The Great Lakes Entomologist

Volume 53
Numbers 3 & 4 - Fall/Winter 2020 *Numbers 3 & 4 - Fall/Winter 2020*
Article 13

December 2020

Bark- and Wood-Infesting Coleoptera and Associated Parasitoids Reared from Shagbark Hickory (Carya ovata) and Slippery elm (Ulmus rubra) in Ingham County, Michigan

Robert A. Haack
USDA Forest Service, robert.haack@usda.gov

Bark- and Wood-Infesting Coleoptera and Associated Parasitoids Reared from Shagbark Hickory (*Carya ovata*) and Slippery Elm (*Ulmus rubra*) in Ingham County, Michigan

Robert A. Haack

USDA Forest Service, Northern Research Station, 3101 Technology Blvd., Suite F, Lansing, MI 48910
[e-mail: robert.haack@usda.gov (emeritus)]

Abstract

Ten species of bark- and wood-infesting Coleoptera (borers) and five parasitoid species (Hymenoptera) were reared from shagbark hickory [*Carya ovata* (Mill.) K. Koch] branches 1-2 years after tree death, and similarly, seven borers and eight parasitoids were reared from slippery elm (*Ulmus rubra* Muhl.) branches one year after tree death in Ingham County, Michigan, in 1986-87. The borers were species of bostrichids, buprestids, cerambycids, and curculionids (including Scolytinae). The parasitoids were braconids, chalcidids, eurytomids, ichneumonids, and pteromalids. One new larval host record was recorded: the cerambycid *Urgleptes querci* (Fitch), being reared from *U. rubra*. This paper presents new Michigan state records for the eurytomids *Eurytoma conica* Provancher and *Eurytoma phloeotribi* Ashmead, the ichneumonid *Xorides humeralis* (Say), and pteromalid *Cheiropachus quadrum* (Fabricius). At the same field site where the above rearings occurred, when newly cut shagbark hickory branches were placed on the ground and at two canopy levels in a healthy hickory tree in May 1986 and then collected 11 months later in April 1987 and placed in rearing cages, borers (two species) and parasitoids (four species) were reared from the branches that had been suspended in the canopy, but none emerged from the branches that had been on the ground, suggesting vertical stratification of both borers and parasitoids.

Keywords: Borers, parasitoids, Hymentoptera, phoretic mites, host range, state records

---

During my working career with the Northern Research Station of the U.S. Forest Service (1986-2015), which has had a Forest Insect Research Unit on the Michigan State University campus since 1956 (Haack 2006), I lived on a 13 ac (5.3 ha) rural property near Dansville, Ingham County, MI (N 42.5481° Lat, W 84.3189° Long). Over 80% of that property was covered by mature northern hardwood (beech-maple) forest. When combined with the neighboring properties, the contiguous woodlots covered over 60 ac (24 ha). The dominant tree species were sugar maple (*Acer saccharum* Marshall) and American beech (*Fagus grandifolia* Ehrh.), followed by yellow birch (*Betula alleghaniensis* Britton), bitternut hickory [*Carya cordiformis* (Wangenh.) K.Koch], shagbark hickory [*Carya ovata* (Mill.) K. Koch], white ash (*Fraxinus americana* L.), black cherry (*Prunus serotina* Ehrh.), northern red oak (*Quercus rubra* L.), white oak (*Quercus alba* L.), American basswood (*Tilia americana* L.), and slippery elm (*Ulmus rubra* Muhl.). Also present, but less common, were tree species in the genera *Amelanchier*, *Carpinus*, *Ostrya, Populus, Prunus,* and *Zanthoxylum*. On several occasions at this Dansville location, I reared bark- and wood-infesting insects and their associates from branch and trunk sections of various tree species. My earliest rearing records were from *C. ovata* and *U. rubra* in 1986-87, and that is the focus of this paper. Although these findings are many years old they are still valuable given that they document larval host records, adult emergence periods, and at times new state records for Michigan insects.

