	*Rhus spp.*
P. torridus Wood	New Mexico	probably *Ambrosia deltoidea* (Torr.) W. W. Payne
P. *virilis* Blackman	Southern Idaho and Wyoming to northern Mexico and western Texas	*Rhus spp.*

Note: With the exception of the Juglandis and Lautus groups (which are listed in full), species with hosts recorded only as "unknown", "unknown vine", "unknown shrub", or other ambiguous host records in Bright (1981) are not included in this table. [1]The identity of the species associated with the names *Perymanium grande* and *Phosphoro* sp. is uncertain.

Trogositidae), an unknown beetle in the family Laemophloeidae, and an unknown beetle in the family Monotomidae, as well as two parasitoids, *Neocalosoter* sp. (Hymenoptera: Pteromalidae) and *Plastanoxus westwoodi* (Hymenoptera: Bethylidae), as natural enemies of WTB on *J. hindsii* in California. Additional information on natural enemy complexes found in association with WTB in its native and invaded ranges is being compiled (S.J. Seybold, USDA Forest Service, pers. comm. 2012). Due to the discovery of the WTB in 2010 in Knox County, Tennessee, and the associated severe damage to black walnut, surveys were initiated to find potential biological control agents. A variety of natural enemies were observed to be associated with the WTB on *J. nigra* in Tennessee, including the predators *Enoclerus nigripes* (Say), *Madoniella dislocatus* (Say), and *Pyticeroides laticornis* (Say) (all Coleoptera: Cleridae) (Fig. 6) and an unknown parasitoid. Specimens of the predaceous clerids were observed on the bark and in the tunnels of walnut twig beetle in walnut bolts maintained in the laboratory. These predators are widely distributed within the eastern United States and Canada (Leavengood, 2008). Both adults and larvae are predators of bark beetles. A study was initiated to determine if these clerids would feed on walnut twig beetle life stages, which they did in laboratory choice and no-choice consumption tests (K. Nix, Univ. Tennessee, pers. comm. 2012). One primary endoparasitoid was discovered emerging from adult, female, walnut twig beetles.

BIOLOGY AND ECOLOGY OF KEY NATURAL ENEMIES

Enoclerus nigripes

Synomyns for *E. nigripes* include; *Clerus nigripes* Say, *Clerus incertus* Lec., *Clerus quadriguttatus* Auctt., Oliv., *Clerus quadriguttatus* Say var. *nigripes* Say, *Enoclerus quadriguttatus*

Oliv., and *Enoclerus quadriguttatus* var. *nigripes* Say. *Enoclerus nigripes* is widely distributed throughout the eastern and midwestern United States and Canada, where it is associated with bark beetles in both conifers and hardwoods. Adults are active during the spring and early summer. The distinguishing characteristics of the adults are that the beetle is 5.0–7.0 mm long and has reddish brown elytra with two transverse yellow bands, outlined with traces of white pubescent setae (Downie and Arnett, 1996) (Fig. 6a).

Madoniella dislocatus

Synomyns for *M. dislocatus* include; *Enoplium dislocatum* Say, *Phlogistosternus dislocates* (Say), and *Phyllobaenus dislocatus* Say. *Madoniella dislocatus* is widely distributed throughout the eastern United States and Canada. It has been found in Florida, Georgia, Indiana, Illinois, Iowa, Kansas, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, West Virginia, and Wisconsin, as well asOntario, Canada (Leavengood, 2008). It is a generalist predator associated with bark beetles in several species of conifers and hardwoods, including *P. juglandis*. Adults are diurnal and active from March into May. The key characteristics that distinguish this species are a slender and elongate appearance (3.5–6.0 mm long), an entirely brown pronotum, three yellowish markings on the elytra, emarginate eyes, and a three-segmented antennal club that is shorter than the remaining antennal segments (Leavengood, 2008) (Fig. 6b).

Pyticeroides laticornis

Synomyns for this clerid include *Ellipotoma laticornis* Say, *Enoplium laticorne* Say, *Ichnea laticornis* Say, and *Neichnea laticornis* Say. *Pyticeroides laticornis* is found in the eastern and central United States and has been recorded in Alabama, Arkansas, Colorado, Connecticut, District of Columbia, Florida, Georgia, Illinois, Indiana, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Missouri, Mississippi, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and West Virginia, as well as Ontario, Canada (Leavengood, 2008). This species is a generalist, diurnal predator of bark beetles that feeds on prey in several hardwood species, attacking all stages of bark beetles in their galleries. The females lay an egg at the entrance hole of the prey, and upon hatching, the larva enters the tunnel and feeds on all the soft tissue of the adult prey, leaving only the exuviae. Mature larvae are believed to overwinter within the tunnel. The key characteristics that distinguish this species are nine antennomeres and a three-segmented antennal club that is longer than funicular, an orange pronotum, and elytra that are entirely black and patternless (Leavengood, 2008) (Fig 6c).

There is very little published information on natural enemies of the walnut twig beetle, especially in its native range in the southwestern United States and northern Mexico. However, with the recent discovery of natural enemies feeding on *P. juglandis* in the invaded range in eastern North America, species of natural enemies from the pest's native range must be evaluated to assess their potential for use as biological control agents in the beetles invaded range. With the rapid spread of this damaging insect-pathogen complex, further consideration and work is needed to develop and implement an integrated pest management program at state and regional levels. Given that 1) the thousand cankers disease pathogen is not systemic, 2) large numbers of beetles are required to kill the tree, and 3) mortality is a gradual process, biological control may be a promising option, compared with other insect/disease complexes such as redbay ambrosia beetle (*Xyleborus glabratus* Eichoff)/laurel wilt, which can kill

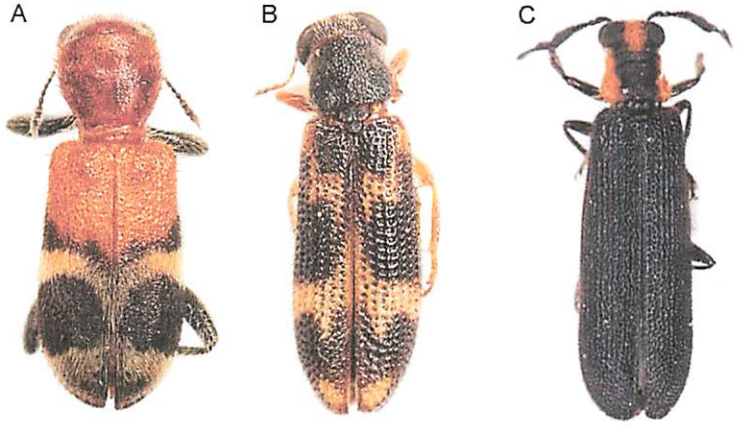

Figure 6 Predators of walnut twig beetle in Tennessee: A) *Enoclerus nigripes* B) *Madoniella dislocatus*, and C) *Pyticeroides laticornis*. Photos by Mike Quinn, TexasEnto.net.

hosts rapidly with a single, beetle-vectored inoculation with a systemic pathogen. The combined use of biological control, chemical control, sanitation, and regulatory limits on the movement of walnut material may have potential to maintain this invasive pest below ecologically damaging levels.

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