11

Cerambycid Pests in Forests and Urban Trees

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CONTENTS

11.1 Introduction

There are more than 36,000 species of Cerambycidae (Coleoptera) recognized worldwide (see Chapter 1), and they are found on all continents except Antarctica (Linsley 1959, 1961). Nearly all cerambycids are phytophagous, feeding primarily on woody plants, although some species do feed on herbaceous plants (see Chapter 3). Cerambycids develop in nearly all parts of woody plants, especially in roots, trunks, and branches, but occasionally also in seeds, pods, cones, and leaves. In addition, cerambycid larvae develop in nearly all major tissues in woody plants, including outer bark, inner bark, cambium, sapwood, heartwood, and pith (see Chapter 3).

Cerambycids utilize a wide diversity of woody plants as larval hosts, but certain plant families serve as hosts to many cerambycid species, while others are rarely used. For example, the number of cerambycid species that utilize various plant families as larval hosts is listed in Table 11.1 for four distinct world regions in the Northern Hemisphere where there is good knowledge of the larval hosts for most cerambycids: Montana, Fennoscandia, Israel, and Korea. (Fennoscandia refers to the countries of Norway, Sweden, Finland, and a small part of neighboring Russia.) The sources used to obtain the host data are listed in the footnotes for Table 11.1. Overall, 44 plant families were identified as larval hosts for the cerambycids of Montana, 23 for Fennoscandia and Denmark, 45 for Israel, and 44 for Korea (Table 11.1). Among the top 10 plant families in each of these world regions were five plant families that all regions had in common (Fagaceae, Pinaceae, Rosaceae, Salicaceae, and Ulmaceae), and an additional three families that were common to at least three of the four world regions (Betulaceae, Fabaceae, and Juglandaceae). Many of the species in these plant families are common trees that dominate the temperate forests in the Northern Hemisphere (Daubenmire 1978).

Cerambycids infest trees in a wide variety of host conditions (Haack and Slansky 1987; Mattson and Haack 1987; Hanks 1999). Some cerambycids infest living trees that vary in condition from healthy to stressed, including many species of *Anoplophora, Enaphalodes, Goes, Lamia, Megacyllene, Oberea, Oncideres, Plectrodera*, and *Saperda*. By contrast, many species of *Arhopalus, Ergates, Parandra*, and *Rhagium* commonly infest dead trees (Craighead 1923; Linsley 1959; Bílý and Mehl 1989; Solomon 1995). In addition, some dead-wood infesting species prefer moist wood (*Mallodon* and *Rhagium*), while others prefer dry wood (*Chlorophorus, Hylotrupes*, and *Stromatium*) (Craighead 1923; Duffy 1953; Linsley 1959; Bense 1995). Because of their requirements for specific host conditions, there is a succession of cerambycids and other wood borers that occur as a living tree first declines, then dies, and later decays (Blackman and Stage 1924; Graham 1925; Savely 1939; Haack et al. 1983; Khan 1985; Harmon et al. 1986; Hanula 1996; Saint-Germain et al. 2007; Lee et al. 2014). With respect to forestry, such host requirements reveal why some cerambycids are pests primarily of living trees, while

TABLE 11.1

Number of Cerambycid Species that Utilize Various Plant Families as Larval Hosts in Four World Regions, Ranked from Highest Number of Cerambycid Species to Lowest and Arranged Alphabetically for Families with the Same Number of Species*

Montana		Finland		Israel		Korea	
Family	**No.**	**Family**	**No.**	**Family**	**No.**	**Family**	**No.**
Pinaceae	69	Fagaceae	63	Fagaceae	34	Ulmaceae	49
Salicaceae	28	Pinaceae	57	Fabaceae	26	Fagaceae	46
Fagaceae	25	Betulaceae	52	Rosaceae	18	Pinaceae	45
Rosaceae	23	Salicaceae	42	Asteraceae	14	Betulaceae	42
Juglandaceae	15	Rosaceae	25	Moraceae	14	Rosaceae	37
Aceraceae	14	Tiliaceae	22	Anacardiaceae	13	Salicaceae	36
Ulmaceae	14	Ulmaceae	20	Ulmaceae	11	Juglandaceae	26
Anacardiaceae	11	Aceraceae	10	Pinaceae	10	Moraceae	23
Fabaceae	11	Juglandaceae	10	Rhamnaceae	10	Leguminosae	22
Betulaceae	10	Oleaceae	10	Salicaceae	10	Vitaceae	14
Vitaceae	10	Celastraceae	5	Boraginaceae	5	Rutaceae	13
Asteraceae	9	Caprifoliaceae	4	Aceraceae	4	Aceraceae	11
Cornaceae	9	Apiaceae	2	Juglandaceae	4	Euphorbiaceae	9
Magnoliaceae	7	Asteraceae	2	Myrtaceae	4	Taxodiaceae	8
Moraceae	7	Araliaceae	2	Rutaceae	4	Cornaceae	7
Caprifoliaceae	6	Rhamnaceae	2	Apiaceae	3	Ebenaceae	7
Celastraceae	5	Aquifoliaceae	1	Oleaceae	3	Oleaceae	7
Grossulariaceae	5	Cornaceae	1	Poaceae	3	Tiliaceae	7
Oleaceae	5	Cupressaceae	1	Arecaceae	2	Araliaceae	6
Tiliaceae	5	Fabaceae	1	Betulaceae	2	Cupressaceae	6
Hamamelidaceae	4	Geraniaceae	1	Brassicaceae	2	Lauraceae	6
Rutaceae	4	Hippocastanaceae	1	Cupressaceae	2	Scrophulariaceae	5
Cupressaceae	3	Moraceae	1	Dipsacaceae	2	Compositae	3
Ericaceae	3	–	–	Euphorbiaceae	2	Gramineae	3
Lauraceae	3	–	–	Labiatae	2	Actinidiaceae	2
Poaceae	3	–	–	Platanaceae	2	Anacardiaceae	2
Asclepiadaceae	2	–	–	Apocynaceae	1	Caprifoliaceae	2
Ebenaceae	2	–	–	Asphodeloideae	1	Elaeagnaceae	2
Hippocastanaceae	2	–	–	Campanulaceae	1	Lythraceae	2
Myrtaceae	2	–	–	Casuarinaceae	1	Meliaceae	2
Scrophulariaceae	2	–	–	Celastraceae	1	Platanaceae	2
Aquifoliaceae	1	–	–	Cornaceae	1	Punicaceae	2
Cactaceae	1	–	–	Cucurbitaceae	1	Rhamnaceae	2
Caryophyllaceae	1	–	–	Elaeagnaceae	1	Styracaceae	2
Elaeagnaceae	1	–	–	Lamiaceae	1	Cannabaceae	1
Euphorbiaceae	1	–	–	Lauraceae	1	Casuarinaceae	1
Malvaceae	1	–	–	Malvaceae	1	Cucurbitaceae	1
Menispermaceae	1	–	–	Meliaceae	1	Daphniphyllaceae	1
Platanaceae	1	–	–	Ranunculaceae	1	Ginkgoaceae	1
Polygonaceae	1	–	–	Sapindaceae	1	Malvaceae	1
Ranunculaceae	1	–	–	Scrophulariaceae	1	Myrtaceae	1
Rhamnaceae	1	–	–	Styracaceae	1	Simaroubaceae	1
Smilacaceae	1	–	–	Tamaricaceae	1	Sterculiaceae	1
Solanaceae	1	–	–	Valerianaceae	1	Urticaceae	1
Unknown	17	–	–	Vitaceae	1	–	–
Total cerambycid species	152		123		104		181

* The information for the cerambycids of Montana was based on Hart et al. (2013) and the accompanying online database http://www.mtent.org/Cerambycidae.html (accessed December 30, 2015), and supplemented as needed with host data from Linsley (1962a, 1962b, 1963, 1964) and Linsley and Chemsak (1972, 1976, 1984, 1995). Similarly, Bílý and Mehl (1989) was the source of the host data for Fennoscandia and Denmark, Sama et al. (2010) for Israel, and Lim et al. (2014) for Korea. These references listed host plants for 89% of the cerambycid species from Montana, 100% for Fennoscandia, 91% for Israel, and 57% for Korea.

others are mostly pests of stressed or recently felled trees or logs, and still others are pests of lumber and wood products.

Although only a small percentage of the world's cerambycids are considered economic pests, there are nevertheless several species that are well-recognized as pests of forest and urban trees as well as wood products. The cerambycids selected for discussion in this chapter represent just a few of the many species reported as economic tree pests worldwide. Their selection was based primarily on a review of forest entomology textbooks, regional cerambycid guides, and major reviews from several world regions. For example, Duffy (1957), Roberts (1969), Wagner et al. (1991), Akanbi and Ashiru (2002), and Schabel (2006) were reviewed for Africa; Zhuravlev and Osmolovskii (1964), Duffy (1968), Gressitt et al. (1970), Rozhkov (1970), Cherepanov (1988a, 1988b, 1990), Xiao (1992), and Shin et al. (2008) for Asia; Froggatt (1923), Duffy (1963), and Elliot et al. (1998) for Australasia; Duffy (1953), Novák (1976), Bílý and Mehl (1989), and Bense (1995) for Europe; Duffy (1960) and Rivas (1992) for Central and South America; Craighead (1923, 1950), Linsley (1962a, 1962b, 1963, 1964), Linsley and Chemsak (1972, 1976, 1984, 1995), Furniss and Carolin (1977), Drooz (1985), Cibrián Tovar et al. (1995), and Solomon (1995) for North America including Mexico; and Browne (1968), Gray (1972), Nair (2007), and Wylie and Speight (2012) for the tropics in general.

For each of the species listed here, details are presented on the insect's native and introduced geographic range, larval hosts, adult size and general appearance, life history, and economic impact. The 43 selected species illustrate the wide range of life-history strategies found among tree-infesting cerambycids throughout the world. The species are listed alphabetically by subfamily, including 28 species of Cerambycinae, 10 Lamiinae, 1 Parandrinae, 2 Prioninae, and 2 Spondylidinae. Geographically, of the 43 treated species, 6 are native primarily to Africa, 11 to Asia, 7 to Australia and nearby areas, 5 to Eurasia, 1 to Europe, 11 to North America, and 2 to South and Central America. In addition, there are several cerambycids that are forest pests but that will be discussed in Chapter 12 as pests of agricultural and horticultural crops, including 2 Cerambycinae: *Aromia bungii* (Faldermann) and *Strongylurus thoracicus* (Pascoe), and 11 Lamiinae: *Analeptes trifasciata* (Fabricius), *Anoplophora chinensis* (Forster), *Apriona germari* (Hope), *Bacchisa atritarsis* (Pic), *Batocera horsfieldi* (Hope), *Batocera lineolata* Chevrolat, *Batocera rufomaculata* (DeGeer), *Celosterna scabrator* (Fabricius), *Oncideres cingulata* (Say), *Plagiohammus spinipennis* (Thomson), and *Saperda candida* Fabricius. Relatively few details are provided on control options in this chapter given that they can vary widely from country to country and over time. Readers with an interest in this topic are directed to the references listed in this chapter as well as to Chapter 8 for a discussion of biological control options, Chapter 9 for cultural control options, Chapter 10 for chemical control options, and Chapter 13 for phytosanitary options.

11.2 Cerambycinae

11.2.1 *Anelaphus parallelus* (Newman)

Anelaphus parallelus is native to eastern North America, including both Canada and the United States. This species often has been confused with *Anelaphus villosus* (Fabricius), another North American twig pruner, and therefore caution must be used when reading the literature (Gosling 1981). *Quercus* is the principal host genus, but occasionally *Carya* and *Juglans* serve as larval hosts (Gosling 1981; Haack 2012). Adults are 10–15 mm long and generally brown in color with lighter-colored patches (Linsley 1963; Figure 11.1).

The typical life cycle is completed in two years and is highly synchronous with adults emerging primarily in odd-numbered years (Gosling 1978; Haack 2012; Figure 2.11 in this book). Eggs usually are laid singly on small twigs. After eclosion, the larva enters the twig, feeds on the wood, and tunnels to the node of the adjoining larger branch during the first summer (Gosling 1981). In the second summer, the larva extends the gallery in the direction of the trunk, feeding in the center of the branch. Eventually, the larva consumes a disc of wood, leaving only the bark intact, and then plugs its gallery with wood fibers. The "pruned" branch eventually breaks where the disc of wood was eaten and falls to

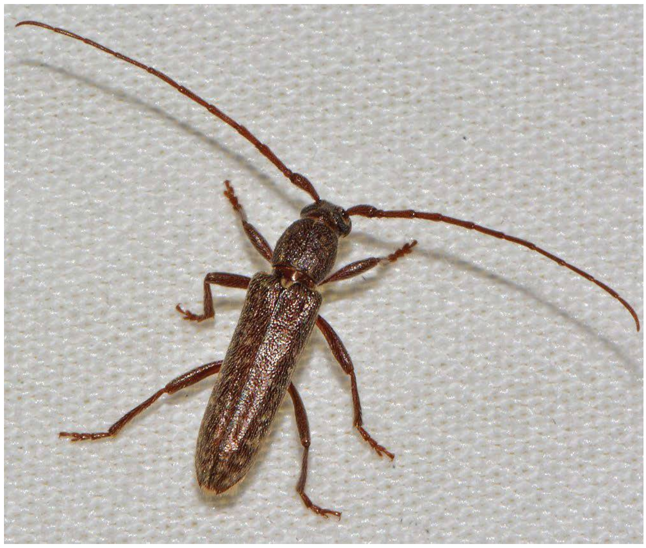

FIGURE 11.1 *Anelaphus parallelus* adult from Missouri (United States). (Courtesy of Jack Foreman at bugguide.net.)

the ground with the larva inside. The larva pupates inside the fallen branch in late summer of the second season, overwinters as a pupa, and emerges as an adult the following spring (Gosling 1978).

Larval damage becomes noticeable as the fallen branches accumulate under infested trees (Gosling 1978; Haack 2012). Although the pruned branches often are a concern to homeowners and park managers, this level of damage is seldom detrimental to trees (Solomon 1995). Control efforts usually are aimed at gathering infested branches from the ground and destroying them by burning or chipping (Solomon 1995; see Chapter 9).

11.2.2 *Callichroma velutinum* (Fabricius)

Callichroma velutinum is native to northern South America (Bolivia, Brazil, French Guiana, Guyana, Peru, and Suriname) and the West Indies (Trinidad) (Duffy 1960; Monné et al. 2012; Bezark 2015a, 2015b). The principal host trees include species of *Achras, Manilkara*, and *Pouteria* (Duffy 1960; Tavakilian et al. 1997). Adults measure 24–42 mm in length and have elytra that are metallic bluish green or violet in color, with two darker longitudinal bands (Duffy 1960; Figure 11.2). The antennae are about twice the body length in males but about the same length as the body in females.

The time needed to complete one generation appears to be less than a year. According to Duffy (1960), adults are active from mid-morning to mid-afternoon. Eggs are laid singly on the bark surface within crevices. After eclosion, larvae tunnel through the bark and feed initially in the cambial region, with late instars tunneling in the sapwood and eventually the heartwood.

In Trinidad, Duffy (1960) reported that stumps and recently cut logs of *Manilkara* are quickly colonized by *C. velutinum*. At times, infestations can be so high that the wood becomes unsuitable for use as lumber or railway ties (Duffy 1960; Gray 1972). Control efforts should be aimed at quickly utilizing newly felled trees to minimize oviposition and early larval development (Duffy 1960).

11.2.3 *Callidiellum rufipenne* (Motschulsky)

Callidiellum rufipenne is native to Asia, occurring in China, Japan, Korea, the Russian Far East, and Taiwan (Duffy 1968; Danilevsky 2015; EPPO 2015). In addition, by the end of 2015, established populations of *C. rufipenne* had been reported in Europe (Belgium, Croatia, France, Italy, and Spain; Campadelli and Sama 1989; Bahillo and Iturrondobeitia 1995; Cocquempot and Lindelöw 2010; Loś and Plewa 2011; Van Meer and Cocquempot 2013; Drumont et al. 2014), North America

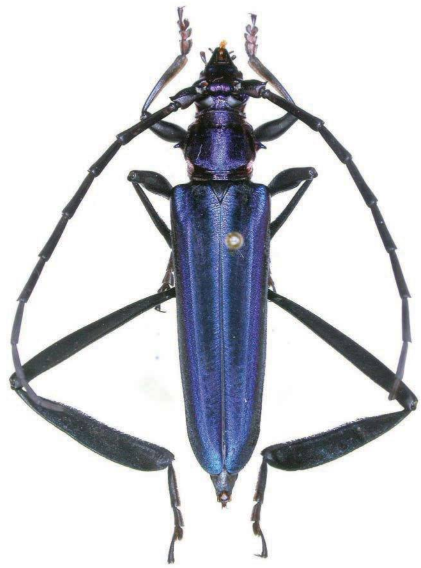

FIGURE 11.2 *Callichroma velutinum* adult from French Guiana. (Courtesy of Daniel Prunier at insecterra.forumactif.com.)

FIGURE 11.3 *Callidiellum rufipenne* adult male from Caucasus, Russia. (Courtesy of Maxim Smirnov at www.zin.ru\Animalia\Coleoptera.)

(United States; Maier and Lemmon 2000; Maier 2007), and South America (Argentina; Turienzo 2006). The principal host genera are conifers in the family Cupressaceae (which now contains genera of the former family Taxodiaceae), including *Chamaecyparis, Cryptomeria, Cupressus, Juniperus*, and *Thuja*. In Asia, the Pinaceae genera *Abies* and *Pinus* are also listed as occasional hosts (Duffy 1968); however, in North America, no Pinaceae have yet been documented as hosts (Maier 2007). Adults measure 6–13 mm in length, with males usually being blackish-blue in color and females being reddish-brown (Hoebeke 1999; Humphreys and Allen 2000; Maier and Lemmon 2000; Figure 11.3).

Callidiellum rufipenne is univoltine. Adults emerge in spring, mate on the bark surface of host trees, and soon begin to oviposit in bark cracks and crevices. Adults apparently do not feed, and typically live for two to three weeks. Eggs hatch in about two weeks and larvae immediately tunnel through the bark and feed in the cambial region, packing their galleries with frass. Mature larvae enter the wood in late summer and construct a cell at the end of their galleries in which they pupate. Pupation occurs in autumn, with adults overwintering within the hosts and emerging through oval-shaped exit holes the following spring (Shibata 1994; Hoebeke 1999; Humphreys and Allen 2000; Maier and Lemmon 2000).

Callidiellum rufipenne generally is considered a secondary pest, primarily infesting weakened or recently dead trees (Shibata 1994). However, in the eastern United States, *C. rufipenne* occasionally has infested living *Chamaecyparis, Juniperus*, and *Thuja* trees and shrubs (Maier and Lemmon 2000; Maier 2007). Heavy infestations of live hosts can result in tree or branch death, but more typically economic impact results from lowering the quality of the wood due to larval feeding. Given its life history traits, *C. rufipenne* can easily move in barked logs, wood packaging material, cut branches, and live plants. Therefore, depending on the product being considered, control options should include insecticidal treatment, inspection, and certification programs for nursery stock, as well as rapid utilization, debarking, and proper heat treatment or fumigation of logs and wood products.

11.2.4 *Chlorophorus carinatus* Aurivillius

Chlorophorus carinatus is native to East Africa, including Kenya, Tanzania, and Uganda (Browne 1968). Both hardwoods (*Acacia, Allophylus, Coffea, Dombeya, Eucalyptus, Fagaropsis, Hagenia, Laguniaria, Premna*, and *Theobroma*) and conifers (*Cupressus, Juniperus, Pinus*, and *Podocarpus*) have been reported as larval hosts (Duffy 1957; Schabel 2006). Tavakilian and Chevillotte (2013) give the length of one adult specimen as 15 mm. Adults are blackish in color with a pattern of gray transverse stripes.

Generation time can be as short as six months (Gardner 1957; Schabel 2006). Adults typically lay eggs on stressed and dying trees as well as on recently cut logs and stumps. Eggs are laid in bark crevices and, after eclosion, the larvae develop primarily in the cambial region. Frass is packed tightly in the larval galleries. Mature larvae enter the sapwood to pupate.

Most damage caused by *C. carinatus* larvae is restricted to the sapwood surface; however, the pupal cells are constructed deeper in the sapwood. In addition, *C. carinatus* will oviposit near bark wounds on apparently healthy *Cupressus* trees, with the resulting larvae tunneling deeper in the sapwood (Browne 1968; Schabel 2006). Given that early larval development occurs primarily in the cambial region, control efforts should focus on rapid utilization and debarking of recently felled trees.

11.2.5 *Citriphaga mixta* Lea

Citriphaga mixta is native to Australia, being first reported in New South Wales where it infests *Citrus* (= *Eremocitrus*) *glauca* (Lindl.) Burkill (desert lime), which is a thorny shrub or small tree native to semiarid areas of Australia (Froggatt 1923; Hawkeswood 1993). Adults are 2–3 cm long, dark brown in color, with white spots on the elytra (Froggatt 1919, 1923).

The life cycle is completed in about a year, with larval development spanning about 10 months and the pupal period taking about four to six weeks (Froggatt 1919, 1923). Eggs are laid on the bark of the trunk near the ground. Larvae tunnel into the wood and upward near the center of the stem for 1–1.5 m. When multiple larvae develop within the same stem, the wood will be riddled with galleries.

Larval tunneling can lead to breakage of branches and stems. In addition, infested trees respond to the larval feeding by secreting gum-like compounds into the wood surrounding the galleries (Froggatt 1923). Given the beetle's life history traits, individual trees, especially ornamentals, would likely require protection of the lower trunk with insecticides or some device to exclude ovipositing adults.