Some of the first major publications to summarize the life cycles of common North American bark-and wood-infesting insects (borers) were by Packard (1890) and Felt (1905). Many similar books have followed, with the most recent book focusing on North American borers that infest hardwood trees (Solomon 1995). Early studies on borers associated with hickory (*Carya* spp.) often focused on the hickory bark beetle, *Scolytus quadrispinosus* Say (Coleoptera: Curculionidae: Scolytinae), which has often reached outbreak levels in the eastern United States (Hopkins 1912, Blackman and Stage 1924, Solomon 1995). By contrast, early studies of borers infesting elm (*Ulmus* spp.) usually focused on the elm borer, *Saperda tridentata*

Olivier (Coleoptera: Cerambycidae) (Packard 1890, Felt and Joutel 1904). Later, in the early decades of the 1900s, after the introduction into the eastern United Sates of the smaller European elm bark beetle [*Scolytus multistriatus* (Marsham) (Coleoptera: Curculionidae: Scolytinae)], and the *Ophiostoma* fungal pathogens that cause Dutch elm disease, several studies were conducted on the major borers and other insects associated with elm that could possibly transmit the fungal spores (Hoffman 1939, Hoffman 1942, Pechuman 1940).

Methods. Study 1. On 19 April 1986, I cut down four *C. ovata* and *U. rubra* trees that had died in the Dansville woodlot in summer 1985 and had remained standing. While cutting the trees, I noticed they were infested with borers (bark- and wood-infesting insects), and therefore decided to place some of the host material in rearing cages. I soon obtained six rearing cages (ca. 60 cm wide, 45 cm deep, and 45 cm tall) that each had a wood floor, a sliding Plexiglas front panel, and fine screening on the other three side walls and upper surface. The cages were placed on a counter, inside a covered shed (ca. 8 × 12 ft or 2.4 × 3.7 m), that had double doors at opposite ends that remained open to allow good air flow. The shed received direct sunlight during the early morning hours, but otherwise was shaded and therefore the temperatures inside the shed were similar to ambient conditions.

On 3 May 1986, I collected two *C. ovata* and three *U. rubra* branches that had been left on the forest floor when I cut the standing trees on 19 April. I selected branches that had evidence of borer attack, such as larval galleries being evident at the cut ends of the branches where they had been attached to the trunk. The branches were 8–10 cm in diameter at their base. The branches were cut in sections to fit inside the rearing cages and utilized down to a branch diameter of about 2 cm. The total length of all branch sections, if placed end to end, was about 12 m for *C. ovata* and 16 m for *U. rubra*. In addition, about 400 cm^2 of the outer bark was removed from the upper trunk of one *U. rubra* tree that had been cut on 19 April, where the diameter was about 20–25 cm diameter. The branch and bark samples were placed separately by tree species inside the rearing cages, and usually checked every 1-2 days for recently emerged insects through August 1986, and then less frequently through October 1986. The elm branches were discarded in November 1986. However, the hickory branch sections were kept in the same cages, outdoors, through the winter, and then checked every 1–2 days for newly emerged insects from mid-April through May 1987. After each collection, all insects were placed in labeled vials by tree species and date and then frozen. Later, once individuals of each morphospecies had been identified, often by experts (see acknowledgments), the insects were totaled by species and emergence date. Specimens of each species were retained by the identifiers in their personal or institutional collections. All parasitoids were identified by staff at the US Department of Agriculture, Systematic Entomology Laboratory in Beltsville, MD.

Study 2. A second study was conducted in 1986–87 to explore how borer and parasitoid infestation levels varied with canopy height. On 28 May 1986, I cut 12 branches from a single, small, healthy *C. ovata* tree in the Dansville woodlot. The branches appeared uninfested at the time of cutting, and they measured 1.2–2.0 m long and 2–6 cm in diameter at their widest end. Four branches, representing a range of sizes, were placed at three heights in another nearby *C. ovata* tree on 28 May 1986. The selected hickory tree was about 10 m tall and grew near the edge of the woodlot (within 10 m). Four of the cut branches were placed on the ground around the base of this tree (ground level), four branches were suspended from lower-canopy branches (ca. 3 m aboveground; lower canopy), and four branches were suspended from mid-canopy branches (ca. 6 m; mid-canopy). For the suspended branches, a rope was tied to one end of each sample branch and then using the rope and various canopy branches as supports the sample branches were raised to the appropriate height and then secured. The twelve branches were left on the ground or suspended for the next 11 months, after which I collected the branches on 26 April 1987, labelled them by treatment, and took them to the USDA Forest Service laboratory on the Michigan State University campus. Each branch was placed in an individual, fine-mesh, cloth sleeve cage that was closed at each end with plastic-coated wire and maintained on a laboratory bench at room temperature. The sleeve cages were examined daily during the work week through July 1987 with all borers and parasitoids collected, placed in labelled vials, and then frozen until identified.

Results. Study 1. In 1986, which was assumed the first year after infestation of the hickory branches given that the trees died in 1985, 199 individual borers representing eight species were reared, including one bostrichid, three buprestids, two cerambycids, and two curculionids (Table 1). The three most common borers from hickory were the bostrichid *Xylobiops basilaris* (Say), the buprestid *Agrilus otiosus* Say, and the curculionid *Magdalis olyra* (Herbst) (Table 1). Considering all borers from hickory, individuals were collected from 7 May to 3 August 1986 (Table 1). Similarly, 18 indi-

Table 1. Collection data for adult bark- and wood-infesting Coleoptera (borers) and parasitoids (Hymenoptera) reared from shagbark hickory (*Carya ovata*) branches outdoors in 1986 and 1987 in Ingham County, Michigan.

FAMILY Species	Number collected 1986	 1987	Collection dates (range)[1] Calendar days	 Julian days (mean)	 Identifier[2]
Borers					
BOSTRICHIDAE					
Xylobiops basilaris (Say)	91	1	7 V–3 VIII	148-215 (156)	RAH
BUPRESTIDAE					
Agrilus otiosus Say	42	1	28 V–19 VI	148-169 (154)	SGW
Anthaxia viridifrons Gory	10		25 V–8 VI	145-159 (150)	SGW
Chrysobothris adelpha Harold	6		11 VII–12 VII	192-193 (193)	SGW
CERAMBYCIDAE					
Dorcaschema nigrum (Say)		1	13 V	133	DCLG
Molorchus bimaculatus bimaculatus Say		5	9–10 V	129-130 (130)	DCLG
Neoclytus acuminatus (Fabricius)	1		19 VI	169	DCLG
Phymatodes testaceus (L.)	2		31 V– 7 VI	151-158 (155)	DCLG
CURCULIONIDAE					
Magdalis olyra (Herbst)	38		7 V–25 V	127-145 (130)	SJK
Scolytus quadrispinosus Say	9		13 VI–19 VI	164-169 (166)	RAH
Parasitoids					
BRACONIDAE					
Doryctes sp.	3		18 V–8 VI	138 – 159 (151)	PMM
Eubazus sp.	10		13 V–17 V	130 – 137 (134)	PMM
Spathius sp.	2		27 V–31 V	147 – 151 (149)	PMM
EURYTOMIDAE					
Eurytoma phloeotribi Ashmead	2		13 V	133	RWC
ICHNEUMONIDAE					
Xorides humeralis (Say)	1		23 V	143	RWC

[1] The collection data presented are combined for both 1986 and 1987.
[2] Identifiers: DCLG = David C. L. Gosling, PMM = Paul M. Marsh, RAH = Robert A. Haack, RWC = Robert W. Carlson, SGW = Stanley G. Wellso, SJK = Steven J. Krauth.

vidual parasitoids, representing five species, were reared from hickory in 1986, including three braconids, one eurytomid, and one ichneumonid (Table 1). The most common parasitoid was an unidentified braconid species in the genus *Eubazus* (Table 1). In addition, several *M. olyra* adults had phoretic mites on their coxae that were identified by John C. Moser as *Pseudotarsonemoides* sp. (Trombidiformes: Tarsonemidae).