11.2.6 *Cordylomera spinicornis* (Fabricius)

Cordylomera spinicornis is native to Africa, being reported from many countries such as Angola, Benin, Cameroon, Central African Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Liberia, Malawi, Mozambique, Niger, Nigeria, Republic of Congo, Senegal, Sierra Leone, Sudan, Tanzania, Togo, Uganda, and Zaire (Duffy 1957, 1980; GBIF 2014). Although *C. spinicornis* apparently has not yet become established outside of Africa, adults have commonly been intercepted in foreign countries, especially on imported logs (O'Connor and Nash 1984; Cocquempot and Mifsud 2013; Rassati et al. 2015). Throughout its native range, *C. spinicornis* primarily infests species in the family Meliaceae such as *Entandrophragma, Guarea, Khaya, Lovoa, Trichilia*, and *Turraeanthus.* In addition, trees in the genera *Acacia, Baphia, Celtis, Funtumia, Guarea, Lasiodiscus, Teclea*, and *Theobroma* have been infested in Africa (Duffy 1957, 1980; Roberts 1969; Wagner et al. 1991). Adults measure 13–25 mm in length and have a metallic coloration that can be various shades of green, blue, and bronze (Duffy 1957; Figure 11.4).

The generation time of *C. spinicornis* has not been reported. Adults typically emerge during the dry season, November to February, and lay eggs on the bark of living host trees and recently cut logs (Roberts 1969). Multiple eggs are laid together in bark crevices. Larvae tunnel primarily in the cambial region, entering the sapwood usually no more than 5 cm to pupate (Duffy 1957).

Cordylomera spinicornis has been reported as a pest of street trees, forest trees, and recently cut logs (Duffy 1957; Roberts 1969; Wagner et al. 1991). Populations can reach high levels in timber yards where logs are sorted and stored (Duffy 1957; Roberts 1969). Although infestation levels can be high, most damage is restricted to the outer 5 cm of the logs (Duffy 1957). Control efforts should focus on rapid debarking and utilization of logs as well as on destruction of logging residue, which also can harbor larvae (Duffy 1957).

11.2.7 *Diotimana undulata* (Pascoe)

Diotimana undulata is native to the Oceania area, including Australia and Papua New Guinea (Duffy 1963; Gray 1968). Note that in Duffy (1963), the species name was spelled as *Diotimana undata*, and a few other authors have followed this spelling. The principal hosts are coniferous species in the genus *Araucaria* (Froggatt 1925; Duffy 1963; Gray 1968); but occasionally species of *Cryptomeria* and *Pinus*, both of which were introduced to Australia, have also been infested by *D. undulata*

FIGURE 11.4 *Cordylomera spinicornis* adult collected at the port of Ravenna, Italy. (Courtesy of Paolo Paolucci and reported in Rassati et al. (2015).)

(Hawkeswood 1993). Adults average about 20 mm long and have a brown–gray vertical pattern on the elytra (Froggatt 1925, 1927).

There appears to be one generation per year. Eggs are laid on the bark surface in crevices. Early instar larvae tunnel primarily in the cambial region, while late instars tunnel into the wood for several centimeters and construct individual pupal cells.

Adults typically oviposit on storm-damaged trees as well as on recently dead trees or cut trunks, branches, and stumps (Froggatt 1925, 1927; Hawkeswood 1993). In Papua New Guinea, however, *D. undulata* was reported to infest living *Araucaria* trees and occasionally cause tree mortality (Gray 1968), but a later report by Gray and Wylie (1974) noted that damage by this beetle to living trees had never become widespread. Control options may require chemical treatment when live trees are at risk, but most efforts should focus on rapid utilization of felled trees.

11.2.8 *Eburia quadrigeminata* (Say)

Eburia quadrigeminata is native to eastern North America and may also occur on some Caribbean islands (Bezark 2015a, 2015b). A large number of hardwood trees serve as larval hosts, including species of *Acer, Carya, Castanea, Fagus, Fraxinus, Gleditsia, Prunus, Robinia, Quercus*, and *Ulmus* (Linsley 1962b). There are a few reports of *E. quadrigeminata* infesting the conifer bald cypress [*Taxodium distichum* (L.) Rich.]; however, this could have resulted from confusion with *Eburia distincta* Haldeman, a species that regularly uses *T. distichum* as a larval host in the southeastern United States (Thomas 1999). Adults are 14–24 mm long and light brown in color, and on each elytron, there are two pairs of longitudinal, ivory-colored spots with one pair located at the base of each elytron and the other near the center (Baker 1972; Figure 11.5).

The typical life cycle is considered to be two years (Baker 1972). Adults emerge during summer and are mostly nocturnal. Eggs often are laid near wounds on trees where the wood is exposed (Craighead 1923). Larvae tunnel primarily in the heartwood, showing a preference for dry, solid wood. The galleries are tightly packed with frass.

The larval galleries of *E. quadrigeminata* result in great economic loss because they are relatively large and penetrate to the heartwood. In addition, this species has the ability to complete development in finished wood products, often many years after manufacture. For example, *E. quadrigeminata* adults were reported to have emerged from flooring at least 14 years after manufacture (Webster 1889) and

FIGURE 11.5 *Eburia quadrigeminata* adult from Illinois (United States). (Courtesy of Tony Gerard at www.inaturalist.org.)

similarly at least 19 years after construction of a doorsill (McNeil 1886) and a wardrobe (Hickin 1951), at least 20 years after construction of a bedstead (Troop 1915), and at least 40 years after construction of a bookcase (Jaques 1918). Given this ability for protracted development, it is not surprising that *E. quadrigeminata* has emerged from furniture constructed in the United States and shipped to other countries such as Argentina (Di Iorio 2004b) and the United Kingdom (Hickin 1951). With respect to control options, damage to the lower trunk of residual trees should be minimized to reduce future infestations, while infested lumber can be fumigated or simply replaced, if possible (Craighead 1950).

11.2.9 *Enaphalodes rufulus* (Haldeman)

Enaphalodes rufulus is native to eastern North America. Oaks (*Quercus*) in both the white oak group and red oak group are infested by *E. rufulus* (Donley and Acciavatti 1980). Adults measure 23–33 mm in length and are brown in color with a mottled appearance (Solomon 1995; Figure 11.6).

The life cycle of *E. rufulus* is completed in two years and is highly synchronous with adults emerging primarily in odd-numbered years (Donley and Acciavatti 1980). Adults are active during the summer months and are mostly nocturnal. Females lay eggs in bark cracks as well as under lichen and vines that are attached to the host trees. On average, females lay 119 eggs during their lifetime (Donley 1978a). Larvae tunnel primarily in the cambial region during their first year of development; during the second year, they eventually tunnel into the sapwood and heartwood and construct individual pupal cells. Larvae pupate the following spring, with the adults emerging through oval-shaped exit holes (Donley and Acciavatti 1980).

Given that *E. rufulus* oviposits primarily along the lower trunk, which is where the highest quality wood occurs, considerable economic damage can result from the larval galleries (Donley and Rast 1984). Fortunately, populations of *E. rufulus* tend to be low, but in recent decades a major outbreak of *E. rufulus* occurred in the central United States (Stephen et al. 2001). For example, prior to the recent outbreak, Hay (1974) considered even one exit hole per tree to be high. By contrast, during the recent outbreak in the central United States, Riggins et al. (2009) estimated that populations peaked at 174 adults emerging

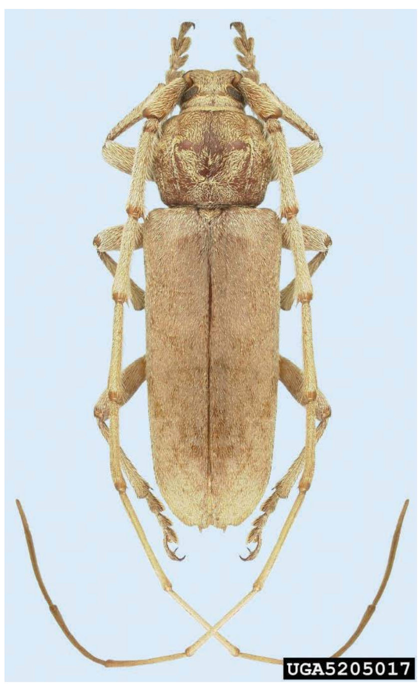

FIGURE 11.6 *Enaphalodes rufulus* adult from Illinois (United States). (Courtesy of Natasha Wright [Bugwood image 5205017].)

per tree for the cohort that emerged in 2001. In forest stands, there often are a few heavily infested trees referred to as "brood" trees. Forest managers should remove brood trees and thereby lower the local borer population (Solomon 1995).

11.2.10 *Glycobius speciosus* (Say)

Glycobius speciosus is native to eastern North America, being found throughout the range of its only known host *Acer saccharum* Marshall (Solomon 1995). Adults measure 22–27 mm in length and are black and yellow in color, having a wasp-like appearance. Some of the key characteristics used to identify the adults include a yellow head and yellow legs, a yellow-banding pattern in the design of a "W" across the elytra near the pronotum, and a black dot near the tip of each elytron (MacAloney 1968; Hoffard and Marshall 1978; Figure 11.7).

The typical life cycle of *G. speciosus* is completed in two years (MacAloney 1968; Hoffard and Marshall 1978; Solomon 1995). Adults are active in summer, laying eggs in bark crevices, under bark scales, and near wounds. Oviposition occurs primarily along the main trunk, usually below 10 m. During the first summer, larvae tunnel primarily in the cambial region and then enter the sapwood a short distance to overwinter. During the second summer, the larvae continue to tunnel in the cambial region at first and then enter the sapwood, tunneling upward for several centimeters. Larvae typically expel frass from their galleries. The larva overwinters at the end of the gallery, which is enlarged into a pupal cell. In spring, before pupating, the larva extends its gallery to near the bark surface to create a tunnel that it will use to exit once an adult. Once the exit tunnel is complete, the larva moves back to the pupal cell, pupates, and then emerges as an adult through an oval-shaped exit hole.

Tree mortality seldom occurs as a result of *G. speciosus* infestation, although individual branch death and crown thinning can occur (Solomon 1995). Most economic losses result from the defects caused by the larval tunnels in the wood of the lower trunk. Besides the actual galleries, the nearby wood often has a twisted grain pattern and can show signs of decay and discoloration (MacAloney 1968; Shigo et al. 1973; Hesterberg et al. 1976; Hoffard and Marshall 1978). Bark ridges often form over the larval galleries that were created in the cambial region, and at times the bark sloughs off, exposing the underlying sapwood and old larval galleries (Hoffard and Marshall 1978). Silvicultural methods are the main control option used for *G. speciosus* in forest stands, including removal of large, low-vigor trees—especially those currently infested (Hoffard and Marshall 1978; Solomon 1995). Insecticidal control is an option for high-value *Acer* trees, such as ornamentals or veneer-quality trees (Solomon 1995).

FIGURE 11.7 *Glycobius speciosus* adult from Canada. (Courtesy of David Cheung at www.dkbdigitaldesigns.com.)

11.2.11 *Hesthesis cingulata* (Kirby)

Hesthesis cingulata is native to Australia, including Tasmania, where it infests various species of *Eucalyptus* (Moore 1966; Elliott and de Little 1984; Elliott et al. 1998). Adults average about 25 mm in length, are wasp-like in appearance with reduced elytra and black coloration, and have one to three white to yellow transverse bands on the abdomen (Elliott et al. 1998).

Hesthesis cingulata is univoltine. Adults are active during summer, with eggs deposited on the lower stem of young eucalypts. Typically, one egg is laid per stem, usually within 5–20 cm of the soil, near the junction of a shoot and the main stem (Moore 1966). Early larval instars tunnel downward in a spiral fashion primarily within the cambial region. Older instars tunnel deeper into the sapwood near the ground but leave a column of woody tissue in the center that supports the stem upright. In response to this feeding, the lower stem becomes swollen and gall-like. The larva ejects frass from holes it makes in the stem (Moore 1966). The larva continues to tunnel downward into the taproot where it later reverses its position and overwinters. Pupation takes place the following spring with the new adults emerging through the stem wall above ground level (Moore 1966).

Hesthesis cingulata usually infests young trees that are 0.5–2.0 m tall (Elliott et al. 1998). Infestation levels vary from plantation to plantation. Infested trees often die as a result of the larval tunneling, although some trees survive, developing new shoots from the base (Moore 1966). Considering that females oviposit on the lower trunk of young trees, protection of the lower trunk by means of pesticides or exclusion techniques may be warranted at times.

11.2.12 *Hoplocerambyx spinicornis* Newman

Hoplocerambyx spinicornis is a widespread Asian species, being found from Afghanistan, Pakistan, India, and Nepal eastward to Borneo, Indonesia, New Guinea, and the Philippine Islands (Duffy 1968). It is a major pest of several tree genera in the family Dipterocarpaceae, including *Anisoptera, Dipterocarpus, Hopea, Parashorea, Pentacme*, and *Shorea*, as well as genera in other families such as *Duabanga* and *Hevea* (Duffy 1968). Adult *H. spinicornis* vary greatly in size from 20 to 65 mm in length and vary in color from reddish brown to brownish black with some gray pubescence (Duffy 1968; Figure 11.8).

FIGURE 11.8 *Hoplocerambyx spinicornis* adult from Vietnam. (Courtesy of Udo Schmidt at www.kaefer-der-welt.com.)

Hoplocerambyx spinicornis is univoltine, with adult emergence occurring during the early monsoon season in June and July (Beeson and Bhatia 1939). Adults are active during the day, feeding on sap and inner bark of their host trees. Adults are strongly attracted to the odors associated with newly felled *Shorea* trees and will fly distances of 1–2 km (Duffy 1968; Singh and Misra 1981). Adults live for about a month, with oviposition beginning about a week after mating. Eggs are laid individually along the trunk and major branches, usually in bark cracks and crevices or in holes or cuts along the bark. Females often lay 100–300 eggs in their lifetime, with the maximum number recorded being 468 eggs (Duffy 1968; Nair 2007). Larvae initially feed in the cambial region, while older instars tunnel in the sapwood and heartwood. Frass is pushed out of the galleries and accumulates around the tree. Mortality of early larval instars can be high, especially when tunneling in vigorous hosts that often exude large amounts of sap in response to the larval feeding. By contrast, survival is relatively high in drought-stressed trees, apparently because of reduced sap flow (Negi and Joshi 2009). In November, in India, the mature larva will construct an exit hole that it will use as an adult the following year; then, it returns to the end of its gallery in the heartwood and seals itself inside by secreting a calcareous solution to plug the gallery. Pupation occurs the next year, usually in April and May, with the adult remaining quiescent until the onset of the monsoon season (Duffy 1968; Nair 2007).

Typically, *H. spinicornis* infests trees that are stressed by drought, defoliation, or disease, or trees that have recently died or were cut. Adults oviposit preferentially on large, mature trees, but during outbreaks smaller trees down to 30 cm in diameter are infested. Both the trunk and major branches are infested. Larval galleries can greatly reduce wood quality because they can be numerous and can extend deep into the heartwood. Tree mortality can occur during outbreaks as a result of high larval densities (over 300 larvae per tree) and the extensive tunneling that effectively girdles the infested trees (Nair 2007). Major outbreaks of *H. spinicornis* have been recorded in India and Pakistan for more than a century, with *Shorea robusta* Roth being the principal host (Beeson and Bhatia 1939; Nair 2007). In India, some *H. spinicornis* outbreaks during the 1900s covered thousands of hectares and resulted in millions of trees killed (Nair 2007). In India and Pakistan, where major outbreaks regularly occur, several integrated control measures have been developed, including monitoring infestation levels in individual stands, selective cutting and removal of infested trees, debarking of trees that cannot be removed promptly, protecting logs in mill yards with cover sprays or tarps, and using trap logs to attract and kill adult beetles (Beeson 1941; Nair 2007).

11.2.13 *Hylotrupes bajulus* (L.)

Hylotrupes bajulus is native to Europe and North Africa but has been introduced to many other countries around the world, including Argentina, Australia, Brazil, China, Madagascar, South Africa, Uruguay, and the United States (Duffy 1968; Di Iorio 2004b). In Australia, efforts were undertaken to eradicate *H. bajulus* (French 1969; Eldridgea and Simpson 1987). Reports that *H. bajulus* occurs in New Zealand are incorrect (Bain 2009). *H. bajulus* primarily infests seasoned coniferous wood, especially *Pinus*, but also *Abies*, *Picea*, and *Pseudotsuga* (Duffy 1953, 1968; Bense 1995). In addition, there have been occasional reports of *H. bajulus* infesting hardwoods in the genera *Acacia, Alnus, Corylus, Juglans, Populus, Quercus*, and *Tamarix* (Duffy 1968). Adults measure 7–21 mm in length and vary in color from reddish brown to brownish black; they have two conspicuous tubercles on the pronotum and have one or two whitish bands or spots on each elytron (Duffy 1968; Baker 1972; Bense 1995; Figure 11.9).

The life cycle of *H. bajulus* can be completed in as short as two to three years, but in seasoned wood that is low in moisture, the larval developmental period can be greatly protracted (Bense 1995). For example, Baker (1972) suggested generation times of three to eight years for *H. bajulus* developing inside structures in the United States, and in one case in the United Kingdom, Bayford (1938) reported the occurrence of *H. bajulus* in *Pinus* furniture that had been manufactured (and apparently infested) at least 17 years earlier.

Adults emerge primarily in the summer months under natural conditions (Bense 1995). Eggs are laid in groups in cracks and crevices in the wood or between pieces of wood that are stacked (Baker 1972). Females typically lay 30–100 eggs in their lifetime, but some females have laid as many as

FIGURE 11.9 *Hylotrupes bajulus* adult female from Spain. (Courtesy of Udo Schmidt at www.kaefer-der-welt.com.)

200–400 eggs (Duffy 1953, 1968). Larvae feed primarily in the sapwood, packing their galleries with fine powdery frass. The larvae seldom break through the surface of the wood when tunneling; thus the frass is concealed within the infested timbers. The sounds produced as the larvae feed usually are audible to the homeowner. Mature larvae tunnel near to the surface of wood and then prepare to pupate deeper in the wood. The pupal period can be as short as two to three weeks. New adults emerge through an oval-shaped exit hole.

Although originally a forest insect, infesting dead branches tree stumps, *H. bajulus* is now primarily a domestic pest of structural timbers (Duffy 1968; Baker 1972; Robinson and Cannon 1979). Heavy infestations of homes and buildings can result in serious damage to roofing, framing, and flooring timbers, as well as to furniture. To remedy such infestations, homeowners often incur high costs for repair and, at times, fumigation. Because of their ability to infest dry wood and their long developmental time, *H. bajulus* has been spread to many countries around the world in infested timber, wood products, and solid wood packaging material.

11.2.14 *Megacyllene robiniae* (Forster)

Megacyllene robiniae is native to the eastern and central United States but has spread to Canada and the southern and western United States with the widespread planting of its only host *Robinia pseudoacacia* L. (Galford 1984). Adults measure 12–19 mm in length and are black in color with transverse yellow bands across the pronotum and elytra (Solomon 1995; Figure 11.10).

Megacyllene robiniae is univoltine, with adults being most active during late summer, when they are observed on host trees or when feeding on pollen of goldenrod (*Solidago*) flowers (Galford 1984). Eggs are laid singly in bark cracks and crevices and around pruning wounds and callus tissue. Oviposition occurs primarily along the trunk and the lower portion of major branches (Harman and Harman 1990). In about a week, the eggs hatch and the new larvae enter the inner bark, construct a small cell, and prepare to overwinter. In spring, the larvae first tunnel into the sapwood; then in summer, they move deeper into the heartwood. The larvae push frass out of their galleries, which tends to be white in color when the

FIGURE 11.10 *Megacyllene robiniae* adult from the United States. (Courtesy of Clemson University–USDA Cooperative Extension Slide Series [Bugwood image 1235175].)

larvae are tunneling in sapwood and yellow when tunneling in heartwood. Prior to pupation, the larva constructs a small tunnel that it will use to exit when an adult. Pupation occurs in late summer and lasts about two weeks. Adults emerge through oval-shaped exit holes (Solomon 1995).

Heavy infestations can weaken trees and lead to trunk and branch breakage. Individual trees can be infested for a number of years before stem breakage occurs; therefore, such trees can serve as hosts to several generations of the borer. Swelling often occurs along the infested portions of the trunk. Adults initially oviposit preferentially on stressed trees—but when populations are high, even dominant, apparently healthy trees can be infested (Galford 1984). Trees weakened by drought, fire, and soil compaction are especially prone to *M. robiniae* infestation (Galford 1984; Solomon 1995). Silvicultural control options include removal of heavily infested trees or, when several infested trees are removed, stump sprouting should be encouraged followed by selection of the most vigorous sprouts. Some *Robinia* selections have shown resistance to *M. robiniae*. Insecticidal sprays are at times warranted and are most effective when applied during the oviposition period in late summer (Galford 1984; Solomon 1995).

11.2.15 *Neoclosterus boppei* Quentin & Villiers

Neoclosterus boppei is native to countries in both East and West Africa, including Guinea, Nigeria, the Republic of the Congo, Sierra Leone, and Tanzania (Roberts 1969; Duffy 1980; Schabel 2006). The common host trees include species of *Brachystegia, Ficus*, and *Isoberlinia* (Schabel 2006). Adults vary in length from 34 to 58 mm, are dark brown to reddish in color, have pectinate (comb-like) antennae, and have stout lateral spines on the pronotum (Quentin and Villiers 1969; Duffy 1980; Figure 11.11).

Details on voltinism have not been reported. Eggs are laid singly on the bark of branches and trunks of living host trees (Roberts 1969). At first, larvae tunnel vertically within the sapwood and eventually enter the heartwood. The larvae expel frass from several sites along their galleries, which accumulates on the forest floor. In addition to frass, large amounts of tree-produced sap also flow from the same holes where the frass is ejected (Roberts 1969; Schabel 2006). Before pupating, larvae construct a tunnel from which to exit once transformed to adults. Pupation occurs in the heartwood at the end of the gallery in a cell lined with wood fibers (Roberts 1969).

FIGURE 11.11 *Neoclosterus boppei* adult from the Democratic Republic of the Congo. (Courtesy of Thierry Bouyer.)

Infestation by *N. boppei* often leads to death of individual branches and stem sections. Recently cut logs can also be infested (Roberts 1969). The larval galleries, which penetrate into the heartwood, lower wood quality. Rapid utilization of logs should help minimize oviposition and larval tunneling.

11.2.16 *Neoclytus acuminatus* (Fabricius)

Neoclytus acuminatus is native to North America, including both Canada and the United States. In addition, *N. acuminatus* has been established in Europe since the early 1900s, being first reported in Italy in 1908 and later spreading to several European countries including the Czech Republic, Croatia, France, Germany, Hungary, Montenegro, Portugal, Serbia, Slovenia, and Switzerland (Cocquempot and Lindelöw 2010). In South America, *N. acuminatus* has been reported as likely established in Argentina after two adults were collected in the field on branches of *Prosopis* in 1998 (Di Iorio 2004b). *N. acuminatus* is highly polyphagous on hardwood trees, shrubs, and vines. In North America, species of *Fraxinus* are preferred followed by *Carya, Celtis, Diospyros*, and *Quercus* (Solomon 1995). Other occasional hosts in North America include species of *Acer, Betula, Carpinus, Castanea, Cercis, Cercocarpus, Cornus, Fagus, Gleditsia, Ilex, Juglans, Liquidambar, Liriodendron, Maclura, Malus, Prunus, Pyrus, Robinia, Sassafras, Syringa, Ulmus*, and *Tilia* (Solomon 1995). In Europe, species of *Fraxinus, Juglans*, and *Ulmus* are common hosts (Cocquempot and Lindelöw 2010), but other European dicot hosts include *Acer, Betula*, *Carpinus, Castanea, Cercis, Corylus, Euonymus, Fagus*, *Ficus*, *Hibiscus*, *Lonicera*, *Morus*, *Ostrya*, *Populus*, *Prunus, Pyrus, Quercus, Robinia*, Rosa, *Salix, Tilia*, *Ulmus*, and *Vitis*, as well as occasionally conifers such as *Abies* (Bense 1995). Adults vary greatly in size from 4 to 18 mm in length (Bense 1995; Solomon 1995). They have a wasp-like appearance, being reddish brown in color with four transverse yellow bands across the elytra (Solomon 1995; Figure 11.12).

In the southern United States, *N. acuminatus* completes two to three generations per year, whereas in the northern United States, this species is mostly univoltine (Solomon 1995). Adults begin emerging in spring and, after mating, they lay eggs in bark cracks and crevices and under lichen and bark scales along the trunk and branches of host plants (Solomon 1995). Adults are active during the day. After egg hatch, larvae penetrate the bark and at first tunnel in the cambial region and then enter the sapwood where they complete their larval development (Solomon 1995). Larval galleries usually do not extend deeper than

FIGURE 11.12 *Neoclytus acuminatus* adult. (Courtesy of Gyorgy Csoka [Bugwood image 1231138].)

the outer heartwood. Most individuals overwinter as larvae. The larvae pack their galleries with granular frass and later, when preparing to pupate, they construct a pupal cell near the outer sapwood surface. New adults chew a circular exit hole through the bark when emerging.

Neoclytus acuminatus often infests stressed, dying, and recently dead trees, as well as recently cut logs with bark. When infestations are high, the sapwood can be riddled with galleries, which greatly reduces the quality of the wood, often making it unmarketable (Solomon 1995). This species has also been reported to infest apparently healthy *Robinia* trees that were planted as windbreaks and in woodlots and, at times, nursery stock and recently planted trees (Barr and Manis 1954; Solomon 1995). During harvest operations, logs should be moved quickly to sawmills for processing to minimize infestation (Solomon 1995).

11.2.17 *Neoclytus rufus* (Olivier)

Neoclytus rufus is known to occur in parts of the Caribbean (Grenada, Trinidad), Central America (Panama), and South America (Argentina, Bolivia, Colombia, French Guiana, Guyana, Paraguay, and Venezuela) (Duffy 1960; Giesbert 1989; Di Iorio 1995; Bezark 2015a, 2015b). Duffy (1960) reporte that *N. rufus* is a pest of *Mora* in Trinidad and *Inga* in Venezuela and has also been reported from *Peltophorum*. In Argentina, Gonzalez and Di Iorio (1996) reported that *N. rufus* infests species of *Celtis, Paullinia, Schinus*, and *Ziziphus*. Adults are 6–13 mm in length, reddish-brown in color, without transverse bands on the pronotum, but with white transverse bands or spots across the elytra (Di Iorio 1995; Figure 11.13).

Neoclytus rufus likely completes one or more generations per year throughout its range given that Duffy (1960) reports that a single generation can be completed in as little as three months. Adults are active during the day, often being observed on the branches, trunks, and recently cut logs of host trees. Eggs are laid in bark cracks and crevices on trees as well as on logs and lumber where some bark is still present (Duffy 1960). Larvae tunnel primarily in the cambial region when bark is present but will penetrate the outer sapwood when bark is lacking. The larvae pack frass within their galleries. After pupation, the new adults emerge through circular exit holes.

Neoclytus rufus commonly infests freshly cut logs and recently sawn lumber, especially when some bark is retained. Adults are commonly observed around sawmills in Trinidad. Larval galleries in the sapwood can lower the quality of affected lumber (Duffy 1960). Logs should be utilized quickly and debarking should be as complete as possible to minimize infestation (Duffy 1960).

FIGURE 11.13 *Neoclytus rufus* adult from Paraguay. (Courtesy of Karina Diarte.)

11.2.18 *Neoplocaederus viridipennis* (Hope)

Neoplocaederus viridipennis is native to several countries in Africa, including Angola, Benin, Cameroon, Central Africa, Guinea-Bissau, Ivory Coast, Nigeria, Sierra Leone, Togo, Uganda, and Zaire (Duffy 1957; Roberts 1969; Vitali 2015). Larval hosts include species of *Canarium, Daniellia, Hevea, Khaya, Milicia* (= *Chlorophora*), *Mitragyna, Phyllanthus, Pseudospondias, Ricenodendron, Spondianthus, Terminalia*, and *Trilepisium* (= *Bosqueia*), and possibly *Theobroma* (Duffy 1957, 1980; Roberts 1969). Adults are 18–22 mm in length, having a black head and prothorax, and elytra that are metallic blue or green (Duffy 1957; Figure 11.14).

Generation time of *N. viridipennis* has not been reported specifically but appears to be univoltine based on data from Duffy (1957) and Roberts (1969). Eggs are laid in bark cracks and crevices along the trunks of mature trees. Larvae feed primarily in the outer sapwood but near to the bark surface. As they tunnel, the larvae construct a number of holes in the bark through which they eject frass. Mature larvae tunnel deeper into the sapwood or heartwood and there construct a pupal chamber that they line with a calcareous secretion. In addition, prior to pupation, larvae plug their galleries with wood fibers (Duffy 1957).

The economic impact of *N. viridipennis* can be high given that living, mature trees are infested and the sapwood is often heavily mined. However, because the heartwood is less frequently tunneled, losses are kept to a minimum (Duffy 1957; Roberts 1969). Because both live trees and recently cut logs can be infested, rapid utilization of logs should help minimize infestation and tunneling.

11.2.19 *Oemida gahani* (Distant)

Oemida gahani is native to East Africa, being reported from the countries of Kenya, Tanzania, Uganda, Zimbabwe, and possibly South Africa (Duffy 1957; Schabel 2006). *O. gahani* is highly polyphagous, developing in both hardwoods and conifers, including both native and exotic species. For example, more than 173 species of woody plants in Africa, representing at least 56 plant families, have been reported as larval hosts of *O. gahani* (Jones and Curry 1964; Schabel 2006; Duffy 1980). Some of the common larval hosts include species of *Acacia, Acrocarpus, Artocarpus, Celtis, Croton, Cupressus, Erythrina, Eucalyptus, Grevillea, Juniperus, Olea, Podocarpus*, and *Trichocladus* (Duffy 1957; Rathore 1995; Schabel 2006). Adults are 8–23 mm in length, brownish in color, with two longitudinal ridges on each elytron.

FIGURE 11.14 *Neoplocaederus viridipennis* adult female from Cameroon. (Courtesy of Francesco Vitali at www.cerambycoidea.com.)

The life cycle of *O. gahani* usually spans one to three years but can extend to 10 years in dry, structural timbers (Curry 1965; Schabel 2006). Adults emerge and are active at night—usually peaking in April and November during the two rainy seasons in Kenya. Adults live for about two to four weeks and apparently do not feed (Curry 1965). With regard to native plants, *O. gahani* typically infests stressed or recently dead or cut trees and logs. By contrast, when infesting exotic trees, *O. gahani* commonly oviposits on living trees (Schabel 2006). Females lay eggs in batches of 50–100, often preferring bark wounds and pruning scars as oviposition sites, as well as old emergence holes in structural timbers (Curry 1965; Schabel 2006). Larvae tunnel in both the sapwood and heartwood and pack their galleries with frass (Curry 1965). The pupal chamber is constructed near the wood surface, and the new adult emerges through an oval-shaped exit hole (Duffy 1957; Curry 1965).

Before the widespread planting of exotic tree plantations in East Africa, *O. gahani* was mostly a pest of stressed and recently cut native trees as well as stumps used for coppicing (Schabel 2006). At times, *O. gahani* would infest apparently healthy native trees, primarily *Juniperus procera* Hochstetter ex Endlicher. As for the exotic plantation trees planted widely in East Africa, species of *Cupressus* were the most heavily infested by *O. gahani*, and to a lesser degree plantations of various *Acacia, Acrocarpus, Eucalyptus*, and *Grevillea* species (Curry 1965; Schabel 2006). Upon felling mature *Cupressus* trees in Kenya during the mid-1900s, evidence of *O. gahani* infestation was found in as many as 34–80% of the trees (Gardner and Evans 1957; Schabel 2006). More recently, the impact of this beetle has been greatly lowered as a result of several changes, such as reduced frequency of pruning, treating pruning scars when pruning does occur, rapid stand sanitation after logging operations, stand conversion to less susceptible tree species such as pines, and kiln-drying wood to reduce possible active infestations in structural timbers (Gardner and Evans 1957; Jones and Curry 1964; Schabel 2006).

11.2.20 *Phoracantha recurva* Newman

Phoracantha recurva is native to Australia and Papua New Guinea (Duffy 1963) and has been considered to be the most common *Phoracantha* species in Australia (Froggatt 1923). This species has been introduced to several countries throughout the world, including parts of Africa (Libya, Malawi, Morocco, South Africa, Tunisia, and Zambia), Asia (Israel and Turkey), Europe (Cyprus, France, Greece, Italy, Malta, Portugal, and Spain), North America (United States), and South America (Argentina, Brazil, Chile, and Uruguay) (Di Iorio 2004a; CABI 2015b). Although *P. recurva* has been reported to occur in New Zealand in various publications (Wang 1995; CABI 2015b), this information is considered incorrect based on misidentification (Bain 2012). Several species of *Eucalyptus* serve as the primary larval hosts for *P. recurva* (Froggatt 1923; Duffy 1963), although a few other tree genera (*Angophora, Cupressus*, and *Syncarpia*) have been reported as occasional hosts in South Africa (Kliejunas et al. 2001). Adults measure 15–30 mm in length, with yellowish-brown antennae and legs, reddish-brown head and pronotum, and yellowish-brown elytra with a dark blackish-brown spot on the basal portion and a transverse band on the apical portion (CABI 2015b; Figure 11.15).

Phoracantha recurva generally completes one generation a year, but multiple generations can occur in tropical and subtropical countries (Löyttyniemi 1983). In Australia, *P. recurva* generally oviposits on stressed or recently cut trees. Similarly, throughout its introduced range, *P. recurva* oviposits on living trees, including both stressed and apparently healthy trees (Ivory 1977; Paine and Millar 2002). Adults are nocturnal. Eggs are laid in batches of up to 40 under bark scales along the trunk and main branches (Duffy 1963; Ivory 1977). Larvae tunnel primarily in the cambial region and pack their galleries with frass. Individual galleries can exceed 1 m in length (Froggatt 1923). Mature larvae tunnel into the sapwood and heartwood to form a pupal cell as well as construct a short tunnel toward the bark that is opposite the entrance into the wood. Larvae then plug the gallery with frass and wood fibers and prepare to pupate. New adults reach the wood surface by tunneling through the gallery they had constructed as mature larvae and emerge through an oval-shaped exit hole. In areas where *P. recurva* coexists with *Phoracantha semipunctata* (Fabricius), with time *P. recurva* tends to largely replace *P. semipunctata* (Paine and Millar 2002; Paine et al. 2011)

Although considered primarily a secondary pest in Australia, *P. recurva* has caused significant mortality of eucalypts in many other parts of the world where these trees have been introduced (Froggatt 1923; Drinkwater 1975; Ivory 1977; Paine et al. 2011; CABI 2015b). Trees infested by *P. recurva* initially display wilted foliage and crown dieback, but extensive larval feeding eventually girdles the tree and leads to tree death. Extensive mortality of eucalypts has occurred in both ornamental and plantation settings (Paine et al. 2011). International movement of *P. recurva* has likely resulted from trade in eucalypt logs, wood products and associated wood packaging materials, and possibly live plants (Haack 2006; CABI 2015b). For example, *P. recurva* and *P. semipunctata* were likely introduced to South Africa in the early 1900s on *Eucalyptus* timbers used as railroad crossties that were imported from Australia (Drinkwater 1975; Cillie and Tribe 1991). Control options often focus on irrigation to reduce tree stress, avoiding trunk injuries, planting *Eucalyptus* species that are more resistant to borer attack, rapid debarking or utilization of logs, and release of biological control agents (FAO 2009; also see Chapter 8).

FIGURE 11.15 *Phoracantha recurva* adult from Gibraltar. (Courtesy of Charles Perez at The Gibraltar Ornithological & Natural History Society [www.gonhs.org].)

11.2.21 *Phoracantha semipunctata* (Fabricius)

Phoracantha semipunctata is native to Australia and Papua New Guinea (Duffy 1963) and has become established in several countries throughout the world, including parts of Africa (Algeria, Egypt, Lesotho, Libya, Malawi, Mauritius, Morocco, Mozambique, South Africa, Swaziland, Tunisia, Zambia, and Zimbabwe), Asia (Israel, Lebanon, and Turkey), Europe (Cyprus, France, Italy, Malta, Portugal, and Spain), North America (Mexico, United States), Oceania (New Zealand), and South America (Argentina, Bolivia, Brazil, Chile, Peru, and Uruguay) (CABI 2015b). Several species of *Eucalyptus* have been recorded as larval hosts for *P. semipunctata* (Duffy 1963; CABI 2015c), although a few other tree genera in the family Myrtaceae have also been recorded as occasional hosts in Australia (*Angophora, Corymbia*, and *Syncarpia*) (Duffy 1963; Kliejunas et al. 2003). Adults measure 16–35 mm in length, being primarily dark reddish-brown in color with each elytron having a yellowish zigzag band near the center and a yellowish apical spot (Duffy 1963; Solomon 1995; CABI 2015c; Figure 11.16).

Phoracantha semipunctata generally completes one to two generations per year, but three annual generations can occur under tropical conditions (Löyttyniemi 1983; Bense 1995; Solomon 1995). Adults are nocturnal. Oviposition typically occurs on stressed or recently cut trees, but in some countries where *P. semipunctata* has been introduced, both stressed and apparently healthy trees can be infested (Drinkwater 1975; Ivory 1977). Eggs usually are laid in bark cracks and under bark scales in batches of 3–30 eggs, and at times batches of 110 eggs have been observed (Duffy 1963; Scriven et al. 1986). Oviposition occurs mostly along the main trunk, but eggs are also laid on large branches (Schabel 2006). Larvae tunnel mostly in the cambial region often constructing galleries over a meter in length and packed with frass (Solomon 1995; Elliott et al. 1998). Mature larvae tunnel 6–10 cm into the wood and construct a pupal cell as well as a short tunnel into the outer bark that they use when exiting the tree as adults (Duffy 1963).

In Australia, *P. semipunctata* typically is a minor pest, infesting stressed, dying, and recently dead or cut trees, but it does not successfully infest dry eucalypt logs and lumber (Duffy 1963). In many countries where *P. semipunctata* has been introduced, this beetle has become a serious pest, resulting in widespread mortality of ornamental and plantation eucalypts (Drinkwater 1975; Löyttyniemi 1983;

FIGURE 11.16 *Phoracantha semipunctata* adult collected in Gibraltar from timber imported from Spain. (Courtesy of Charles Perez at The Gibraltar Ornithological & Natural History Society [www.gonhs.org].)

Scriven et al. 1986; Elliott et al. 1998; Schabel 2006). As mentioned earlier, in many areas where both *P. recurva* and *P. semipunctata* have been introduced, *P. recurva* tends to displace *P. semipunctata* (Paine and Millar 2002; Paine et al. 2011). Control efforts for *P. semipunctata* are similar to those listed earlier for *P. recurva*.

11.2.22 *Phymatodes testaceus* (L.)

Phymatodes testaceus is native to Eurasia and North Africa and has been reported as introduced to North America (Canada and United States) since the mid-1800s—and apparently to Japan as well (LeConte 1850; Cherepanov 1988a; Bense 1995; LaBonte et al. 2005; Swift and Ray 2010). Several hardwood species serve as larval hosts, including *Carpinus, Carya, Castanea, Corylus, Fagus, Fraxinus, Malus, Prunus, Quercus, Salix*, and *Ulmus* (Linsley 1964; Bense 1995). *Quercus* appears to be the preferred host in Europe and North America (Craighead 1923; Duffy 1953; Cherepanov 1988a). In addition, Craighead (1923) stated that others had recorded the conifers *Picea* and *Tsuga* as larval hosts of *P. testaceus* in North America. Adults measure 7–17 mm in length and are variable in color including solid shades of yellow, brown, red, blue, black, violet, and green, or are of two colors where the elytra and pronotum differ (Linsley 1964; Novák 1976; Cherepanov 1988a; Figure 11.17).

Generally, one to three years is required for *P. testaceus* to complete one generation (Duffy 1953; Linsley 1964). Eggs are laid in bark cracks or crevices on recently dead trees or cut logs (Duffy 1953). Larvae tunnel primarily within the bark or in the cambial region and retain frass within their galleries (Craighead 1950). Mature larvae tunnel a few centimeters into the outer sapwood to construct pupal cells when the outer bark is relatively thin, or if the bark is sufficiently thick, they will construct an oval cell within the cambial region in which to pupate (Duffy 1953). Pupation and adult emergence usually occur in spring to early summer (Duffy 1953).

This cerambycid has been a major pest in the tan bark industry in both Europe and North America (Craighead 1923; Duffy 1953). Traditionally, tannins are extracted from tree bark and used to treat animal skins in the process of making leather. *Quercus* bark is a common source of tannins in both Europe and North America. High populations of *P. testaceus* are able to form in the tan bark industry

FIGURE 11.17 *Phymatodes testaceus* adult from the United States. (Courtesy of Steven Valley [Bugwood image 5445446].)

because bark is stored either on cut logs or separated from the logs, and *P. testaceus* larvae can complete development in both situations (Craighead 1950). Given that most galleries do not penetrate deeply into the sapwood, *P. testaceus* generally is not considered a major wood pest (Duffy 1953). In the tanbark industry, long-term storage of bark should be avoided to reduce population buildups of *P. testaceus* (Craighead 1950).

11.2.23 *Semanotus bifasciatus* (Motschulsky)

Semanotus bifasciatus is native to China, Japan, Korea, and the Russian Far East (Duffy 1968; Cherepanov 1988a). The primary larval hosts are species of *Juniperus*, but species of *Chamaecyparis, Platycladus*, *Thuja*, and *Thujopsis* are also infested (Duffy 1968; Cherepanov 1988a; Ma et al. 2010). Adults vary in length from 8 to 14 mm (Cherepanov 1988a), and their head and elytra are shades of brown to black with white transverse bands across the elytra (Cherepanov 1988a; Figure 11.18).

Semanotus bifasciatus generally completes its life cycle in one year in the southern part of its range, although two years is common in its northern range (Kim and Park 1984; Cherepanov 1988a). Adults are most active during spring and summer, emerging earlier in the southern portion of their range. Adults are active at dusk when they mate and lay eggs on the trunks of recently dead and dying trees (Cherepanov 1988a; Iwata et al. 2007). Adults apparently do not feed (Cherepanov 1988a; Yan 2003). Eggs are laid in bark crevices. Average fecundity has been reported by Cherepanov (1988a) as 48 eggs per female and by Yan (2003) as 69 eggs. Kim and Park (1984) reported that in Korea, the egg stage lasted 16–20 days, the larval stage 112–126 days, the pupal stage 15–21 days, and adult lifespan 19 days for females and 16 days for males. After hatching from the eggs, larvae penetrate the bark and feed primarily in the cambial region and later enter the sapwood to pupate (Cherepanov 1988a; Yan 2003). Iwata et al. (2007) reported that, in fallen logs, larvae develop best on the lower portion of the log that is in contact with the soil where the wood moisture content is higher. Pupation occurs in the sapwood in frass-plugged cells constructed at a depth of about 2 cm below the cambial region (Cherepanov 1988a). Pupation occurs in late summer, with new adults remaining within their pupal cells to overwinter until the next year when they chew an oval-shaped exit hole and emerge (Cherepanov 1988a; Yan 2003).

FIGURE 11.18 *Semanotus bifasciatus* adult. (Courtesy of the Pest and Diseases Image Library [Bugwood image 5488621].)