In 1987, the apparent second year after infestation, only eight individual borers, representing four species in three families, were collected from the hickory branches (Table 1). Neither of the two cerambycids that emerged in 1987 [*Dorcaschema nigrum* (Say) and *Molorchus bimaculatus bimaculatus* Say] had been collected in 1986. However, each of the other two species collected in 1987 (one *A. otiosus* and one *X. basilaris*) had been collected in 1986 on several occasions (Table 1).

Considering the rearing data from elm, 615 individual borers representing seven species were collected in 1986, including one buprestid, three cerambycids, and three curculionids (Table 2). The two most common borers from elm were the curculionids *Magdalis barbita* (Say) and *S. multistriatus* (Table 2). Considering all borers from elm, individuals emerged from 7 May to 2 July 1986 (Table 2). As for the parasitoids from elm, 611 individuals representing eight species were reared in 1986, including three braconids, one chalcidid, two eurytomids, one ichneumonid, and one pteromalid (Table 2). The two most common parasitoids were unidentified species of *Eubazus* and *Spathius* (Table 2). In addition, several adult weevils of *Magdalis armicollis* (Say) had phoretic mites on their coxae that were identified by John C. Moser as *Pyemotes scolyti* (Oudemans) (Trombidiformes: Pyemotidae).

Study 2. Overall, 46 borers and 36 parasitoids were reared from the 12 hickory branches that had been placed beneath or suspended in a hickory tree for nearly a year (Table 3). No borers or parasitoids

Table 2. Collection data for adult bark- and wood-infesting Coleoptera (borers) and parasitoids (Hymenoptera) reared from slippery elm (*Ulmus rubra*) branches outdoors in 1986 in Ingham County, Michigan.

FAMILY Species	Number collected	Collection dates (range)[1] Calendar days	 Julian days (mean)	Identifier[1]
Borers				
BUPRESTIDAE				
Anthaxia viridifrons Gory	15	27 V–15 VI	147–166 (152)	SGW
CERAMBYCIDAE				
Neoclytus acuminatus (Fabricius)	3	8 VI–24 VI	159–175 (165)	DCLG
Saperda tridentata Olivier	11	10 V–18 V	130–138 (135)	DCLG
Urgleptes querci (Fitch)	2	4 VI–2 VII	155–183 (169)	DCLG
CURCULIONIDAE				
Magdalis armicollis (Say)	25	11 V–11 VI	142–162 (146)	SJK
Magdalis barbita (Say)	477	7 V–31 V	127–151 (137)	SJK
Scolytus multistriatus (Marsham)	82	27 V–2 VII	147–183 (170)	RAH
Parasitoids				
BRACONIDAE				
Doryctes sp.	1	29 V	149	PMM
Eubazus sp.	259	9 V–12 VI	129–163 (145)	PMM
Spathius sp.	312	8 V–1 VII	128–182 (160)	PMM
CHALCIDIDAE				
Trigonura ulmi Burks	1	1 VI	152	RWC
EURYTOMIDAE				
Eurytoma conica Provancher	9	1 VI– 19 VI	152–170 (157)	RWC
Eurytoma phloeotribi Ashmead	13	25 V–15 VI	145–166 (159)	RWC
ICHNEUMONIDAE				
Xorides albopictus (Cresson)	11	9 V–22 V	129–142 (134)	RWC
PTEROMALIDAE				
Cheiropachus quadrum (Fabricius)	5	30 V–31 V	150–151 (151)	EEG

[1] Identifiers: as given in footnote 2 in Table 1 with the addition of EEG = Eric E. Grissell.

were reared from the branches placed on the ground, compared with 17 borers and 7 parasitoids collected from branches in the lower-canopy, and 29 borers and 29 parasitoids from branches in the mid-canopy (Table 3).