Semanotus bifasciatus typically is considered a secondary pest of stressed and recently dead trees (Iwata et al. 2007). However, occasionally it has been reported as a major pest of living trees, especially in urban and ornamental settings (Kim and Park 1984; Yan 2003; Gao et al. 2007). For example, Gao et al. (2007) reported that *S. bifasciatus* was infesting ancient cypress trees in several areas of China. To minimize losses, logs should be transported from the forest and utilized quickly. For ornamental plantings, various biological control options have been investigated, including mites, nematodes, and parasitoids (Qiu 1999; Sun 2000; Ma et al. 2010).

11.2.24 *Stromatium barbatum* F.

Stromatium barbatum is native to Asia, including Bangladesh, India, Myanmar, Nepal, Pakistan, Sri Lanka, and Thailand as well as the Andaman and Nicobar Islands (Duffy 1968; Vitali 2015). In addition, *S. barbatum* has been introduced to the African countries of Somalia and Tanzania as well as to various nearby islands in the Indian Ocean, including Madagascar, Mauritius, Réunion, Rodrigues, and the Seychelles (Duffy 1968; Duffy 1980; Vitali 2015). Schabel (2006) stated that *S. barbatum* was likely introduced to Africa in the 1950s. Given that *S. barbatum* is a drywood-infesting species, it is capable of developing in a wide array of hosts, with more than 350 species recorded as hosts, including both conifer and hardwood trees as well as bamboo and some woody vines such as grape (Beeson and Bhatia 1939; Duffy 1968; Salini and Yadav 2011). Adults vary in length from 12 to 29 mm, and their general color varies from reddish brown to brownish black (Duffy 1968; Figure 11.19).

Stromatium barbatum completes its life cycle in one to several years. For example, in India, Beeson and Bhatia (1939) reported that adults of the same cohort emerged in one to seven years from the same host material, *Albizia stipulata* (DC.) Boivin, with most (93%) requiring two to four years. The longest development period reported was 10 years (Duffy 1968). Based largely on Beeson and Bhatia (1939) and Duffy (1953), it is known that eggs of *S. barbatum* are laid on rough wood surfaces or in cracks and holes in wood either with or without bark. Eggs are laid singly or in small groups. On average, each female lays about 100 eggs, with a maximum of 246 eggs recorded. Larvae create powdery frass that is packed tightly in their galleries, which occur in both sapwood and heartwood. At times, the galleries are so numerous in individual pieces of wood that only the exterior wood surfaces are left intact. Larvae pupate at the end of their galleries without constructing any discrete pupal cell.

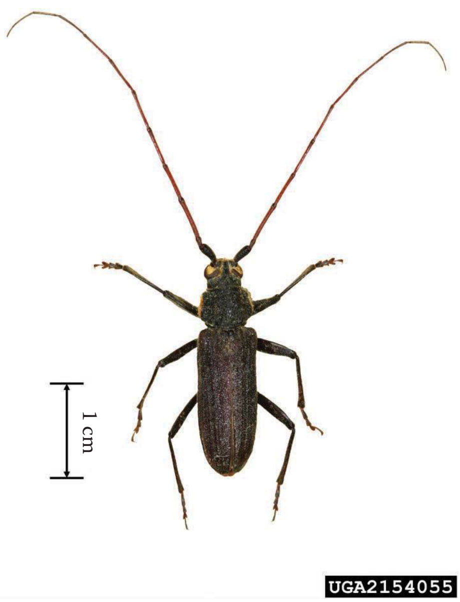

FIGURE 11.19 *Stromatium barbatum* adult. (Courtesy of Christopher Pierce [Bugwood image 2154055].)

The economic impact of *S. barbatum* can be significant given this insect's wide host range and its ability to infest dry, seasoned wood. This species can infest a wide array of wood products, including packaging materials, lumber, furniture, bamboo stakes, and even museum specimens (Duffy 1953; Schabel 2006), and therefore is frequently transported in international trade (Cocquempot et al. 2014). Control efforts often focus on impregnation, fumigation, and the application of various insecticides and protectants (Duffy 1968).

11.2.25 *Strongylurus decoratus* (McKeown)

Strongylurus decoratus is native to Australia (Duffy 1963). The principal host is *Araucaria cunninghamii* Aiton ex D.Don, with *A. bidwillii* Hook. listed as a minor host (Duffy 1963; Elliott et al. 1998). Adults measure 18–28 mm in length and are brown in color, with five white markings on the thorax and black forward-pointing chevron markings on each elytron (Elliott et al. 1998).

Strongylurus decoratus is univoltine. Females oviposit on branches and the terminal shoots of their host plants, typically laying one egg per branch (Wylie 1982; Elliott et al. 1998; Wylie and Speight 2012). The larvae first tunnel within the cambial region and later move into the wood and tunnel in the center of the branch. Prior to pupation, the larva creates a spiral tunnel where the branch usually breaks, with the larva remaining in the tree. The larva then prepares a pupal chamber but first creates a set of exit holes close to where the spiral gallery was originally made as well as another set about 3–11 cm below the first set. It plugs both ends of the gallery between these two sets of potential exit holes with wood fibers and then pupates. The new adult departs the branch using one of the premade exit holes.

The oviposition behavior of *S. decorates* results in branch pruning. Damage usually is minor, especially when older trees are infested, but on occasion severe damage can occur—especially in young *Araucaria* plantations when the main leader is infested (Wylie 1982; Elliott et al. 1998; Wylie and Speight 2012). This insect has been found infesting trees that varied in age from four to more than 30 years, with heights ranging from 3 to 31 m (Wylie 1982; Wylie and Speight 2012). Wylie (1982) stated that proper site and choice of tree provenance can reduce infestation levels.

11.2.26 *Trichoferus campestris* (Faldermann)

Trichoferus campestris is native to Asia, including Armenia, China, Japan, Kazakhstan, Korea, Kyrgyzstan, Mongolia, Russia, Tajikistan, and Uzbekistan (Cherepanov 1988a; Smith 2009). In addition, *T. campestris* has become established in several countries in Europe (Dascalu et al. 2013) and in both Canada (Grebennikov et al. 2010; Bullas-Appleton et al. 2014) and the United States (Burfitt et al. 2015). Much of the early literature for this species was published under the synonym *Hesperophanes campestris* (Faldermann). Several genera of mostly hardwoods and a few conifers are reported as hosts of *T. campestris* in Asia (Cherepanov 1988a; Iwata and Yamada 1990), but mostly hardwoods have been recorded as hosts in Europe and North America (Dascalu et al. 2013; Bullas-Appleton et al. 2014; Burfitt et al. 2015). Some of the common genera infested include *Acer, Betula, Broussonetia*, *Gleditsia, Malus, Morus*, *Prunus, Salix*, and *Sorbus*. Larvae often are associated with stressed and dying hosts but are also able to complete development in dry wood (Smith 2009). Adults measure 11–20 mm in length and are various shades of brown (Smith 2009; Figure 11.20).

Most reports suggest that *T. campestris* requires one to two years to complete a single generation (Cherepanov 1988a; Švácha and Danilevsky 1988; Smith 2009). Adults are active during the summer months and are mostly nocturnal (Cherepanov 1988a; Smith 2009). Eggs usually are laid singly under bark flakes (Cherepanov 1988a). Early instar larvae tunnel primarily in the cambial region, with late instars entering the outer sapwood to pupate. Frass is often extruded from the galleries and can collect at the base of the tree (Bullas-Appleton et al. 2014). Bark appears to be necessary for oviposition and early instar development (Iwata and Yamada 1990). Individuals overwinter as larvae and pupate in spring (Cherepanov 1988a).

Although tree death has not been attributed to *T. campestris*, heavy infestation can reduce tree vigor (Smith 2009). In addition, given that larvae can develop in dry wood (Iwata and Yamada 1990), this species has been found in association with wood rafters and lumber (Dascalu et al. 2013) as well as

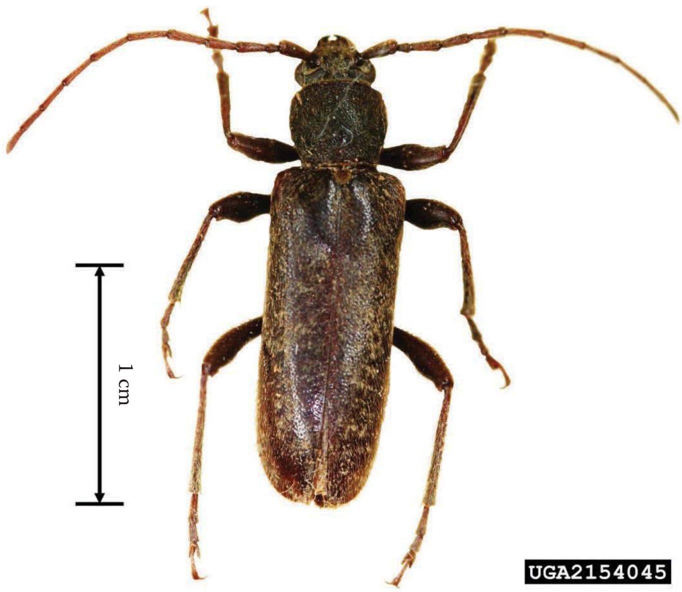

FIGURE 11.20 *Trichoferus campestris* adult. (Courtesy of Christopher Pierce [Bugwood image 2154045].)

wood packaging material used in international trade (Allen and Humble 2002; Cocquempot 2006; Haack 2006). Given that *T. campestris* can infest living, stressed, and recently cut trees, as well as complete development in dry wood, control requires an integrated approach that includes inspection and possible treatment of live trees, rapid utilization of cut trees, and proper heat treatment or fumigation of wood packaging material.

11.2.27 *Xylotrechus altaicus* Gebler

Xylotrechus altaicus is native to Russia (primarily east of the Urals in Siberia) and northern Mongolia (Rozhkov 1970; Cherepanov 1988b) and apparently has not become established elsewhere in the world (as of 2015). The only reported larval host is larch (*Larix*). Adults are 11–24 mm in length, with reddish legs and antennae, blackish head and thorax, and elytra that are brownish in color with two or three lighter-colored transverse bands (Rozhkov 1970; Cherepanov 1988b; EPPO 2005; Figure 11.21).

Xylotrechus altaicus typically requires two years to complete a single generation in Siberia. Adults are active during the summer months, living two to three weeks, and not feeding as adults (Rozhkov 1970; Cherepanov 1988b). Females oviposit in bark crevices, usually laying 50–70 eggs in their lifetime, with a maximum of 145 eggs recorded, and preferring to oviposit on the sunlit side of the tree trunk (Rozhkov 1970; Cherepanov 1988b). Oviposition occurs throughout the trunk. Larvae eclose from the eggs in one to two weeks and at first tunnel back and forth between the cambial region and the outer bark, a behavior that seems to allow the young larvae to escape from host resin (Cherepanov 1988b). During their first winter, larvae reside within the cambial region or outer bark. During the second summer, the larvae first create galleries in the cambial region that are perpendicular to the trunk, which collectively can girdle the host tree. Later that summer, the larvae enter the sapwood and continue to tunnel perpendicular to the trunk and therein spend the second winter. During the second spring, the larvae tunnel close to the bark and construct a pupal cell at the end of their gallery in the outer bark or sapwood. Pupation occurs in early summer and lasts two to three weeks (Cherepanov 1988b).

Xylotrechus altaicus usually is a secondary pest, infesting trees that have been weakened by fire, defoliation, and other stressors. However, during outbreaks of this cerambycid, apparently healthy larch trees can be infested and killed (USDA Forest Service 1991). Rozhkov (1970) reported that some outbreaks can last for decades and extend over large areas. Given that this borer can cause widespread tree

FIGURE 11.21 *Xylotrechus altaicus* adult from Mongolia. (Courtesy of Vladimir Petko [Bugwood image 5174039].)

mortality, it could easily be transported in cut logs and wood packaging (Rozhkov 1970; USDA Forest Service 1991; EPPO 2005). For example, in one study in Russia, an average of 36 larval galleries was recorded within the sapwood per meter-length of trunk (Cherepanov 1988b). Given that *X. altaicus* commonly infests stressed trees, sanitation efforts should be initiated promptly following major stress events such as fire and defoliation (EPPO 2005). In addition, rapid transport and debarking of logs would help reduce borer populations, especially during the first year of infestation.

11.2.28 *Xystrocera festiva* Thomson

Xystrocera festiva is native to Indonesia, Malaysia, and Myanmar (Duffy 1968; Nair 2007). Several broadleaf woody plants serve as hosts, such as species of *Acacia, Albizia, Coffea, Paraserianthes, Pithecolobium*, and *Theobroma* (Duffy 1968). *Paraserianthes falcataria* (L.) Nielsen, for example, is a fast-growing leguminous tree native to Southeast Asia where it is commonly used in plantation forestry and often infested by *X. festiva* (Endang and Haneda 2010). Adults are 30–35 mm in length and overall are brownish in color with blue–green lateral margins along the prothorax and elytra (Nair 2007; Figure 11.22).

Xystrocera festiva is reported to complete a generation in about 190 days (Duffy 1968) and thus potentially could complete two generations per year. However, in nature, all life stages are present at any one time given that there are overlapping generations (Nair 2007). Adults are nocturnal and live for about four to 10 days (Duffy 1968; Nair 2007). Females lay clusters of eggs in bark crevices on live trees, usually 3–8 m above groundline (Nair 2007; Endang and Haneda 2010). The egg clusters usually contain 20–40 eggs each (Johki and Hidaka 1987) but can contain more than 100 eggs at times (Nair 2007). Individual females can lay as many as 170–400 eggs in their lifetime (Duffy 1968; Nair 2007). After hatching, the larvae enter the cambial region and feed gregariously, which is unusual for cerambycids (Johki and Hidaka 1987). While feeding within the cambial region, larvae tunnel mostly in a downward direction, but later, after the larvae enter the sapwood, they construct individual galleries in an upward direction and therein pupate (Nair 2007). The pupal period averages 18 days (Duffy 1968).

Xystrocera festiva can infest *P. falcataria* trees when they are only two to three years old. As a result of the gregarious feeding behavior by larvae in the cambial region, young trees are easily girdled and killed (Nair 2007). Infestations can lead to growth reduction, stem breakage, and tree death (Nair 2007). Trees of all ages can be infested (Endang and Haneda 2010). Pest populations can be lowered by removing heavily infested trees during thinning operations (Nair 2007). In young plantations, annual inspections should be conducted during the first six years with all infested trees removed. Adults can be collected during the tree removal process, with any eggs produced being placed in the plantations to encourage parasitism (Nair 2007).

FIGURE 11.22 *Xystrocera festiva* adult from Sumatra. (Courtesy of Udo Schmidt at www.kaefer-der-welt.com.)

11.3 Lamiinae

11.3.1 *Anoplophora glabripennis* (Motschulsky)

Anoplophora glabripennis is native to Asia, primarily in China and Korea; however, during the past 20 years, *A. glabripennis* has become established in several countries in both North America and Europe (Hérard et al. 2006; Haack et al. 2010a; see Chapter 13). *A. glabripennis* is highly polyphagous, infesting broadleaf tree species in at least 15 plant families (Haack et al. 2010a). In Asia, the most commonly infested tree genera include *Acer, Populus, Salix*, and *Ulmus*; and similarly, in North America and Europe, the most commonly infested host genera include *Acer, Aesculus*, *Betula*, *Populus, Salix*, and *Ulmus* (Haack et al. 2006; Haack et al. 2010a; Sjöman et al. 2014; Straw et al. 2014; Faccoli et al. 2015; Table 11.2). Adults measure 17–40 mm in length and are glossy black in color, with usually 10–20 distinct irregular-shaped patches on the elytra that range in color from white to shades of yellow and orange (Haack et al. 2010a; Figure 11.23).

The life cycle of *A. glabripennis* usually is completed in one year, but two years may be needed in colder parts of its range (Haack et al. 2010a). Adults are most active in the summer months. After emergence, adults conduct maturation feeding for one to two weeks on twigs and foliage of host trees. Adults usually mate on the trunks and branches of host trees and then females chew funnel-shaped oviposition pits through the bark into which a single egg is inserted. Oviposition usually starts in the upper trunk and branches and then occurs lower along the trunk in succeeding years (Haack et al. 2006). Eggs typically hatch in one to two weeks, and the emerging larvae first tunnel in the cambial region and later move into the sapwood and heartwood. Overwintering usually occurs in the larval stage, with pupation occurring in late spring to early summer. Pupation occurs at the end of the larval gallery. The new adults emerge through circular exit holes that are 10–15 mm in diameter (Haack et al. 2010a).

Anoplophora glabripennis can cause widespread tree mortality because it successfully infests apparently healthy trees and causes tree death after several years of successive attack. Extensive tree mortality

TABLE 11.2

Summary Data (as of January 2016) for the Status of Infestations of *Anoplophora glabripennis* in Five U.S. States.

State	Year of Discovery	Status in December 2015	No. Infested Trees Cut[a]	No. High Risk Trees Cut[b]	Top Five Infested Tree Genera as of April 2015
Illinois	1998	Eradicated	1,551	220	*Acer, Ulmus, Fraxinus, Salix, Aesculus*
Massachusetts	2008	Ongoing	24,404	10,679	*Acer, Betula, Ulmus, Populus, Fraxinus*
New Jersey	2002	Eradicated	730	21,251	*Acer, Ulmus, Salix, Betula*
New York	1996	Ongoing	7,062	16,658	*Acer, Ulmus, Salix, Aesculus, Betula*
Ohio	2011	Ongoing	16,446	61,557	*Acer, Aesculus, Ulmus, Salix, Populus*

[a] Total number of trees cut during the eradication program that were considered infested with *A. glabripennis* by state.
[b] Total number of trees cut during the eradication program that were considered high risk, which meant that they were potential host trees growing close to infested trees but not known to be infested themselves.

FIGURE 11.23 *Anoplophora glabripennis* adult from United States. (Courtesy of Steven Valley [Bugwood image 5449526].)

has occurred in China, involving millions of trees, especially in northern China where large-scale tree planting efforts occurred (Pan 2005; Zhao et al. 2007). Given this threat, active eradication programs have been undertaken in all European and North American countries where *A. glabripennis* has been introduced. For example, in the United States, established populations of *A. glabripennis* had been found in five states as of January 2016 (Illinois, Massachusetts, New Jersey, New York, and Ohio), with the first populations being found in New York in 1996 and the most recent in Ohio in 2011. Of these five states, all *A. glabripennis* infestations have been eradicated in only Illinois and New Jersey, while efforts are still ongoing in the other three states (Table 11.2).

Details on the control efforts for *A. glabripennis* in China, Europe, and North America are provided in Hérard et al. (2006) and Haack et al. (2010a). Eradication is the goal for all outbreak areas in Europe and North America and generally include tree surveys of varying intensities in concentric zones around known infested areas, removal of all infested trees, and at times removal of nearby host trees that are not obviously infested but could be (i.e., so-called high-risk trees; see Table 11.2). In the United States, observers at first only surveyed trees for signs of infestation from the ground using binoculars, but later, tree climbers and bucket trucks were used to improve efficiency in finding *A. glabripennis* exit holes and oviposition pits. After infested trees are cut, they are chipped and sometimes burned. In China, *A. glabripennis* greatly expanded its natural range in the late 1900s as a result of large-scale tree planting efforts that used many species that were highly susceptible to *A. glabripennis* (Haack et al. 2010a). As a result, millions of infested trees were cut in China as well as an internal quarantine was established to reduce the likelihood of human-assisted spread (Haack et al. 2010a).

11.3.2 *Apriona swainsoni* (Hope)

Apriona swainsoni is native to China, India, Korea, Laos, Myanmar, Thailand, and Vietnam (Duffy 1968; Liu et al. 2006). The principal hosts include woody tree and vine species of *Butea, Caesalpinia, Dalbergia, Ligustrum*, *Paulownia, Salix, Sophora*, and *Tectona* (Duffy 1968; EPPO 2013). In China, Liu and Tang (2002) reported that *Sophora japonica* L. was one of the most highly susceptible tree species. Adults measure 25–40 mm in length and are brown in color with white specks (Beeson 1941; Figure 11.24).

Apriona swainsoni tends to have a two-year life cycle (Duan 2001). Adults are active during the summer months, mating and ovipositing primarily at night (Duan 2001). Adults conduct maturation feeding on host bark (Duan 2001; Wang 2011). Females lay 27–62 eggs each, placing them in bark crevices along the trunk and main branches (Duan 2001; Wang 2011). Larval galleries are constructed initially in the cambial region and later in the sapwood with larvae first tunneling toward the center of the stem or branch and then upward and finally outward to nearly the wood surface (Duan 2001). Individuals overwinter as larvae in both years of development. Pupation occurs in late spring to early summer.

FIGURE 11.24 *Apriona swainsoni* adult from Vietnam. (Courtesy of Ben Sale at commons.wikimedia.org.)

Beeson (1941) and Duffy (1968) report that when *Butea* vines are present along tree trunks, females often oviposit in the vines, with the resulting larvae first developing in the vine and then tunneling into the supporting tree to complete development.

Apriona swainsoni can cause severe damage to trees growing in natural forests, plantations, and in urban settings (Tang and Liu 2000; Liu et al. 2006; EPPO 2013). Infested trees usually are at least 7–8 cm in diameter (Duan 2001; Liu and Tang 2002); however, Beeson (1941) reported that some teak trees of more than 1 m in diameter were infested. In China, urban plantings of *S. japonica* have been heavily infested, with many trees exhibiting 60–70 exit holes each (Liu et al. 2006). In addition, given that *A. swainsoni* is not found throughout all of China, an internal quarantine has been in place since 1996 (Liu et al. 2006). In teak plantations, it is recommended that vines be removed from the trunks to reduce oviposition on the vines (Beeson 1941; Duffy 1968). Various biological control agents have been tested for their ability to control *A. swainsoni* in China (Lu et al. 2011; Wang et al. 2014).

11.3.3 *Aristobia horridula* Hope

Aristobia horridula occurs in China, India, Myanmar, Nepal, Thailand, and Vietnam (Duffy 1968; Dhakal et al. 2005; Nair 2007; Wylie and Speight 2012). The principal hosts include species of *Dalbergia, Pterocarpus*, and *Xylia* (Beeson 1941; FAO 2007; Nair 2007; Wylie and Speight 2012). Adults measure 27–32 mm in length and are brown in color, with elytra studded with bristle-like long bluish hairs and dense tufts of hairs on the distal portion of the first and second antennal segments (Nair 2007).

Aristobia horridula generally is univoltine, with adults most active during the summer months in India but apparently year-round in Thailand (Hutacharern and Panya 1996; Nair 2007). Adults are active during the day, feeding on bark of young branches and laying eggs singly in transverse cuts made in the bark of living trees (Nair 2007). Adult movement usually occurs in short bursts of flight of just 10–20 m (Hutacharern and Panya 1996). Most oviposition occurs along the lower trunk (Nair 2007). The larvae construct galleries that measure 50–75 cm in total length and penetrate both sapwood and heartwood (Hutacharern and Panya 1996; Nair 2007). As larvae feed, infested trees often become swollen and exude resin near the oviposition site (Nair 2007). Pupation occurs at the end of the gallery in the heartwood. Adults produce circular exit holes.

Aristobia horridula has caused extensive damage in young plantations of *Dalbergia cochinchinensis* Pierre ex Laness, *D. sissoo* Roxb., and *Pterocarpus macrocarpus* Kurz in India and Nepal, and similarly to plantations of *D. cochinchinensis, P. macrocarpus*, and *Pterocarpus indicus* Willd. in Thailand (Mishra et al. 1985; Hutacharern and Panya 1996; Dhakal et al. 2005; Nair 2007; Wylie and Speight 2012). When small-diameter trees are infested, they are prone to wind throw (Nair 2007). Infestation levels in plantations often reach 30–90% and, in some stands, all trees can be infested (Mishra et al. 1985; Hutacharern and Panya 1996; Dhakal et al. 2005). To protect trees, the lower 2 m of trunk often are treated with insecticides or other solutions (Hutacharern and Panya 1996; Nair 2007).

11.3.4 *Goes tigrinus* (DeGeer)

Goes tigrinus is found throughout the eastern United States where it infests species of *Quercus*, especially members of the white oak group (Solomon 1995). Adults measure 22–44 mm in length and have an overall brownish-grayish mottled appearance that forms an irregular dark band across the lower half of the elytra (Linsley and Chemsak 1984; Figure 11.25).

Goes tigrinus usually requires three to four years to complete a single generation (Solomon 1995). Adults become active in spring to early summer in the southern United States but not until mid-summer in the northern United States (Solomon 1995). Adults feed on twigs and leaf petioles for one to two weeks after emergence before mating and initiating oviposition. Females are reported to lay only 9–15 eggs in their lifetime (Solomon 1995). Oviposition involves first chewing an oval pit through the bark before inserting a single egg through the base of the pit into the cambial region. Larvae tend to tunnel upward for 11–23 cm, first in the sapwood and then in the heartwood (Solomon 1995). Larvae expel frass and wood shavings from near the origin of their gallery that accumulate at the base of the tree (Solomon 1977, 1995). Individuals overwinter as larvae in all years of development. Pupation occurs at the end of the

FIGURE 11.25 *Goes tigrinus* adult from Texas (United States). (Courtesy of Mike Quinn at bugguide.net.)

gallery in spring or early summer, after which the new adult extends the gallery from the pupal chamber to the bark, chewing a circular exit hole (Solomon 1995).

Goes tigrinus infests *Quercus* trees in both urban and natural forest settings. Although infestation by *G. tigrinus* seldom causes tree death, the value of lumber from heavily infested trees is greatly reduced given that larval galleries penetrate both sapwood and heartwood (Solomon 1995). In Ohio, Donley (1978b) demonstrated that young oak trees, 10–25 cm in diameter at breast height (DBH), were most often infested. Moreover, it was shown that within most forest stands, there usually are just a few "brood" trees (often less than 5% of all host trees present) that produce most of the borers, and that by removing these brood trees, the borer population could be greatly reduced (Donley 1978b; Solomon 1995).

11.3.5 *Monochamus alternatus* Hope

Monochamus alternatus is native to China, Japan, Korea, Laos, Taiwan, and Vietnam (Duffy 1968; Akbulut and Stamps 2012). The larval hosts of *M. alternatus* are conifers in the genera *Abies, Cedrus, Larix, Picea*, and *Pinus* (Akbulut and Stamps 2012). Adults measure 18–31 mm in length and have an overall reddish-brown color along with two pinkish longitudinal stripes on the pronotum and several small white and black patches on the elytra (Duffy 1968; Figure 11.26).

Monochamus alternatus typically is univoltine; however, in southern China, it may have two generations per year, and occasionally, two years are required to complete a single generation, especially when eggs are laid late in the year (Song et al. 1991; Akbulut and Stamps 2012; Togashi 2013). Adults are active during the summer months throughout much of their range and nearly year-round in their southern range (Song et al. 1991). Adults live for several weeks, feeding at first on twigs of healthy host trees to become sexually mature, and then ovipositing on trunks and branches of stressed, dying, or recently cut host trees (Togashi and Magira 1981). Females chew an oviposition pit in the bark and then usually lay a single egg within the cambial region (Togashi and Magira 1981). Depending on the time of year of adult emergence, females lay (on average) 23–86 eggs in their lifetime (Togashi and Magira 1981). Eggs hatch in about a week. The early larval instars feed and tunnel in the cambial region, with late instars entering the sapwood for a few centimeters and then turning to follow the wood grain and constructing

FIGURE 11.26 *Monochamus alternatus* adult. (Courtesy of Steven Valley [Bugwood image 5477456].)

a pupal chamber. Individuals overwinter in the larval stage. Adults create a circular exit hole when they emerge (Kobayashi et al. 1984).

The galleries of *M. alternatus* often are numerous, and because they penetrate deep within the wood, they lower the value of logs used for lumber (Duffy 1968). In addition, *M. alternatus* is the principal vector in Asia of the pinewood nematode, *Bursaphelenchus xylophilus* (Steiner & Buhrer) Nickle, which is the causal agent of pine wilt disease (Kobayashi et al. 1984; Togashi 2013). When adults emerge from infected trees, they can carry thousands of nematodes in their tracheal system, which are later released into healthy and dying pine trees when the adult beetles feed and oviposit (Kobayashi et al. 1984; Akbulut and Stamps 2012).

A thorough review of the control options available for *M. alternatus* has been prepared by the Centre for Agriculture and Biosciences International (CABI 2015a). Infested logs can be chipped, burned, or buried under at least 15 cm of soil. In outbreak areas of pine wilt disease, localized clear-cutting of infested trees followed by log treatment has reduced disease spread. Several pesticides have been tested and include insecticides applied to tree trunks and foliage as well as to target adults because they conduct maturation feeding and oviposit. Nematicides can also be used to inhibit development of pine wilt disease. Various biological control strategies have been developed using entomophagous fungi, nematodes, and larval parasitoids. Trap trees can be used to attract ovipositing adults followed by removal and destruction of the trees or logs. Traps baited with pheromones or with alpha-pinene and ethanol can be used to capture local adults and to serve as a tool for monitoring and control. In addition, breeding programs for resistance to pine wilt disease in Asian pines have been developed in China and Japan (Nose and Shiraishi 2008).

11.3.6 *Monochamus sutor* (L.)

Monochamus sutor is native to much of the Eurasian conifer belt from Spain through China and Russia to Korea and Japan (Bílý and Mehl 1989; Cherepanov 1990). The primary larval hosts of *M. sutor* in Europe are *Picea* and *Pinus* (Duffy 1953; Bílý and Mehl 1989; Bense 1995), with *Larix* being a major host in Siberia (Rozhkov 1970; Zhang et al. 1993) and *Abies* also serving as an occasional host (Novák 1976). *M. sutor* adults measure 15–26 mm in length (Cherepanov 1990). They have a strong spine on each side of the pronotum and overall are black in color with a yellow spot on the scutellum and several yellowish to whitish colored spots on the elytra that form three transverse dark-colored bands (Novák 1976; Bense 1995; Figure 11.27). Antennae in males are one-and-a-half to two times the body length (Rozhkov 1970).

Depending on local conditions, *M. sutor* requires one to three years to complete a single generation. Adults generally are active from late spring through summer. Adults conduct maturation feeding on twig bark for several days (Novák 1976). Females construct oviposition pits in the bark and then insert their ovipositor at the base and deposit one or a few eggs into the cambial region (Rozhkov 1970; Novák 1976). On average, females lay about 50 eggs in their lifetime (Duffy 1953). Early larval instars tunnel in the cambial region, scoring the sapwood deeply, and expel frass through the bark (Novák 1976). Late instars enter the sapwood and heartwood. Individuals overwinter as larvae. Some larval galleries extend from one side of the tree to the other side, while others are U-shaped in which the gallery starts and ends on the same side of the tree (Trägårdh 1930). Pupation occurs at the end of the gallery in spring or summer with the new adults emerging through a circular exit hole.

Monochamus sutor oviposits primarily on recently cut trees, especially along the lower trunk, and therefore greatly reduces their value (Duffy 1953; Novák 1976). At times, *M. sutor* has reached outbreak levels following large-scale defoliation events and fire (Rozhkov 1970; Zhang et al. 1993; Yuan et al. 2008). In addition, *M. sutor* is a potential vector of pinewood nematodes (Akbulut and Stamps 2012). Given the nature of *M. sutor* to rapidly infest recently cut trees, harvesting operations need to swiftly transport logs to sawmills and then process them, or if not possible, logs should be debarked (Rozhkov 1970).

FIGURE 11.27 *Monochamus sutor* adult from Austria. (Courtesy of Siga at commons.wikimedia.org.)

11.3.7 *Monochamus titillator* (F.)

Monochamus titillator is native to the eastern United States, Canada (Ontario), and the Bahamas (Browne et al. 1993; Evans 2014; Bezark 2015a) and was apparently introduced to Cuba (Peck 2005). The primary larval hosts include species of *Pinus* (Webb 1909; Baker 1972; Drooz 1985), but some authors also list *Abies* and *Picea* as potential hosts (Duffy 1953; Linsley and Chemsak 1984). Adults of *M. titillator* measure 16–31 mm in length and have a mottled appearance with a reddish-brown background color with small brown and gray patches (Webb 1909; Linsley and Chemsak 1984; Figure 11.28). The antennae are more than twice the body length in males and about the same length as the body in females (Linsley and Chemsak 1984).

The life cycle of *M. titillator* generally is univoltine with a partial second generation occurring in the southern United States (Webb 1909). Akbulut and Stamps (2012), however, state that *M. titillator* can complete up to three generations per year. Generations are overlapping, with most adults being present in the summer months, but likely year-round in the southern United States (Webb 1909; Baker 1972). Newly emerged adults feed on the bark of pine twigs until sexually mature (Luzzi et al. 1984; Akbulut and Stamps 2012). Typically, adults mate and oviposit on the trunks and major branches of severely weakened host trees, such as wind-thrown trees, bark beetle-infested trees, or on freshly cut logs (Webb 1909; Coulson et al. 1976; Akbulut and Stamps 2012). Females usually chew a funnel-shaped pit through the outer bark and then insert their ovipositor and lay one to nine eggs in a radial pattern (Webb 1909; Dodds et al. 2002). The eggs hatch in about a week with the new larvae first feeding in the cambial region and then entering the sapwood—usually constructing a deep U-shaped gallery—and then back to near the wood surface (Webb 1909). Pupation occurs at the end of the gallery with the new adult chewing a circular exit hole through the sapwood when it emerges (Webb 1909).

Most economic losses attributed to *M. titillator* result from the larval galleries that reduce wood quality and value. For example, Webb (1909) reported that, after a major wind event in the southern United States, nearly all storm-damaged trees were infested by *M. titillator* within a few months, and their galleries affected about 25% of the lumber cut from each log. *M. titillator* is also a major vector

FIGURE 11.28 *Monochamus titillator* adult from Louisiana (United States). (Courtesy of Natasha Wright [Bugwood image 5205031].)

of the pinewood nematode in North America (Luzzi et al. 1984) and therefore poses a risk to Asian and European pines if introduced elsewhere in pine logs, lumber, or wood packaging (Evans et al. 1996; Sathyapala 2004). Logs should be utilized quickly to minimize losses, especially from late-instar larvae that enter the sapwood. When rapid utilization is not possible, logs can be stored under water sprinklers, which limit oviposition (Syme and Saucier 1995).

11.3.8 *Plectrodera scalator* (Fabricius)

Plectrodera scalator is native to the eastern United States where it primarily utilizes species of *Populus* as larval hosts but will also infest *Salix* (Linsley and Chemsak 1984; Solomon 1995; Bezark 2015a). Adults of *P. scalator* measure 25–40 mm in length and generally are black in color with large white areas on the head and around the eyes, a series of white transverse bands on the thorax and elytra that produce a checkered appearance, and strong lateral prothoracic black spines (Linsley and Chemsak 1984; Solomon 1995; Figure 11.29).

The life cycle of *P. scalator* usually is completed in one to two years (Solomon 1995). Adults are most active in the summer months, first feeding on leaf petioles and twigs to become sexually mature, and then mating and ovipositing at the base of host trees. Adult females chew pits in the bark just below the soil line, insert their ovipositor, and usually lay a single egg (Solomon 1980, 1995). Eggs hatch in two to three weeks, with the new larvae first tunneling downward within the cambial region of the taproot, and eventually mine the sapwood (Solomon 1980). Most galleries are below ground, but some are found above ground level, especially when multiple larvae are found in the same host (Solomon 1980). Pupation occurs within the gallery in spring or early summer, lasting about three to four weeks (Solomon 1980). New adults chew exit holes through the bark near the groundline (Solomon 1980).

Plectrodera scalator infests nursery stock as well as young trees in plantations and natural stands (Solomon 1980). In nurseries, one- to two-year-old seedlings commonly are infested. A single larva seldom kills the seedling outright but can weaken it and make it susceptible to breakage. However, when

FIGURE 11.29 *Plectrodera scalator* adult from Oklahoma (United States). (Courtesy of Ben Sale at commons.wikimedia.org.)

multiple larvae occur in a single seedling or young tree, stem breakage is common (Solomon 1980). In one survey, Solomon (1980) reported that, on average, 4.6 larvae per tree were found in three-year-old *Populus* trees. In nursery beds, *Populus* trees can be protected with insecticides (Solomon 1980). When selecting new nursery sites, managers should choose sites far from known active *P. scalator* infestations, and they should use uninfested cuttings to establish the nursery. Moreover, it is recommended to rogue old rootstocks every three years and start with new cuttings to keep *P. scalator* populations low (Solomon 1980).

11.3.9 *Saperda calcarata* Say

Saperda calcarata is native to both Canada and the United States, being found throughout most of North America (Linsley and Chemsak 1984). The principal larval hosts of *S. calcarata* include species of *Populus*, with species of *Salix* being reported as occasional hosts. *S. calcarata* adults are 18–31 mm in length and have an overall grayish color with brown dots and a faint yellowish pattern on the head, prothorax, and elytra (Linsley and Chemsak 1984; Solomon 1995; Figure 11.30). The antennae are about the length of the body.

Saperda calcarata generally has a two-year life cycle in the southern United States but three to five years in the northern United States and Canada (Drouin and Wong 1975; Solomon 1995). Adults are active from late spring through summer, first feeding on foliage and twigs for about a week before mating and ovipositing. Females chew niches in the bark along the trunk and major branches and usually lay one egg per niche (Craighead 1923; Drouin and Wong 1975). Females usually oviposit on living trees that are at least 8 cm in diameter, but trees as small as 4 cm in diameter have been infested (Solomon 1995). Females oviposit preferentially on open-grown trees (Solomon 1995). Eggs hatch in about two weeks, and the larvae first feed in the cambial region and then in the sapwood and heartwood (Craighead 1923; Drouin and Wong 1975). Completed larval galleries are 15–25 cm in length (Solomon 1995). Individuals overwinter as larvae in each year of development. Larvae expel frass and wood shavings from enlarged holes constructed where they first entered the tree (Drouin and Wong 1975). Trees respond to the larval feeding by exuding sap that flows from the entry holes (Solomon 1995). Multiple larvae often are found feeding in the same region of a tree (Solomon 1995). Pupation occurs at the end of the gallery in spring or early summer, with the new adults emerging from the original entry hole (Solomon 1995).

FIGURE 11.30 *Saperda calcarata* adult in United States. (Courtesy of Whitney Cranshaw [Bugwood image 1325084].)

Small trees can be girdled and killed by *S. calcarata* larvae, but infestations seldom kill larger trees (Solomon 1995). However, larval feeding, especially when multiple larvae are present, weakens trees and makes them prone to breakage from wind and snow (Drouin and Wong 1975; Solomon 1995). Solomon (1995) provided data from several surveys conducted in Canada and the United States in which an average of 20–63% of the *Populus* trees inspected had evidence of current and past *S. calcarata* infestation. In addition, larval galleries can serve as infection courts for various canker fungi (Anderson and Martin 1981). When infested trees are used for lumber, their value is reduced because of the larval galleries and staining (Solomon 1995). Silvicultural control options include proper site selection, maintaining well-stocked stands, and harvesting stands at maturity (Solomon 1995). Several systemic insecticides were tested against larvae by Drouin and Wong (1975).

11.3.10 *Saperda carcharias* (L.)

Saperda carcharias is native to much of Palearctic Eurasia from Spain and the United Kingdom eastward to Siberia, China, and Korea (Novák 1976; Bílý and Mehl 1989; Bense 1995). The principal larval hosts are species of *Populus*, with *Salix* species serving as occasional hosts (Duffy 1953; Bense 1995). *S. carcharias* adults are 18–30 mm long and have an overall dark body with yellowish-gray to yellowish-brown pubescence and numerous black spots on the head, prothorax, and elytra (Ritchie 1920; Novák 1976; Bense 1995; Figure 11.31). In general, the antennae of males are slightly longer than the body, whereas in females they are shorter than the body length (Novák 1976).

The life cycle of *S. carcharias* usually is completed in two to four years (Ritchie 1920; Bílý and Mehl 1989). Adults are active during the summer months. After emergence, adults conduct maturation feeding on foliage and twig bark of host trees (Ritchie 1920; Novák 1976). Adults usually mate on twigs and then the females oviposit on the trunks of both young and mature live trees, especially those growing in open settings (Novák 1976). Females use their mandibles to cut a vertical slit in the bark and then turn and deposit a single egg under the bark (Ritchie 1920). On average, each female lays 40–50 eggs (Novák 1976). Larvae do not eclose from the eggs until the following spring at which time they first feed in the cambial region and then enter the sapwood, tunneling downward at first and then reversing

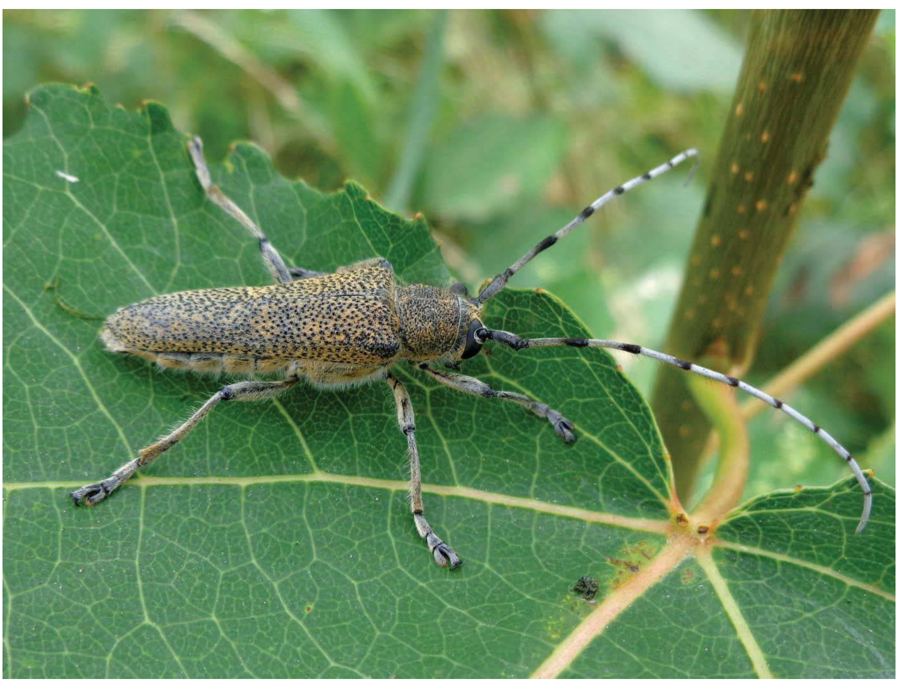

FIGURE 11.31 *Saperda carcharias* adult on *Populus* in Latvia. (Courtesy of AfroBrazilian at commons.wikimedia.org.)

direction and tunneling upward (Ritchie 1920; Novák 1976). Larvae eject frass from their galleries, which can extend 25–50 cm overall (Novák 1976). Several larvae can be found in the same trees, often tunneling near each other (Ritchie 1920). Trees often become swollen around the feeding sites (Novák 1976). Pupation occurs at the end of the larval gallery in spring and lasts for about one month (Novák 1976). Adults emerge through an oval-shaped exit hole (Ritchie 1920).

Infestation by *S. carcharias* can cause severe economic losses given that otherwise healthy trees often are infested and that the larval galleries extend to the heartwood. Small-diameter trees can be killed by just a few larvae. Larger-diameter trees often suffer growth loss, and the galleries can serve as infection courts for fungi. Lumber from infested trees is greatly reduced in value because of the extensive tunneling (Ritchie 1920; Duffy 1953; Novák 1976; de Tillesse et al. 2007). Insecticides have been used to protect high-value trees, with products applied to the trunks to kill early larval instars, and systemic insecticides have been used for late-instar larvae that are deeper in the wood (CABI 2010). Various barriers have also been tested to restrict adult beetles from climbing on trunks (Allegro 1990).