Discussion. As trees die and decay, there is a succession of borers, parasitoids and other associated insects that colonize the woody tissues (Haack and Slansky 1987, Hanula 1996, Grove 2002). Several studies have documented insect succession in decaying logs and branches of specific tree species, including species of *Carya* (Blackman and Stage 1924), *Larix* (Blackman and Stage 1918), *Pinus* (Savely 1939), *Quercus* (Savely 1939), *Tilia* (Townsend 1886), and *Ulmus* (Tucker 1907, Marković and Stojanović 2012).

Species of *Carya* and *Ulmus* are known larval hosts for all the borers reared in the present study (Packard 1890, Felt and Joutel 1904, Felt 1905, Blackman and Stage 1924, Gosling 1973, 1984, Wellso et al. 1976, Solomon 1995). In fact, all borers reared in this study from *C. ovata* have been previously reported from *C. ovata*. Similarly, all borers reared in this study from *U. rubra*, except one, have been previously reported from *U. rubra*. The one exception is the cerambycid *Urgleptes querci* (Fitch), which has been reared from many hardwood tree species, including American elm (*Ulmus americana* L.) (Gosling 1984, MacRae 1993), but I did not find any published records of this beetle being reared from *U. rubra*. The emergence data for the borers reared in this study agree broadly with the seasonal adult activity periods reported by others for these same species (Felt 1905, Yanega 1996, Solomon 1995).

As for new state records for Michigan, I have found in-print published Michigan records for all the borers presented in this study (Gosling 1973, Gosling and Gosling 1977, Wellso et al. 1976, Downie and Arnett 1996, Cognato et al. 2009, and many additional online searches using Google Scholar through November 2020), except the bostrichid *X. basilaris*. However, using the online SCAN database (https://scan-bugs.org/) in November 2020, which contains collection records of insects from over 100 North American arthropod collections,

Table 3. Number and dimensions of shagbark hickory (*Carya ovata*) branches that were cut in May 1986 from a healthy tree and placed at one of three positions at the base of or in the canopy of another hickory tree until April 1987 when taken indoors for rearing any associated borers and parasitoids that were present (see Methods for details).

	Branch location		
Parameter	**Ground level**	**Lower canopy**	**Mid-canopy**
Branch data			
Number	4	4	4
Diam at cut end, range (cm)	2.1–4.4	3.1–5.4	1.9–5.3
Length, range (m)	1.2–1.7	1.6–1.8	1.3–2.0
Number of borers reared[1]			
Xylobiops basilaris (Say)	0	12	18
Agrilus otiosus Say	0	5	11
Number of parasitoids reared[1]			
Doryctes sp.	0	2	1
Eubazus sp.	0	0	3
Spathius sp.	0	5	24
Eurytoma phloeotribi Ashmead	0	0	1

[1] The numbers of borers and parasitoids are the total number of individuals reared for all four branches that were at each location.

Michigan specimens of *X. basilaris* have been deposited at the A. J. Cook Arthropod Research Collection (ARC) at Michigan State University (MSU), as well as on BugGuide.net (photo # 604222). With respect to the six parasitoids that were identified to the species level, I found in-print published Michigan records for only two species, including the chalcidid *Trigonura ulmi* Burks (Rowher 1920, Shaddy et al. 1978) and the ichneumonid *Xorides albopictus* (Cresson) (Krombein et al. 1979). For the other four parasitoids, I found no in-print published records, nor any Michigan records in the SCAN database or on BugGuide.net and therefore the following parasitoids are considered new state records for Michigan; the eurytomids *Eurytoma conica* Provancher and *Eurytoma phloeotribi* Ashmead, the ichneumonid *Xorides humeralis* (Say), and the pteromalid *Cheiropachus quadrum* (Fabricius).