11.4 Parandrinae

11.4.1 *Neandra brunnea* (Fabricius)

Neandra (= *Parandra*) *brunnea* is native to Canada and the United States, being most common in eastern North America (Brooks 1915; Linsley 1962a). In addition, *N. brunnea* has been considered established in the area of Dresden, Germany, since the early 1900s, likely having been moved in association with World War I (Cocquempot and Lindelöw 2010). Most hardwoods and some conifers serve as larval hosts to *N. brunnea*. Solomon (1995) listed the following hardwood genera as common North American hosts: *Acer, Carya, Castanea, Fagus, Fraxinus, Juglans*, *Liquidambar, Liriodendron, Malus, Populus*, *Prunus, Pyrus, Quercus, Robinia, Salix*, *Ulmus*, and *Tilia*. In Germany, *Populus* and *Tilia* have been reported as larval hosts (Cocquempot and Lindelöw 2010). Adults measure 8–21 mm in length, are in various shades of brown color, and are very similar in appearance to some stag beetles (Lucanidae) (Linsley 1962a; Baker 1972; Solomon 1995; Figure 11.32).

The typical life cycle of *N. brunnea* is thought to span two to four years (Gahan 1911; Brooks 1915; Craighead 1950; Baker 1972; Solomon 1995). Adults are active in summer, often laying eggs in exposed

FIGURE 11.32 *Neandra brunnea* adult from United States. (Courtesy of Joseph Berger [Bugwood image 5385937].)

wood near the ground, such as near bark wounds or on wood structures that are in contact with moist soil (Craighead 1950). Apparently some adults do not emerge from the wood when mature but rather stay within the wood, mate, and lay eggs (Craighead 1950). The larvae tunnel in both sapwood and heartwood, often gregariously, which tends to honeycomb the wood. The individual galleries are packed with granular frass. The mature larva constructs an oval pupal cell at the end of the gallery and also plugs the gallery with a wad of wood fibers. The pupal period usually spans about a month (Brooks 1915).

Neandra brunnea has been reported as a destructive pest in the United States since the late 1800s (Brooks 1915). Most reports have referred to stem breakage of mature shade trees and fruit trees especially in the lower meter of trunk, where most larval tunneling occurs (Brooks 1915). During the late 1800s and early 1900s, *N. brunnea* was considered a major pest of wood poles used to support telegraph and telephone lines in the eastern United States, especially those made from *Castanea* trees (Snyder 1911; Gahan 1911). Given that oviposition usually occurs near exposed dead wood, wounding of trees should be avoided, and when wounds do occur, they should be covered if possible (Brooks 1915; Solomon 1995).

11.5 Prioninae

11.5.1 *Mallodon downesii* Hope

Mallodon downesii is found throughout much of central and southern Africa, from Senegal to Kenya to South Africa, and also in Madagascar (Delahaye and Tavakilian 2009). This species is highly polyphagous, infesting a wide variety of woody plants that include dozens of crop trees (e.g., cacao, ceara rubber, coffee, and kapok) as well as timber and ornamental trees (e.g., species of *Acacia, Albizia, Ceiba, Cleistopholis, Cordia, Daniellia, Delonix, Ekebergia, Ficus, Khaya, Lophira, Parinari, Pterocarpus, Tamarindus, Tectona*, and many more) (Duffy 1957, 1980; Roberts 1969; Rathore 1995; Delahaye and Tavakilian 2009). *M. downesii* is found in many environments from rain forest to savanna (Roberts 1969). *M. downesii* adults measure 27–70 mm in length and are reddish brown in color with very large mandibles, antennae about half the length of the body, and elytra that are lustrous with reflexed margins (Duffy 1957; Delahaye and Tavakilian 2009; Figure 11.33).

The life cycle of *M. downesii* generally is thought to be completed in a year or less (Duffy 1957). Adults can be found nearly year-round in many locations but from March to October is most common (Roberts 1969). Eggs are laid in bark cracks or under bark of recently cut trees, logs, stumps, and exposed

FIGURE 11.33 *Mallodon downesii* adult male from Cameroon. (Courtesy of Ben Sale at commons.wikimedia.org.)

roots (Duffy 1957). Females will oviposit on both decayed and sound wood. The larvae first tunnel in the sapwood and later in the heartwood, penetrating to depths of more than 20 cm (Duffy 1957). The larval galleries are filled with coarse wood shavings. Pupation occurs within the wood often at a depth of 10–15 cm (Duffy 1957).

In many situations, *M. downesii* is considered a minor pest given that oviposition often occurs in well-decayed wood that has little commercial value (Duffy 1957). However, at times, *M. downesii* infests dying trees and recently cut logs that have sound wood; in these situations, the commercial value of the lumber is reduced (Duffy 1957; Roberts 1969). Given this beetle's life history traits, infestations could be lowered by utilizing logs soon after harvesting and by chemically treating or possibly chipping or grinding logging debris and stumps (Mayné 1914).

11.5.2 *Paroplites australis* (Erichson)

Paroplites australis is native to Australia, being found primarily in the coastal areas of New South Wales, Queensland, Tasmania, and Victoria (McKeown 1947; Duffy 1963). The principal host plants are members of the genus *Banksia*, especially *Banksia serrata* L.f., but *P. australis* has also been reported to infest native and introduced trees in the genera *Angophora, Betula, Casuarina, Eucalyptus, Quercus*, and *Salix* (Froggatt 1923; McKeown 1947; Duffy 1963; Fearn 1989; Hawkeswood 1992; Hawkeswood and Turner 2003). *P. australis* adults are 27–53 mm long, dark reddish brown, with slightly flattened elytra, antennae shorter than its body length, and a flattened prothorax that is finely toothed along the outer margin (Froggatt 1923; Elliott et al. 1998; Figure 11.34).

The duration of the life cycle has not been studied in detail but is likely annual based on observations given in Fearn (1989) and Hawkeswood (1992). Adults are present during the summer months, mating and laying eggs at night, while being mostly inactive on the bark of host trees during the day (Froggatt 1923; Hawkeswood 1992; Hawkeswood and Turner 2003). Adults lay eggs on both living and dead host trees (Hawkeswood 1992). The larvae tunnel deep within the sapwood and heartwood of the main trunk and major branches, creating wide galleries that are packed with frass and wood shavings (Froggatt 1923; Hawkeswood 1992). Several larvae can be present within the same tree. For example, Froggatt (1923) mentioned that more than 30 adults were reared from the trunk section of a single *B. serrata* tree. Pupation occurs at the end of the gallery in a large oval chamber, which is constructed close to the wood surface (Froggatt 1923; Hawkeswood 1992).

Trees in both natural and urban settings are infested by *P. australis* (Froggatt 1923; Hawkeswood 1992). Heavily infested trees are easily broken during wind storms (Froggatt 1923). *P. australis* potentially is a major pest given that it infests living trees in several plant families. Froggatt (1923) recommends destruction of infested live trees as well as recently cut or dead host trees.

FIGURE 11.34 *Paroplites australis* adult from Australia. (Courtesy of CSIRO at scienceimage.csiro.au.)

11.6 Spondylidinae

11.6.1 *Tetropium castaneum* (L.)

Tetropium castaneum is native to Palearctic Eurasia from Spain through Russia to China, and Mongolia, Korea, and Japan (Novák 1976; Bílý and Mehl 1989; Bense 1995). *T. castaneum* is not known to be established in North America, although it has been intercepted and trapped on occasion (LaBonte et al. 2005). Species of *Picea* and *Pinus* are the preferred larval hosts; however, *T. castaneum* will also infest species of *Abies* and *Larix* (Rozhkov 1970; Novák 1976). *T. castaneum* adults measure 9–18 mm in length and usually have a black head and pronotum with brown or black elytra (Novák 1976; Figure 11.35). The adult body is flattened dorsoventrally, their eyes are separated into two halves, and they have a pronounced longitudinal groove between the antennae (Novák 1976).

Tetropium castaneum usually completes its life cycle in one year, but two years may be needed occasionally. Adults are active throughout the summer months, especially during June–July, mating and laying eggs on the bark of host trees. Eggs usually are laid singly or in small batches in bark crevices or under bark flakes, hatching in 10–14 days (Novák 1976; Bílý and Mehl 1989). Larvae feed initially in the cambial region, constructing irregular galleries with granular frass, and then enter the sapwood, tunneling perpendicular to the wood surface at first to a depth of 2–4 cm and then boring parallel to the surface of the wood for another 3–4 cm (Trägårdh 1930; Novák 1976). Individuals overwinter in the larval stage at the end of their galleries, pupating in spring or summer. Adults emerge through oval-shaped exit holes.

Tetropium castaneum typically infests recently cut logs and stumps but can infest living trees, especially those stressed by drought, air pollution, disease, and defoliation. Larval galleries cause structural damage and can reduce the value of lumber (Novák 1976). Living trees can be killed by *T. castaneum* especially after multiple years of infestation. Logs should be utilized quickly to minimize infestation and larval tunneling (Novák 1976).

FIGURE 11.35 *Tetropium castaneum* adult from Russia. (Courtesy of Karill Makarov at cerambycidae.org.)

11.6.2 *Tetropium fuscum* (F.)

Tetropium fuscum is native to Eurasia, occurring from central and northern Europe to Siberia and Japan (Novák 1976; Bílý and Mehl 1989; Bense 1995). Outside its native range, *T. fuscum* has become established in Canada, being first reported in Nova Scotia in 2000 (Smith and Hurley 2000) and showing very limited spread as of 2010 (Rhainds et al. 2011). In Europe, the most common larval hosts of *T. fuscum* include species of *Picea* and *Pinus* (Bílý and Mehl 1989; Bense 1995), but *Abies* and *Larix* may also be infested (Novák 1976). In Canada, only species of *Picea* have been reported as larval hosts so far (Smith and Humble 2000; Flaherty et al. 2011). *T. fuscum* adults are 8–18 mm in length, appear dorsoventrally flattened, and their head and pronotum are dark brown to black, while the elytra are various lighter shades of brown (Novák 1976; Smith and Humble 2000; Figure 11.36). The eyes are divided (Smith and Humble 2000).

The biology of *T. fuscum* is very similar to that described earlier for *T. castaneum*. The life cycle of *T. fuscum* usually is univoltine in both Eurasia (Bílý and Mehl, 1989) and Canada (Smith and Humble 2000). Adults are active from late spring through summer, with females ovipositing in bark cracks and crevices (Smith and Humble 2000). Eggs usually are laid singly or in small clusters in bark cracks along the trunk (Smith and Hurley 2000). Resin often exudes from infested trees at sites where the larvae are feeding (Smith and Humble 2000). Larvae first tunnel in the cambial region and then form a hook-like gallery in the sapwood by first boring perpendicular to the wood surface for 2–4 cm and then boring parallel to the stem surface for about 3–4 cm (Novák 1976). Overwintering takes place in the larval stage at the end of the gallery, with pupation occurring the following spring (Bílý and Mehl 1989). Adults construct oval-shaped exit holes as they emerge (Novák 1976).

In Eurasia, *T. fuscum* generally infests weakened and recently dead host trees, but in Canada, apparently healthy spruce trees have been infested and killed (Smith and Humble 2000). In Canada, an active eradication effort was attempted from 2000 to 2006, but since then a containment program has been in place in Nova Scotia to reduce the likelihood of human-assisted transport of infested host material (CFIA 2015). Extensive tunneling of the sapwood by larvae reduces wood quality and value (Novák 1976).

FIGURE 11.36 *Tetropium fuscum* adult from Germany. (Courtesy of Udo Schmidt at www.kaefer-der-welt.com.)

Logs should be utilized quickly to minimize infestation and wood quality as a result of larval tunneling (Novák 1976). Heat treatment has been shown to be effective in sanitizing wood cut from infested trees (Mushrow et al. 2004).

11.7 Summary and Future Outlook

The cerambycid species discussed in this chapter represent only a few of the thousands of tree-infesting species found throughout the world. Many more species could have been included but were lacking basic life history data. For example, for the large African Prioninae species *Tithoes confinis* (Castelnau) (Figure 11.37), many references were found describing its geographic range, larval host range, size, and color, but few papers provided information on its life cycle and economic impact. There is therefore a great need for basic research on the biology and ecology of most of the world's cerambycids. Not only would such basic information be useful to people within the native range of each insect but also to others throughout the world if these species become established elsewhere. This is especially important for species that may cause little economic impact in their native range but that become major pests when introduced elsewhere or when new host plants are grown within an insect's native range. Such relationships have been well documented throughout the world for many bark- and wood-infesting borers in addition to cerambycids (Yan et al. 2005; Haack 2006; Poland and McCullough 2006; Cocquempot and Lindelöw 2010; Haack et al. 2010a; Nielsen et al. 2011; Haack and Rabaglia 2013; Montecchio and Faccoli 2013; Haack et al. 2015).

Most of the tree-infesting cerambycids that have become established in areas outside their native range were likely moved inadvertently by humans in logs, lumber, firewood, wood packaging, and in live plants (Haack 2006; Haack et al. 2010a, 2010b, 2014; Liebhold et al. 2012; Rassati et al. 2016, see Chapter 13). As an example of the diversity of cerambycid species moved in international trade, data are presented in Table 11.3 on the number of cerambycid interceptions that were made at U.S. ports of entry on wood packaging and wood products during 1984–2008 and identified to at least the genus level. Overall, there were 2,655 cerambycid interceptions identified to at least the genus level, representing 76% of all 3,483 wood-associated cerambycid interceptions made during this period. Overall, the 2,655 interceptions represent 84 genera in five subfamilies, including 46 genera of Cerambycinae, 28 Lamiinae, 2 Lepturinae, 4 Prioninae, and 4 Spondylidinae (Table 11.3). Given this evidence, there is a great likelihood that many more cerambycid species will become established outside their native ranges in the future as a result of world trade and travel (Brockerhoff et al. 2014), although international standards to regulate wood packaging such as International Standards for Phytosanitary Measures (ISPM) No. 15 will help lower the arrival rate of potential pests (Haack et al. 2014).

FIGURE 11.37 *Tithoes confinis* adult male from Tanzania. (Courtesy of Ben Sale at commons.wikimedia.org.)

TABLE 11.3

Number of Cerambycid Interceptions on Wood Packaging and Wood Products at U.S. Ports of Entry from 1984 to 2008 that Were Identified to at Least the Genus Level (N = 2,655)

Subfamily Genus	Number of Interceptions	Major World Region Where Infested Imports Originated
Cerambycinae	807	–
Acyphoderes	1	South America
Aeolesthes	2	Asia
Aromia	1	Asia
Callidiellum	44	Asia
Callidium	64	Eurasia
Cerambyx	2	South America
Ceresium	140	Eurasia
Chlorida	2	South America
Chlorophorus	17	Eurasia
Chydarteres	1	South America
Clytus	5	Europe
Demonax	1	Asia
Dere	1	Asia
Diorthus	1	Asia
Eburia	2	Central America
Elaphidion	5	Asia, Central America
Epipedocera	1	Asia
Euryscelis	1	South America
Gnaphalodes	2	Mexico
Gracilia	1	Europe
Hesperophanes	78	Eurasia
Hylotrupes	21	Eurasia
Icosium	5	Europe
Knulliana	1	Asia
Lissonotus	1	South America
Megacyllene	4	Central America, South America
Molorchus	39	Europe
Nathrius	2	South America
Neoclytus	5	Central America, South America
Odontocera	2	South America
Pachydissus	2	Asia
Palaeocallidium	2	Asia
Perissus	1	Asia
Phoracantha	11	Africa, Oceania, South America
Phymatodes	70	Eurasia, Mexico
Placosternus	1	South America
Plagionotus	25	Eurasia
Pyrrhidium	30	Eurasia
Semanotus	3	Asia
Smodicum	1	South America
Stizocera	1	Central America
Stromatium	11	Eurasia
Trachyderes	19	South America
Trichoferus	6	Asia

(Continued)

TABLE 11.3 ***(Continued)***

Number of Cerambycid Interceptions on Wood Packaging and Wood Products at U.S. Ports of Entry from 1984 to 2008 that Were Identified to at Least the Genus Level (N = 2,655)

Subfamily Genus	Number of Interceptions	Major World Region Where Infested Imports Originated
Xylotrechus	159	Eurasia
Xystrocera	13	Eurasia, Africa
Lamiinae	691	–
Acanthocinus	14	Europe
Agapanthia	2	Europe
Anelaphus	7	Central America
Anoplophora	41	Asia
Apriona	1	Asia
Ataxia	1	Mexico
Batocera	12	Asia
Coptops	5	Asia
Desmiphora	1	Mexico
Dihammus	1	Oceania
Glenea	1	Asia
Lagocheirus	2	Central America
Lamia	10	Europe
Leiopus	1	Europe
Leptostylus	4	Central America
Lepturges	1	Central America
Monochamus	540	Eurasia, Mexico
Nyssodrysina	2	Asia
Olenecamptus	4	Asia
Oncideres	2	Mexico
Petrognatha	1	Africa
Pogonocherus	8	Europe
Prosoplus	1	Asia
Pterolophia	2	Asia
Ropica	1	Asia
Saperda	22	Eurasia
Steirastoma	1	South America
Urgleptes	3	Central America, South America
Lepturinae	43	–
Leptura	17	Asia
Rhagium	26	Eurasia
Prioninae	9	–
Derobrachus	1	Mexico
Mallodon	2	Mexico
Prionus	3	Eurasia
Stenodontes	3	Central America South America
Spondylidinae	1,105	–
Arhopalus	637	Eurasia, Central America
Asemum	11	Eurasia
Oxypleurus	7	Europe
Tetropium	450	Eurasia, Canada

Source: USDA APHIS Pest ID database (see Haack et al. 2014).

Data are presented alphabetically by subfamily and genus. The principal world regions that were the origin of the infested imports are listed.

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REFERENCES

Akanbi, M. O., and M. O. Ashiru. 2002. *A handbook of forest and wood insects of Nigeria*. Ibadan: Forestry Research Institute of Nigeria and Agbo Areo.

Akbulut, S., and W. T. Stamps. 2012. Insect vectors of the pinewood nematode: A review of the biology and ecology of *Monochamus* species. *Forest Pathology* 42: 89–99.

Allegro, G. 1990. Lotta meccanica contro i principali insetti xilofagi del pioppo mediante impiego di sbarramenti sui tronchi. *L' Informatore Agrario* 46: 91–95.

Allen, E. A., and L. M. Humble. 2002. Nonindigenous species introductions: A threat to Canada's forests and forest economy. *Canadian Journal of Plant Pathology* 24: 103–110.

Anderson, G. W., and M. P. Martin. 1981. Factors related to incidence of *Hypoxylon* cankers in aspen and survival of cankered trees. *Forest Science* 27: 461–476.

Bahillo de la Puebla, P., and J. C. Iturrondobeitia Bilbao. 1995. Primera cita de *Callidiellum rufipenne* (Motschulsky, 1860) para la Península Ibérica (Coleoptera: Cerambycidae). *Boletín de la Asociación española de Entomología* 19: 204.

Bain, J. 2009. *Hylotrupes bajulus*—Setting the record straight. Forest Health News 196, Rotorua, New Zealand: Scion. http://www.scionresearch.com/_data/assets/pdf_file/0008/6884/FHNews-196_July.pdf (accessed December 30, 2015).

Bain, J. 2012. *Phoracantha* longhorn beetles in New Zealand. Forest Health News 222, Rotorua, New Zealand, Scion. http://www.scionresearch.com/_data/assets/pdf_file/0010/37729/FHNews-222_Feb2012.pdf (accessed December 30, 2015).

Baker, W. L. 1972. *Eastern forest insects*. Washington, DC: USDA Forest Service, Miscellaneous Publication No. 1175.

Barr, W. F., and H. C. Manis. 1954. The red-headed ash borer in Idaho. *Journal of Economic Entomology* 47: 1150.

Bayford, E. G. 1938. Retarded development: *Hylotrupes bajulus* L. *The Naturalist, London* 980: 254–256.

Beeson, C. F. C. 1941. *The ecology and control of the forest insects of India and the neighbouring countries.* Dehra Dun: Bishen Singh Mahendra Pal Singh.

Beeson, C. F. C., and B. M. Bhatia. 1939. On the biology of the Cerambycidae (Coleopt.). *Indian Forest Records (new series) Entomology* 5: 1–235.

Bense, U. 1995. *Longhorn beetles. Illustrated key to the Cerambycidae and Vesperidae of Europe.* Weikersheim, Germany: Margraf Verlag.

Bezark, L. G. 2015a. New World Cerambycidae catalog. https://apps2.cdfa.ca.gov/publicApps/plant/bycidDB/wdefault.asp?w=n (accessed December 30, 2015).

Bezark, L. G. 2015b. Checklist of the Oxypeltidae, Vesperidae, Disteniidae and Cerambycidae, (Coleoptera) of the Western Hemisphere. (2015 ed.). https://apps2.cdfa.ca.gov/publicApps/plant/bycidDB/checklists/WestHemiCerambycidae2015.pdf (accessed December 30, 2015).

Bílý, S., and O. Mehl. 1989. Longhorn beetles (Coleoptera, Cerambycidae) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavica* 22: 1–204.

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

Brockerhoff, E. G., M. Kimberley, A. M. Liebhold, R. A. Haack, and J. F. Cavey. 2014. Predicting how altering propagule pressure changes establishment rates of biological invaders across species pools. *Ecology* 95: 594–601.

Brooks, F. E. 1915. The parandra borer as an orchard enemy. *USDA Bureau of Entomology Bulletin* 262: 1–7.

Browne, F. G. 1968. *Pests and diseases of forest plantation trees: An annotated list of the principal species occurring in the British Commonwealth*. Oxford: Clarendon Press.

Browne, D. J., S. B. Peck, and M. A. Ivie. 1993. The longhorn beetles (Coleoptera Cerambycidae) of the Bahama Islands with an analysis of species-area relationships, distribution patterns, origin of the fauna and an annotated species list. *Tropical Zoology* 6: 27–53.

Bullas-Appleton, E., T. Kimoto, and J. J. Turgeon. 2014. Discovery of *Trichoferus campestris* (Coleoptera: Cerambycidae) in Ontario, Canada and first host record in North America. *The Canadian Entomologist* 146: 111–116.

Burfitt, C. E., K. Watson, C. A. Pratt, and J. Caputo. 2015. Total records of velvet longhorn beetle *Trichoferus campestris* Faldermann (Coleoptera: Cerambycidae) from Utah. In *USDA lnteragency research forum on invasive species, 2015*, eds. K. A. McManus, and K. W. Gottschalk, 57. Ft. Collins, CO: USDA Forest Service, Forest Health Technology Enterprise Team, FHTET-2015-09.

CABI. 2010. *Saperda carcharias* (large poplar borer). Invasive species compendium. http://www.cabi.org/isc/datasheet/48316 (accessed February 9, 2016).

CABI. 2015a. *Monochamus alternatus* (Japanese pine sawyer). Invasive species compendium. http://www.cabi.org/isc/datasheet/34719 (accessed February 9, 2016).

CABI. 2015b. *Phoracantha recurva* (eucalyptus longhorned borer). Invasive species compendium. http://www.cabi.org/isc/datasheet/40371 (accessed December 30, 2015).

CABI. 2015c. *Phoracantha semipunctata* (eucalyptus longhorned borer). Invasive species compendium. http://www.cabi.org/isc/datasheet/40372 (accessed December 30, 2015).

Campadelli, G., and G. Sama. 1989. First record in Italy of a Japanese cerambycid: *Callidiellum rufipenne* Motschulsky. *Bollettino dell'Instituto di Entomologia "Guido Grandi" della Universita degli Studi di Bologna* 43: 69–73.

CFIA (Canadian Food Inspection Agency). 2015. Brown spruce longhorn beetle—*Tetropium fuscum*. http://www.inspection.gc.ca/plants/plant-pests-invasive-species/insects/brown-spruce-longhorn-beetle/eng/1330656129493/1330656721978 (accessed December 30, 2015).

Cherepanov, A. I. 1988a. *Cerambycidae of Northern Asia, Vol. 2, Cerambycinae, Part I.* New Delhi: Amerind.

Cherepanov, A. I. 1988b. *Cerambycidae of Northern Asia. Vol. 2: Cerambycinae. Part 2.* New Delhi: Amerind.

Cherepanov, A. I. 1990. *Cerambycidae of Northern Asia. Vol. 3: Lamiinae. Part 1.* New Delhi: Amerind.

Cibrián Tovar, D., J. T. Méndez Montiel, R. Campos Bolaños, H. O. Yates III, and J. E. Flores Lara. 1995. *Forest insects of Mexico.* Chapingo, Mexico: Universidad Autónoma Chapingo.

Cillie, J. J., and G. D. Tribe. 1991. A method for monitoring egg production by the *Eucalyptus* borers *Phoracantha* spp. (Cerambycidae). *South African Forestry Journal* 157: 24–26.

Cocquempot, C. 2006. Alien longhorned beetles (Coleoptera: Cerambycidae): Original interceptions and introductions in Europe, mainly France, and notes about recently imported species. *Redia* 89: 35–50.

Cocquempot, C., and A. Lindelöw. 2010. Longhorn beetles (Coleoptera, Cerambycidae). *BioRisk* 4: 193–218.

Cocquempot, C., and D. Mifsud. 2013. First European interception of the brown fir longhorn beetle, *Callidiellum villosulum* (Fairmaire, 1900) (Coleoptera, Cerambycidae). *Bulletin of the Entomological Society of Malta* 6: 143–147.

Cocquempot, C., A. Drumont, D. Brosens, and H. V. Ghate. 2014. First interception of the cerambycid beetle *Stromatium longicorne* (Newman, 1842) in Belgium and distribution notes on other species of *Stromatium* (Coleoptera: Cerambycidae: Cerambycinae). *Bulletin de la Société royale belge d'Entomologie* 150: 201–206.

Coulson, R. N., A. M. Mayyasi, J. L. Foltz, and F. P. Hain. 1976. Interspecific competition between *Monochamus titillator* and *Dendroctonus frontalis*. *Environmental Entomology* 5: 235–247.

Craighead, F. C. 1923. North American cerambycid larvae. *Bulletin of the Canada Department of Agriculture* 27: 1–239.

Craighead, F. C. 1950. *Insect enemies of eastern forests*. Washington, DC: USDA Forest Service, Miscellaneous Publication No. 657.

Curry, S. J. 1965. The biology and control of *Oemida gahani* Distant, (Cerambycidae), in Kenya. *East African Agricultural and Forestry Journal* 31: 224–235.

Danilevsky, M. L. 2015. Systematic list of longicorn beetles (Cerambycoidea) of the territory of the former USSR. http://www.cerambycidae.net/ussr.pdf (accessed December 30, 2015).

Dascalu, M-M; R Serafim, Å Lindelöw. 2013. Range expansion of *Trichoferus campestris* (Faldermann) (Coleoptera: Cerambycidae) in Europe with the confirmation of its presence in Romania. *Entomologica Fennica* 24: 142–146.

Daubenmire, R. 1978. *Plant geography: With special reference to North America*. New York, Academic Press.

Delahaye, N., and G. L. Tavakilian. 2009. Note sur *Mallodon downesii* Hope, 1843, et mise en synonymie de *M. plagiatum* Thomson, 1867 (Coleoptera, Cerambycidae). *Bulletin de la Société entomologique de France* 114: 39–45.

de Tillesse, V., L. Nef, J. G. Charles, A. Hopkin, and S. Augustin. 2007. *Damaging poplar insects—Internationally important species*. Rome: Food and Agricultural Organization. http://www.fao.org/forestry/foris/pdf/ipc/damaging_poplar_insects_eBook.pdf (accessed December 30, 2015).

Dhakal, L. P., P. K. Jha, and E. D. Kjaer. 2005. Mortality in *Dalbergia sissoo* (Roxb.) following heavy infection by *Aristobia horridula* (Hope) beetles. Will genetic variation in susceptibility play a role in combating declining health? *Forest Ecology and Management* 218: 270–276.

Di Iorio, O. R. 1995. The genus *Neoclytus* Thomson, 1860 (Coleoptera: Cerambycidae) in Argentina. *Insecta Mundi* 9: 335–345.

Di Iorio, O. R. 2004a. Exotic species of Cerambycidae (Coleoptera) introduced in Argentina. Part 1: The genus *Phoracantha* Newman, 1840. *Agrociencia* 38: 503–515.

Di Iorio, O. R. 2004b. Exotic species of Cerambycidae (Coleoptera) introduced in Argentina. Part 2: New records, host plants, emergence periods, and current status. *Agrociencia* 38: 663–678.

Dodds, K. J., C. Graber, and F. M. Stephen. 2002. Oviposition biology of *Acanthocinus nodosus* (Coleoptera: Cerambycidae) in *Pinus taeda*. *Florida Entomologist* 85: 452–457.

Donley, D. E. 1978a. Oviposition by the red oak borer, *Enaphalodes rufulus* Coleoptera: Cerambycidae. *Annals of the Entomological Society of America* 71: 496–498.

Donley, D. E. 1978b. Distribution of the white oak borer *Goes tigrinus* DeGeer (Coleoptera: Cerambycidae) in a mixed oak stand. In *Proceedings, Central Hardwood Forest Conference*, 14–16 November 1978, 529–539. West Lafayette, Indiana: Purdue University, Department of Forestry and Natural Resources.

Donley, D. E., and Acciavatti, R. E. 1980. Red oak borer. *USDA Forest Service, Forest Insect & Disease Leaflet* 163.

Donley, D. E., and E. Rast. 1984. Vertical distribution of the red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae), in red oak. *Environmental Entomology* 13: 41–44.

Drinkwater, T. W. 1975. The present pest status of eucalyptus borers *Phoracantha* spp. in South Africa. In *Proceedings of the First Congress of the Entomological Society of Southern Africa*, ed. H. J. R. Durr, J. H. Giliomee, and S. Neser, 119–129. Pretoria: Entomological Society of Southern Africa.

Drooz, A. T., ed. 1985. *Insects of eastern forests*. Washington, DC: USDA Forest Service Miscellaneous Publication 1426.

Drouin, J. A., and H. R. Wong. 1975. Biology, damage, and chemical control of the poplar borer (*Saperda calcarata*) in the junction of the root and stem of balsam poplar in western Canada. *Canadian Journal of Forest Research* 5: 433–439.

Drumont A., K. Smets, K. Scheers, A. Thomaes, R. Vandenhoudt, and M. Lodewyckx. 2014. *Callidiellum rufipenne* (Motschulsky, 1861) en Belgique: bilan de sa présence et de son installation sur notre territoire (Coleoptera: Cerambycidae: Cerambycinae). *Bulletin de la Société royale belge d'Entomologie* 150: 239–249.

Duan Y. 2001. Study on *Apriona swainsoni* Hope of devastating pest in *Sophora japonica* Linn. *Journal of Anhui Agricultural Sciences* 29: 375–377.

Duffy E. A. J. 1953. *A monograph of the immature stages of British and imported timber beetles (Cerambycidae).* London: British Museum (Natural History).

Duffy E. A. J. 1957. *A monograph of the immature stages of African timber beetles (Cerambycidae).* London: British Museum (Natural History).

Duffy E. A. J. 1960. *A monograph of the immature stages of neotropical timber beetles (Cerambycidae).* London: British Museum (Natural History).

Duffy E. A. J. 1963. *A monograph of the immature stages of Australasian timber beetles (Cerambycidae).* London: British Museum (Natural History).

Duffy E. A. J. 1968. *A monograph of the immature stages of oriental timber beetles (Cerambycidae).* London: British Museum (Natural History).

Duffy E. A. J. 1980. *A monograph of the immature stages of African timber beetles (Cerambycidae) supplement.* Slough, England: Commonwealth Institute of Entomology.

Eldridgea, R. H., and J. A. Simpson. 1987. Development of contingency plans for use against exotic pests and diseases of trees and timber. 3. Histories of control measures against some introduced pests and diseases of forests and forest products in Australia. *Australian Forestry* 50: 24–36.

Elliot, H. J., and D. W. de Little 1984. *Insect pests of trees and timber in Tasmania*. Hobart, Tasmania: Forestry Commission.

Elliot, H. J., C. P. Ohmart, and F. R. Wylie. 1998. *Insect pests of Australian forests: Ecology and management.* Melbourne: Butterworth-Heinemann.

Endang, A. H., and N. F. Haneda. 2010. Infestation of *Xystrocera festiva* in *Paraserianthes falcataria* plantation in East Java, Indonesia. *Journal of Tropical Forest Science* 22: 397–402.

EPPO (European and Mediterranean Plant Protection Organization). 2005. *Xylotrechus altaicus*. *EPPO Bulletin* 35: 406–408.

EPPO (European and Mediterranean Plant Protection Organization). 2013. Pest risk analysis for *Apriona germari, A. japonica, A. cinerea*. Paris: EPPO. http://www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRA_intro.htm (accessed December 30, 2015).

EPPO (European and Mediterranean Plant Protection Organization). 2015. *Callidiellum rufipenne*. EPPO Global Database. https://gd.eppo.int/taxon/CLLLRU (accessed December 30, 2015).

Evans, A. V. 2014. *Beetles of eastern North America*. Princeton, NJ: Princeton University Press.

Evans, H. F., D. G. McNamara, H. Braasch, J. Chadoeuf, and C. Magnusson. 1996. Pest risk analysis (PRA) for the territories of the European Union (as PRA area) on *Bursaphelenchus xylophilus* and its vectors in the genus *Monochamus*. *EPPO Bulletin* 26: 199–249.

Faccoli, M., R. Favaro, M. T. Smith, and J. Wu. 2015. Life history of the Asian longhorn beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in southern Europe. *Agricultural and Forest Entomology* 17: 188–196.

FAO (Food and Agriculture Organization). 2007. *Overview of forest pests Thailand*. Rome: Food and Agriculture Organization, Forest Resources Development Service Working Paper FBS/32E.

FAO (Food and Agriculture Organization). 2009. *Global review of forest pests and diseases*. Rome: Food and Agriculture Organization, FAO Forestry Paper 156.

Fearn, S. 1989. Some observations on the habits of *Paroplites australis* (Erichson) (Coleoptera: Cerambycidae, Prioninae) and its damaging effects on the food plant *Banksia marginata* Cav. in Tasmania. *Australian Entomological Magazine* 16(4): 81–84.

Flaherty, L., J. D. Sweeney, D. Pureswaran, and D. T. Quiring. 2011. Influence of host tree condition on the performance of *Tetropium fuscum* (Coleoptera: Cerambycidae). *Environmental Entomology* 40: 1200–1209.

French, J. R. J. 1969. Occurrence and control of European house borer in New South Wales. *Australian Forestry* 33: 13–18.

Froggatt, W. W. 1919. The native lime-tree borer (*Citriphaga mixta* Lea). *Agricultural Gazette of New South Wales* 30: 261–267.

Froggatt, W. W. 1923. *Forest insects of Australia*. Sydney: Government Printer.

Froggatt, W. W. 1925. Forest insects. No. 6. The hoop pine longicorn (*Diotima undulata* Pascoe). *The Australian Forestry Journal* 8: 6–8.

Froggatt, W. W. 1927. *Forest insects and timber borers*. Sydney: Government Printer.

Furniss, R. L. and V. M. Carolin. 1977. *Western forest insects*. Washington, DC: USDA, Forest Service, Miscellaneous Publication No. 1339.

Gahan, A. 1911. Some notes on *Parandra brunnea*. *Journal of Economic Entomology* 4: 299–301.

Galford, J. R. 1984. The locust borer. *USDA Forest Service, Forest Insect & Disease Leaflet* 71.

Gao, S. I., Z. C. Xu, and X. C. Gong. 2007. Progress in research on *Semanotus bifasciatus*. *Forest Pest and Disease* 26(3): 19–22, 38.

Gardner, J. C. M. 1957. An annotated list of East African forest insects. *East African Agriculture and Forestry Research Organisation, Forestry Technical Note* 7.

Gardner, J. C. M., and J. O. Evans. 1957. Notes on *Oemida gahani* Distant (Cerambycidae). Part II: *East African Agricultural Journal* 22: 224–230.

GBIF (Global Biodiversity Information Facility). 2014. *Cordylomera spinicornis* (Fabricius, 1775). http://www.gbif.org/species/4738460/ (accessed December 30, 2015).

Giesbert, E. F. 1989. A new species and new record in the genus *Neoclytus* Thomson (Coleoptera: Cerambycidae) for Panama. *The Coleopterists Bulletin* 43: 269–273.

Gonzalez, O. E. and O. R. Di Iorio. 1996. Plantas hospedadoras de Cerambycidae (Coleoptera) en el noreste de Argentina. *Revista de Biologia Tropical* 44: 167–175.

Gosling, D. C. L. 1978. Observations on the biology of the oak twig pruner, *Elaphidionoides parallelus*, (Coleoptera: Cerambycidae) in Michigan. *The Great Lakes Entomologist* 11: 1–10.

Gosling, D. C. L. 1981. Correct identity of the oak twig pruner (Coleoptera: Cerambycidae). *The Great Lakes Entomologist* 14: 179–180.

Graham, S. A. 1925. The felled tree trunk as an ecological unit. *Ecology* 6: 397–411.

Gray, B. 1968. Forest tree and timber insect pests in the territory of Papua and New Guinea. *Pacific Insects* 10: 301–323.

Gray, B. 1972. Economic tropical forest entomology. *Annual Review of Entomology* 17: 313–352.

Gray, B., and F. R. Wylie. 1974. Forest tree and timber insect pests in Papua New Guinea. II: *Pacific Insects* 16: 67–115.

Grebennikov, V. V., B. D. Gill, and R. Vigneault. 2010. *Trichoferus campestris* (Falmermann) (Coleoptera: Cerambycidae), an Asian wood-boring beetle recorded in North America. *The Coleopterists Bulletin* 64: 13–20.

Gressitt, J. L., J. A. Rondon, and S. von Breuning. 1970. Cerambycid beetles of Laos (Longicornes du Laos). *Pacific Insects Monograph* 24: 1–651.

Haack, R. A. 2006. Exotic bark- and wood-boring Coleoptera in the United States: Recent establishments and interceptions. *Canadian Journal of Forest Research* 36: 269–288.

Haack, R. A. 2012. Seasonality of oak twig pruner shoot fall: A long-term dog walking study. *Newsletter of the Michigan Entomological Society* 57: 24.

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

Haack, R. A., and R. J. Rabaglia. 2013. Exotic bark and ambrosia beetles in the USA: Potential and current invaders. In *Potential invasive pests of agricultural crop species*, ed. J. E. Peña. 48–74. Wallingford: CABI International.

Haack, R. A., D. M. Benjamin, and K. D. Haack. 1983. Buprestidae, Cerambycidae, and Scolytidae associated with successive stages of *Agrilus bilineatus* (Coleoptera: Buprestidae) infestations of oaks in Wisconsin. *The Great Lakes Entomologist* 16: 47–55.

Haack, R. A., L. S. Bauer, R.-T. Gao, J. J. McCarthy, D. L. Miller, T. R. Petrice, and T. M. Poland. 2006. *Anoplophora glabripennis* within-tree distribution, seasonal development, and host suitability in China and Chicago. *The Great Lakes Entomologist* 39: 169–183.

Haack, R. A., F. Hérard, J. Sun, and J. J. Turgeon. 2010a. Managing invasive populations of Asian longhorned beetle and citrus longhorned beetle: A worldwide perspective. *Annual Review of Entomology* 55: 521–546.

Haack, R. A., T. R. Petrice, and A. C. Wiedenhoeft. 2010b. Incidence of bark- and wood-boring insects in firewood: A survey at Michigan's Mackinac Bridge. *Journal of Economic Entomology* 103: 1682–1692.

Haack, R. A., K. O. Britton, E. G. Brockerhoff, et al. 2014. Effectiveness of the international phytosanitary standard ISPM No. 15 on reducing wood borer infestation rates in wood packaging material entering the United States. *PLoS One* 9(5): e96611. doi:10.1371/journal.pone.0096611.

Haack, R. A., Y. Baranchikov, L. S. Bauer, and T. M. Poland. 2015. Emerald ash borer biology and invasion history. In *Biology and control of emerald ash borer*, eds. R. G. Van Driesche, and R. C. Reardon, 1–13. Morgantown, WV: USDA Forest Service, Forest Health Technology Enterprise Team, FHTET-2014-09.

Hanks, L. M. 1999. Influence of the larval host plant on reproductive strategies of cerambycid beetles. *Annual Review of Entomology* 44: 483–505.

Hanula, J. L. 1996. Relationship of wood-feeding insects and coarse woody debris. In *Biodiversity and coarse woody debris in southern forests, proceedings of the workshop on coarse woody debris in southern forests: Effects on biodiversity*, eds. J. W. McMinn, and D. A. Crossley Jr., 55–81. Asheville, NC: USDA Forest Service, Southern Research Station, General Technical Report SE-94.

Harman, D. M., and A. L. Harman. 1990. Height distribution of locust borer attacks (Coleoptera: Cerambycidae) in black locust. *Environmental Entomology* 19: 501–504.

Harmon, M. E., J. F. Franklin, F. J. Swanson, et al. 1986. Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15: 133–302.

Hart, C. J., J. S. Cope, and M. A. Ivie. 2013. A checklist of the Cerambycidae (Coleoptera) of Montana, USA, with distribution maps. *The Coleopterists Bulletin* 67: 133–148.

Hawkeswood, T. J. 1992. Review of the biology, host plants and immature stages of the Australian Cerambycidae (Coleoptera). Part 1: Parandrinae and Prioninae. *Giornale Italiano di Entomologia* 6: 207–224.

Hawkeswood, T. J. 1993. Review of the biology, host plants and immature stages of the Australian Cerambycidae. Part 2: Cerambycinae (tribes Oemini, Cerambycini, Hesperophanini, Callidiopini, Neostenini, Aphanasiini, Phlyctaenodini, Tessarommatini and Piesarthrini). *Giornale Italiano di Entomologia* 6: 313–355.

Hawkeswood, T. J. and J. R. Turner. 2003. Notes on the Australian longicorn beetle *Paroplites australis* (Erichson, 1842) (Coleoptera: Cerambycidae) with a new record from the Sydney District, New South Wales, Australia. *Entomologische Zeitschrift Stuttgart* 113(9): 270–271.

Hay, C. J. 1974. Survival and mortality of red oak borer larvae on black, scarlet, and northern red oak in eastern Kentucky. *Annals of the Entomological Society of America* 67: 981–986.

Hérard, F., M. Ciampitti, M. Maspero et al. 2006. *Anoplophora* spp. in Europe: Infestations and management process. *EPPO Bulletin* 36: 470–474.

Hesterberg, G. A., C. J. Wright, and D. J. Frederick. 1976. Decay risk for sugar maple borer scars. *Journal of Forestry* 74: 443–445.

Hickin, N. E. 1951. Delayed emergence of *Eburia quadrigeminata* Say (Col., Cerambycidae). *Entomologists Monthly Magazine* 87: 51.

Hoebeke, E. R. 1999. Japanese cedar longhorned beetle in the eastern United States. *USDA Animal and Plant Health Inspection Service, Pest Alert* 81–35–004.