The borers and parasitoids listed in Tables 1 and 3 all emerged the year after the host material was apparently first infested, indicating a univoltine life cycle for these species. The two *A. otiosus* and *X. basilaris* adults that were reared from hickory branches two years after their apparent initial infestation suggests that these two species can have a 2-year life cycle at times. A 2-year life cycle for borers that are typically univoltine can occur when eggs are laid in late summer, and thus the resulting larvae require two seasons of feeding before being able to pupate. Also, if the host material becomes excessively dry, larval development time can be protracted, which can delay adult emergence by a year or more (Haack and Slansky 1987, Haack 2017). For example, the buprestid *Agrilus planipennis* Fairmaire is typically univoltine, but a 2-year life cycle was recorded for some individuals reared from cut firewood (Petrice and Haack 2007). By contrast, the two cerambycid species (one *D. nigrum* and five *M. b. bimaculatus*) that emerged from hickory branches in 1987, but for which none emerged in 1986, may commonly have a 2-year life cycle. In support of this contention consider the rearing data of Blackman and Stage (1924), who collected insects from trunk and branch sections of hickory trees in New York that had died 1-6 years earlier, which also indicated a 2-year life cycle for both *D. nigrum* and *M. b. bimaculatus*.

I did not attempt to associate the parasitoids reared in this study with their insect hosts. However, based on other studies, largely summarized in Krombein et al. (1979), the braconids, chalcidids, eurytomids, and pteromalids reared in this study are common parasitoids of many bark beetles (Curculionidae: Scolytinae) and weevils in the genus *Magdalis*. Similarly, ichneumonids in the genus *Xorides* are common parasitoids of cerambycid larvae. In fact, *X. albopictus* has been reared from *S. tridentata*, and *X. humeralis* has been reared from *Phymatodes testaceus* (L) and *Neoclytus acuminatus* (Fabricius) (Krombein et al. 1979) – all three (cerambycids) of which were reared in the present study (Tables 1-2). Some of the parasitoids reared in this study could also have used the bostrichids and buprestids as hosts, given that they were the most common borers reared from hickory

(Tables 1 and 3), and that several families of hymenopteran parasitoids have been reared from various *Agrilus* and *Xylobiops* species (Krombein et al. 1979, Petrice et al. 2009, Taylor et al. 2012, Bertone et al. 2017).

Vertical stratification has been reported for many forest insects, with some favoring the canopy of trees to search for food, hosts and oviposition sites, while others search mostly in the understory (Ulyshen 2011). Variation in vertical distribution has been documented for both borers and parasitoids (Pucci 2008, Hardersen et al. 2014, Di Giovanni et al. 2015, Rassati et al. 2019, Sheehan et al. 2019). Given that the hickory branches used in the present study were more heavily infested by both borers and parasitoids when placed in the canopy than on the ground, suggests that the insects listed in Table 3 display vertical stratification when searching for suitable host material.

Acknowledgments

The author thanks Robert W. Carlson [Systematic Entomology Laboratory (SEL), Beltsville, MD], David C. L. Gosling (Glen Oaks Community College, MI), Eric E. Grissell (SEL), Steven J. Krauth (University of Wisconsin-Madison), Paul M. Marsh (SEL), John C. Moser (USDA Forest Service, Pineville, LA), and Stanley G Wellso (USDA Agricultural Research Service, West Lafayette, IN), for providing identification services; and William Ruesink (Illinois Natural History Survey, emeritus), Davide Rassati (University of Padua, Italy), and two anonymous reviewers for commenting on an earlier draft of this paper. The affiliations listed above were those of the researchers at the time when they provided assistance to this project. This research was supported in part by the USDA Forest Service.

Literature Cited

Bertone, M. A., C. A. Nalepa, K. L. F. Oten, and S. P. Turner. 2017. Record of the hymenopteran parasitoid *Xorides (Exomus) humeralis* (Ichneumonidae: Xoridinae) from emerald ash borer galleries (Coleoptera: Buprestidae) in North Carolina. Proceedings of the Entomological Society of Washington 119: 514–517.

Blackman, M. W. and H. H. Stage. 1918. Notes on insects bred from the bark and wood of the American larch. New York State College of Forestry, Technical Bulletin 10: 11–115.

Blackman, M. W. and H. H. Stage. 1924. On the succession of insects living in the bark and wood of dead, dying, and decaying hickory. New York State College of Forestry, Technical Bulletin 17: 3–269.

Cognato, A. I., N. Barc, M. Philip, R. Mech, A. D. Smith, E. Galbraith, A. J. Storer, and L. R. Kirkendall. 2009. The native and introduced bark and ambrosia beetles of Michigan (Coleoptera: Curculionidae, Scolytinae). The Great Lakes Entomologist 42: 101–120.

Di Giovanni, F., P. Cerretti, F. Mason, E. Minari, and L. Marini. 2015. Vertical stratification of ichneumonid wasp communities: the effects of forest structure and life-history traits. Insect Science 22: 688–699.

Downie, N. M. and R. H. Arnett, Jr. 1996. The beetles of northeastern North America. The Sandhill Crane Press, Gainesville, FL. 1721 pp.

Felt, E. P. 1905. Insects affecting park and woodland trees. New York State Museum Memoir 8: Vol 1. The University of the State of New York, Albany, NY. 459 pp.

Felt, E. P. and H. Joutel. 1904. Monograph of the genus *Saperda*. New York State Museum Bulletin 74: 1–86.

Gosling, D. C. L. 1973. An annotated list of the Cerambycidae of Michigan (Coleoptera) part I, introduction and the subfamilies Parandrinae, Prioninae, Spondylinae, Aseminae, and Cerambycinae. The Great Lakes Entomologist 6: 65–84.

Gosling, D. C. L. 1984. Cerambycid host plants in a southwestern Michigan woodland (Coleoptera: Cerambycidae). The Great Lakes Entomologist 17: 69–78.

Gosling, D. C. L., and N. M. Gosling. 1977. An annotated list of the Cerambycidae of Michigan (Coleoptera). Part II, the subfamilies Lepturinae and Lamiinae. The Great Lakes Entomologist 10: 1–37.

Grove, S. J. 2002. Saproxylic insect ecology and the sustainable management of forests. Annual Review of Ecology and Systematics 33: 1–23.

Haack, R. A. 2006. The US Forest Service Insect Unit in East Lansing, MI, turns 50. Newsletter of the Michigan Entomological Society. 51 (3-4): 4.

Haack, R. A. 2017. Feeding biology of cerambycids, pp 105–124. In: Q. Wang (ed.), Cerambycidae of the world—biology and pest management. CRC Press, Boca Raton, FL.

Haack, R. A. and F. Slansky. 1987. Nutritional ecology of wood-feeding Coleoptera, Lepidoptera, and Hymenoptera, pp. 449-486. In: F. Slansky and J. G. Rodriguez (eds.), Nutritional ecology of insects, mites, spiders and related invertebrates. John Wiley, New York.

Hanula, J. L. 1996. Relationship of wood-feeding insects and coarse woody debris. pp. 55–81. In: J. McMinn and D. A. Crossley (eds.) Biodiversity and coarse woody debris in south-

ern forests. US Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. General Technical Report SE-GTR-94. Asheville, NC.

Hardersen, S., G. Curletti, L. Leseigneur, G. Platia, G. Liberti, P. Leo, P. Cornacchia, and E. Gatti. 2014. Spatio-temporal analysis of beetles from the canopy and ground layer in an Italian lowland forest. Bulletin of Insectology 67: 87-97.

Hoffman, C. H. 1939. Observations on the biology of *Saperda tridentata* Oliv. and *Magdalis armicollis* Say (Coleoptera). Journal of Economic Entomology 32: 848–851.

Hoffman, C. H. 1942. Annotated list of elm insects in the United States**.** US Department of Agriculture, Miscellaneous Publication No. 466. Washington, D.C. 20 pp.

Hopkins, A. D. 1912. The dying hickory trees – cause and remedy. US Department of Agriculture, Bureau of Entomology, Circular No. 144. Washington, D.C. 5 pp.

Krombein, K. V., P. V. Hurd, Jr., D. R. Smith, and B. D. Burks. 1979. Catalog of the Hymenoptera in America North of Mexico. Smithsonian Institution Press, Washington, D.C. 2730 pp.

MacRae, T. C. 1993. Annotated checklist of the longhorned beetles (Coleoptera. Cerambycidae and Disteniidae) occurring in Missouri. Insecta Mundi 7: 223–252.

Marković, Č. and A. Stojanović. 2012. Fauna of phloemo-xylophagous insects, their parasitoids and predators on *Ulmus minor* in Serbia. Biologia 67: 584–589.

Packard, A. S. 1890. Fifth report of the United States Entomological Commission: being a revised and enlarged edition of Bulletin No. 7, on insects injurious to forest and shade trees. US Department of Agriculture, Washington, D.C. 957 pp.

Pechuman, L. L. 1940. Notes on the feeding and breeding habits of *Saperda tridentata* Oliv. Bulletin of the Brooklyn Entomological Society 35: 113–116.

Petrice, T. R. and R. A. Haack. 2007. Can emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), emerge from logs two summers after infested trees are cut? The Great Lakes Entomologist. 40: 92–95.

Petrice, T. R., R. A. Haack, J. S. Strazanac, and J. P. Lelito, 2009. Biology and larval morphology of *Agrilus subcinctus* (Coleoptera: Buprestidae), with comparisons to the emerald ash borer, *Agrilus planipennis*. The Great Lakes Entomologist 42: 173–184.

Pucci, T. 2008. A comparison of the parasitic wasps (Hymenoptera) at elevated versus ground yellow pan traps in a beech-maple forest. Journal of Hymenoptera Research 17: 116–123.

Rassati, D., L. Marini, M. Marchioro, P. Rapuzzi, G. Magnani, R. Poloni, F. Di Giovanni, P. Mayo, and J. Sweeney. 2019. Developing trapping protocols for wood-boring beetles associated with broadleaf trees. Journal of Pest Science 92: 267–279.

Rowher, S. A. 1920. The North American ichneumon flies of the Tribes Labenini, Rhyssini, Xoridini, Odontomerini, and Phytodietini. Proceedings of the United States National Museum 57: 405–474.

Savely, H. E. 1939. Ecological relations of certain animals in dead pine and oak logs. Ecological Monographs 9: 321–385.

Shaddy, J. H, H. W. Ried, J. G. Truchan, D. A. Valek, and S. Ilnitzky. 1978. Dutch elm disease: biology and control of vectors in Michigan. Michigan State University, Agricultural Experiment Station, Research Report 354. 4 pp.

Sheehan, T. N., M. D. Ulyshen, S. Horn, and E. R. Hoebeke. 2019. Vertical and horizontal distribution of bark and woodboring beetles by feeding guild: is there an optimal trap location for detection? Journal of Pest Science 92: 237–241.

Solomon, J. D. 1995. Guide to insect borers in North American broadleaf trees and shrubs. US Department of Agriculture, Forest Service, Agriculture Handbook, AH-706. Washington, D.C. 735 pp.

Taylor, P. B., J. J. Duan, R. W. Fuester, M. Hoddle, and R. Van Driesche. 2012. Parasitoid guilds of *Agrilus* woodborers (Coleoptera: Buprestidae): their diversity and potential for use in biological control. Psyche 819329: 1–10. doi:10.1155/2012/813929

Townsend, C. H. T. 1886. Coleoptera found in dead trunks of *Tilia americana* L. in October. The Canadian Entomologist 18: 65–68.

Tucker, E. S. 1907. Concerning some insects collected and bred from dead and dying elm. Transactions of the Kansas Academy of Science 21: 158–162.

Ulyshen, M. D. 2011. Arthropod vertical stratification in temperate deciduous forests: implications for conservation-oriented management. Forest Ecology and Management 261: 1479–1489.

Wellso, S. G., G. V. Manley, and J. A. Jackman. 1976. Key and notes on the Buprestidae (Coleoptera) of Michigan. The Great Lakes Entomologist 9: 1–22.

Yanega, D. 1996. Field guide to northeastern longhorned beetles (Coleoptera: Cerambycidae). Illinois Natural History Survey Manual 6, Champaign. IL. 174 pp.