Hoffard, W. H., and P. T. Marshall. 1978. *How to identify and control the sugar maple borer*. Delaware, OH: USDA Forest Service, Northeastern Area, State and Private Forestry, NA-GR-1. http://www.na.fs.fed.us/spfo/pubs/howtos/ht_mapleborer/mapleborer.htm (accessed December 30, 2015).

Humphreys, N., and E. Allen. 2000. Lesser cedar longicorn beetle—*Callidiellum rufipenne*. Exotic Forest Pest Advisory—Pacific Forestry Centre, Canadian Forest Service, No. 4. http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/5507.pdf (accessed December 30, 2015).

Hutacharern, C., and S. E. Panya. 1996. Biology and control of *Aristobia horridula* (Hope) (Coleoptera: Cerambycidae), a pest of *Pterocarpus macrocarpus*. In *Impact of diseases and insect pests in tropical forests*, eds. K. S. S. Nair, J. K. Sharma, and R. V. Varma, 392–397. Proceedings of the IUFRO Symposium, Peechi, India, 23–26 November 1993.

Ivory, M. H. 1977. Preliminary investigations of the pests of exotic forest trees in Zambia. *Commonwealth Forestry Review* 56: 47–56.

Iwata, R., and F. Yamada. 1990. Notes on the biology of *Hesperophanes campestris* (Faldermann) (Col., Cerambycidae), a drywood borer in Japan. *Material und Organismen* 25: 305–313.

Iwata, R., T. Maro, Y. Yonezawa, T. Yahagi, and Y. Fujikawa. 2007. Period of adult activity and response to wood moisture content as major segregating factors in the coexistence of two conifer longhorn beetles, *Callidiellum rufipenne and Semanotus bifasciatus* (Coleoptera: Cerambycidae). *European Journal of Entomology* 104: 341–345.

Jaques, H. E. 1918. A long-lifed woodboring beetle. *Proceedings of the Iowa Academy of Science* 25: 175.

Johki, Y., and T. Hidaka. 1987. Group feeding in larvae of the albizia borer, *Xystrocera festiva* (Coleoptera: Cerambycidae). *Journal of Ethology* 5: 89–91.

Jones, T., and S. J Curry. 1964. *Oemida gahani* Distant (Cerambycidae), its host plants, host range and distribution. *East African Agricultural and Forestry Journal* 30: 149–161.

Khan, T. N. 1985. Community and succession of the round-head borers (Coleoptera: Cerambycidae) infesting the felled logs of White Dhup, *Canarium euphyllum* Kurz. *Proceedings of the Indian Academy of Sciences (Animal Sciences)* 94: 435–441.

Kim, K. C., and J. D. Park. 1984. Studies on ecology and injury characteristics of Japanese *Juniperus* bark borer, *Semanotus bifasciatus* Motschulsky. *Korean Journal of Plant Protection* 23: 109–115.

Kliejunas, J. T., B. M. Tkacz, H. H. Burdsall, et al. 2001. *Pest risk assessment of the importation into the United States of unprocessed Eucalyptus logs and chips from South America.* Madison, WI: USDA Forest Service, Forest Products Laboratory, General Technical Report FPL-GTR-124.

Kliejunas, J. T., H. H. Burdsall, G. A. DeNitto, et al. 2003. *Pest risk assessment of the importation into the United States of unprocessed logs and chips of eighteen eucalypt species from Australia.* Madison, WI: USDA Forest Service, Forest Products Laboratory, General Technical Report FPL-GTR-137.

Kobayashi, F., A. Yamane, and T. Ikeda. 1984. The Japanese pine sawyer beetle as the vector of pine wilt disease. *Annual Review of Entomology* 29: 115–135.

LaBonte, J. R., A. D. Mudge, and K. J. R. Johnson. 2005. Nonindigenous woodboring Coleoptera (Cerambycidae, Curculionidae: Scolytinae) new to Oregon and Washington, 1999–2002: Consequences of the intracontinental movement of raw wood products and solid wood packing materials. *Proceedings of the Entomological Society of Washington* 107: 554–564.

LeConte, J. L. 1850. An attempt to classify the longicorn Coleoptera of the part of America north of Mexico. *Journal of the Academy of Natural Sciences of Philadelphia* 2(Series 2): 2–38.

Lee, S.-I., J. R. Spence, and D. W. Langor. 2014. Succession of saproxylic beetles associated with decomposition of boreal white spruce logs. *Agricultural and Forest Entomology* 16: 391–405.

Liebhold, A. M., E. G. Brockerhoff, L. J. Garrett, J. L. Parke, and K. O. Britton. 2012. Live plant imports: The major pathway for forest insect and pathogen invasions of the US. *Frontiers in Ecology and the Environment* 10: 135–143.

Lim, J., S.-Y. Jung, J.-S. Lim, et al. 2014. A review of host plants of Cerambycidae (Coleoptera: Chrysomeloidea) with new host records for fourteen cerambycids, including the Asian longhorn beetle (*Anoplophora glabripennis* Motschulsky), in Korea. *Korean Journal of Applied Entomology* 53: 111–133.

Linsley, E. G. 1959. Ecology of Cerambycidae. *Annual Review of Entomology* 4: 99–138.

Linsley, E. G. 1961. The Cerambycidae of North America. Part I: Introduction. *University of California Publications in Entomology* 18: 1–135.

Linsley, E. G. 1962a. The Cerambycidae of North America. Part II: Taxonomy and classification of the Parandrinae, Prioninae, Spondylinae and Aseminae. *University of California Publications in Entomology* 19: 1–102.

Linsley, E. G. 1962b. The Cerambycidae of North America. Part III: Taxonomy and classification of the subfamily Cerambycinae, tribes Opsimini through Megaderini. *University of California Publications in Entomology* 20: 1–188.

Linsley, E. G. 1963. The Cerambycidae of North America. Part IV: Taxonomy and classification of the subfamily Cerambycinae, tribes Elaphidionini through Rhinotragini. *University of California Publications in Entomology* 21: 1–165.

Linsley, E. G. 1964. The Cerambycidae of North America. Part V: Taxonomy and classification of the subfamily Cerambycinae, tribes Callichromini through Ancylocerini. *University of California Publications in Entomology* 22: 1–197.

Linsley, E. G., and J. A. Chemsak. 1972. Cerambycidae of North America. Part VI, No. 1: Taxonomy and classification of the subfamily Lepturinae. *University of California Publications in Entomology* 69: 1–138.

Linsley, E. G., and J. A. Chemsak. 1976. Cerambycidae of North America. Part VI, No. 2: Taxonomy and classification of the subfamily Lepturinae. *University of California Publications in Entomology* 80: 1–186.

Linsley, E. G., and J. A. Chemsak. 1984. The Cerambycidae of North America. Part VII, No. 1: Taxonomy and classification of the subfamily Lamiinae, tribes Parmenini through Acanthoderini. *University of California Publications in Entomology* 102: 1–258.

Linsley, E. G., and J. A. Chemsak. 1995. The Cerambycidae of North America. Part VII, No. 2: Taxonomy and classification of the subfamily Lamiinae, tribes Acanthocinini through Hemilophini. *University of California Publications in Entomology* 114: 1–292.

Liu, G., and Y. Tang. 2002. The relationships between *Apriona swainsoni* and its host trees. *Scientia Silvae Sinicae* 38(3): 106–113.

Liu, H., Y. Luo, J. Wen, Z. Zhang, J. Feng, and W. Tao. 2006. Pest risk assessment of *Dendroctonus valens, Hyphantria cunea* and *Apriona swainsoni* in Beijing. *Frontiers of Forestry in China* 1: 328–335.

Łoś, K. and R. Plewa. 2011. *Callidiellum rufipenne* (motschulsky, 1862) (Coleoptera: Cerambycidae)—New to the fauna of Croatia with remarks of its biology. *Nature Journal (Opole Scientific Society)* 44: 141–144.

Löyttyniemi, K. 1983. Flight pattern and voltinism of *Phoracantha* beetles (Coleoptera: Cerambycidae) in a semihumid tropical climate in Zambia. *Annales Entomologici Fennici* 49: 49–53.

Lu, X., Z. Yang, X. Sun, L. Qiao, X. Wang, and J. Wei. 2011. Biological control of *Apriona swainsoni* (Coleoptera: Cerambycidae) by releasing the parasitic beetle *Dastarcus helophoroides* (Coleoptera: Bothrideridae). *Scientia Silvae Sinicae* 47(10): 16–121.

Luzzi, M. A., R. C. Wilkinson, and A. C. Tarjan. 1984. Transmission of the pinewood nematode, *Bursaphelenchus xylophilus*, to slash pine trees and log bolts by a cerambycid beetle, *Monocharnus titillator*, in Florida. *Journal of Nematology* 16: 37–40.

Ma, L.-Q., Y.-F. Zhu, C.-J. Cao, et al. 2010. Utilization of *Pyemotes* sp. and *Scleroderma guani* Xiao et Wu to control the larvae of *Semanotus bifasciatus*. *Forest Research* 23: 313–317.

MacAloney, H. J. 1968. The sugar maple borer. *USDA Forest Service, Forest Pest Leaflet* 108.

Maier, C. T. 2007. Distribution and hosts of *Callidiellum rufipenne* (Coleoptera: Cerambycidae), an Asian cedar borer established in the eastern United States. *Journal of Economic Entomology* 100: 1291–1297.

Maier, C. T., and Lemmon, C. R. 2000. Discovery of the small Japanese cedar longhorned beetle, *Callidiellum rufipenne* (Motschulsky) (Coleoptera: Cerambycidae), in live arborvitae in Connecticut. *Proceedings of the Entomological Society of Washington* 102: 747–754.

Mattson, W. J., and R. A. Haack. 1987. The role of drought in outbreaks of plant-eating insects. *BioScience* 37: 110–118.

Mayné, R. 1914. Les ennemis de l'Hévéa au Congo Belge. *Bulletin Agricole du Congo Belge* 5: 577–596.

McKeown, K. C. 1947. Catalogue of the Cerambycidae (Coleoptera) of Australia. *Australian Museum Memoir* 10: 1–190.

McNeil, J. 1886. A remarkable case of longevity in a longicorn beetle (*Eburia quadrigeminata*). *American Naturalist* 20: 1055–1057.

Mishra, S. C., V. Veer, and A. Chandra. 1985. *Aristobia horridula* Hope (Coleoptera: Lamiidae) a new pest of shisham (*Dalbergia sissoo* Roxb.) in West Bengal. *Indian Forester* 111: 738–741.

Monné, M. A., E. H. Nearns, S. C. Carbonel Carril, I. P. Swift, and M. L. Monné. 2012. Preliminary checklist of the Cerambycidae, Disteniidae, and Vesperidae (Coleoptera) of Peru. *Insecta Mundi* 0213: 1–48.

Montecchio, L., and M. Faccoli. 2013. First record of thousand cankers disease *Geosmithia morbida* and walnut twig beetle *Pityophthorus juglandis* on *Juglans nigra* in Europe. *Plant Disease* 98: 696.

Moore, K. M. 1966. Observations on some Australian forest insects. 21. *Hesthesis cingulata* (Kirby) (Coleoptera: Cerambycidae), attacking young plants of *Eucalyptus pilularis* Smith. *Australian Zoologist* 13: 299–301.

Mushrow, L., A. Morrison, J. D. Sweeney, and D. T. Quiring, 2004. Heat as a phytosanitary treatment for the brown spruce longhorn beetle. *Forestry Chronicle* 80: 224–228.

Nair, K. S. S. 2007. *Tropical forest insect pests: Ecology, impact, and management*. Cambridge: Cambridge University Press.

Negi, S. and V. D. Joshi. 2009. Role of moisture content in rendering the sal tree component susceptible to the borer (*Hoplocerambyx spinicornis*) attack. *Asian Journal of Animal Science* 3: 190–192.

Nielsen, D. G., V. L. Muilenburg, and D. A. Herms. 2011. Interspecific variation in resistance of Asian, European, and North American birches (*Betula* spp.) to bronze birch borer (Coleoptera: Buprestidae). *Environmental Entomology* 40: 648–653.

Nose, M., and S. Shiraishi. 2008. Breeding for resistance to pine wilt disease. In *Pine Wilt Disease*, eds. B. G. Zhao, K. Futai, J. R. Sutherland, and Y. Takeuchi, 334–350. Tokyo: Springer.

Novak, V. 1976. *Atlas of insects harmful to forest trees, Vol. 1.* Amsterdam: Elsevier.

O'Connor, J. P., and R. Nash. 1984. Insects imported into Ireland. 6. Records of Orthoptera, Dermaptera, Lepidoptera and Coleoptera. *The Irish Naturalists' Journal* 21: 351–353.

Paine, T. D, and J. G. Millar. 2002. Insect pests of eucalypts in California: Implications of managing invasive species. *Bulletin of Entomological Research* 92: 147–151.

Paine, T. D., M. J. Steinbauer, and S. A. Lawson. 2011. Native and exotic pests of *Eucalyptus*: A worldwide perspective. *Annual Review of Entomology* 56: 181–201.

Pan, H. Y. 2005. *Review of the Asian longhorned beetle: Research, biology, distribution and management in China.* Rome: Food and Agriculture Organization, Forest Resources Development Service Working Paper FBS/6E.

Peck, S. B. 2005. *A checklist of the beetles of Cuba with data on distributions and bionomics (Insecta: Coleoptera)*. Arthropods of Florida and Neighboring Land 18: 1–241. Gainesville, FL: Florida Department of Agriculture and Consumer Services.

Poland, T. M., and D. G. McCullough. 2006. Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry* 104: 118–124.

Qiu, L. 1999. Control of wood borer larvae by releasing *Scleroderma guani* in Chinese fir forests. *Chinese Journal of Biological Control* 15: 8–11.

Quentin, R. M., and A. Villiers. 1969. Révision des Plectogasterini, nov. trib. (Col. Cerambycidae Cerambycinae). *Annales de la Société Entomologique de France (Nouvelle Série)* 5: 613–646.

Rassati, D., M. Faccoli, L. Marini, R. A. Haack, A. Battisti, and E. P. Toffolo. 2015. Exploring the role of wood waste landfills in early detection of non-native alien wood-boring beetles. *Journal of Pest Science* 88: 563–572.

Rassati, D., F. Lieutier, and M. Faccoli. 2016. Alien wood-boring beetles in Mediterranean regions. In *Insects and diseases of Mediterranean forest systems*, eds. T. D. Paine, and F. Lieutier, 293–327. Cham, Switzerland: Springer International.

Rathore, M. P. S. 1995. *Insect pests in agroforestry*. Nairobi: ICRAF Working Paper No. 70.

Rhainds, M., W. E. Mackinnon, K. B. Porter, J. D. Sweeney, and P. J. Silk. 2011. Evidence for limited spatial spread in an exotic longhorn beetle, *Tetropium fuscum* (Coleoptera: Cerambycidae). *Journal of Economic Entomology* 104: 1928–1933.

Riggins, J. J., L. D. Galligan, and F. M. Stephen. 2009. Rise and fall of red oak borer (Coleoptera: Cerambycidae) in the Ozark Mountains of Arkansas, USA. *Florida Entomologist* 92: 426–433.

Ritchie, W. 1920. The structure, bionomics, and economic importance of *Saperda carcharias* Linn., "the large poplar longhorn." *Annals of Applied Biology* 7: 299–343.

Rivas, C. 1992. *Forest pests in Central America: Handbook. Technical manual No. 3.* Turrialba, Costa Rica: CATIE.

Roberts, H. 1969. Forest insects of Nigeria with notes on their biology and distribution. *Commonwealth Forestry Institute Paper* 44: 1–206.

Robinson, W. H., and K. F. Cannon. 1979. The life history and habits of the old house borer *Hylotrupes bajulus* (L.) and its distribution in Pennsylvania. *Melsheimer Entomological Series* 27: 30–34.

Rozhkov, A. S. 1970. *Pests of Siberian larch*. Jerusalem: Israel Program for Scientific Translations.

Saint-Germain, M., P. Drapeau, and C. M. Buddle. 2007. Host-use patterns of saproxylic phloeophagous and xylophagous Coleoptera adults and larvae along the decay gradient in standing dead black spruce and aspen. *Ecography* 30: 737–748.

Salini, S., and D. S. Yadav. 2011. Occurrence of *Stromatium barbatum* (Fabr.) (Coleoptera: Cerambycidae) on grapevine in Maharashtra, India. *Pest Management in Horticultural Ecosystems* 17: 48–50.

Sama, G., J. Buse, E. Orbach, A. L. L. Friedman, O. Rittner, and V. Chikatunov. 2010. A new catalogue of the Cerambycidae (Coleoptera) of Israel with notes on their distribution and host plants. *Munis Entomology & Zoology* 5: 1–51.

Sathyapala, S. 2004. *Pest risk analysis, biosecurity risk to New Zealand of pinewood nematode (Bursaphelenchus xylophilus)*. Wellington: New Zealand, Ministry of Agriculture and Forestry.

Savely, H. E. 1939. Ecological relations of certain animals in dead pine and oak logs. *Ecological Monographs* 9: 323–385.

Schabel, H. G. 2006 *Forest entomology in East Africa*. Dordrecht: Springer.

Scriven, G. T., E. L. Reeves, and R. F. Luck. 1986. Beetle from Australia threatens eucalyptus. *California Agriculture* 40(7–8): 4–6.

Shibata, E. 1994. Population studies of *Callidiellum rufipenne* (Coleoptera: Cerambycidae) on Japanese cedar logs. *Annals of the Entomological Society of America* 87: 836–841.

Shigo, A. L., W. B. Leak, and S. M. Filip. 1973. Sugar maple borer injury in four hardwood stands in New Hampshire. *Canadian Journal of Forest Research* 3: 512–515.

Shin, S. C., K. S. Choi, W. I. Choi, Y. J. Chung, S. G. Lee, and C. S. Kim. 2008. *A new illustrated book of forest insect pests.* Seoul: Upgo MunHwa.

Singh, P., and R. M. Misra. 1981. Distance response of sal heartwood borer, *Hoplocerambyx spinicornis* Newman (Cerambycidae: Coleoptera) to freshly felled sal trees. *Indian Forester* 107: 305–308.

Sjöman, H.; J. Östberg, and J. Nilsson. 2014. Review of host trees for the wood-boring pests *Anoplophora glabripennis* and *Anoplophora chinensis*: An urban forest perspective. *Arboriculture & Urban Forestry* 40: 143–164.

Smith, I. M. 2009. *Hesperophanes campestris. EPPO Bulletin* 39: 51–54.

Smith, G. A., and L. M. Humble. 2000. The brown spruce longhorn beetle. Victoria, BC: Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Exotic Forest Pest Advisory 5. http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/5529.pdf (accessed December 30, 2015).

Smith G., and J. E. Hurley. 2000. First North American record of the Palearctic species *Tetropium fuscum* (Fabricius) (Coleoptera: Cerambycidae). *The Coleopterists Bulletin* 54: 540.

Snyder, T. E. 1911. Damage to telephone and telegraph poles by wood-boring insects. *USDA Bureau of Entomology Circular* 134: 1–6.

Solomon, J. D. 1977. Frass characteristics for identifying insect borers (Lepidoptera: Cossidae and Sesiidae; Coleoptera: Cerambycidae) in living hardwoods. *Canadian Entomologist* 109: 295–303.

Solomon, J. D. 1980. *Cottonwood borer (Plectrodera scalator)—A guide to its biology, damage, and control.* New Orleans, LA: USDA Forest Service, Southern Forest Experiment Station, Research Paper SO-157.

Solomon, J. D. 1995. *Guide to insect borers in North American broadleaf trees and shrubs.* Washington, DC: USDA Forest Service, Agriculture Handbook AH-706.

Song, S. H., L. Q. Zhang, H. H. Huang, and X. M. Cui. 1991. Preliminary study of biology of *Monochamus alternatus* Hope. *Forest Science and Technology* 6: 9–13.

Stephen, F. M., V. B. Salisbury, and F. L. Oliveria. 2001. Red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae), in the Ozark Mountains of Arkansas, U.S.A: An unexpected and remarkable forest disturbance. *Integrated Pest Management Reviews* 6: 247–252.

Straw, N. A., N. J. Fielding, C. Tilbury, D. T. Williams, and D. Inward. 2014. Host plant selection and resource utilisation by Asian longhorn beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in southern England. *Forestry* 88: 84–95.

Sun, X.-S. 2000. The application of nematodes for control *Semanotus bifasciatus sinoauster* Gressitt. *Journal of Fujian College of Forestry* 20: 49–51.

Švácha, P., and M. L. Danilevsky. 1988. Cerambycoid larvae of Europe and Soviet Union (Coleoptera, Cerambycoidea). Part II: *Acta Universitatis Carolinae—Biologica* 31: 121–284.

Swift, I. P., and A. M. Ray. 2010. Nomenclatural changes in North American *Phymatodes* Mulsant (Coleoptera: Cerambycidae) *Zootaxa* 2448: 35–52.

Syme, J. H. and J. R. Saucier. 1995. Effects of long-term storage of southern pine sawlogs under water sprinklers. *Forest Products Journal* 45: 47–50.

Tang, Y. P., and G. H. Liu. 2000. Study on forecast of ovipositing occurrence time of *Apriona swainsoni*. *Scientia Silvae Sinicae* 36(6): 86–89.

Tavakilian, G., and H. Chevillotte. 2013. Titan database about longhorns or timber-beetles (Cerambycidae). http://lully.snv.jussieu.fr/titan/index.html (accessed December 30, 2015).

Tavakilian, G., A. Berkov, B. Meurer-Grimesi, and S. Mori. 1997. Neotropical tree species and their faunas of xylophagous longicorns (Coleoptera: Cerambycidae) in French Guiana. *The Botanical Review* 63: 304–355.

Thomas, M. C. 1999. The genus *Eburia* Audinet-Serville in Florida (Coleoptera: Cerambycidae). *Florida Department of Agriculture, Entomology Circular* 396: 1–4.

Togashi, K. 2013. Nematode-vector beetle relation and the regulatory mechanism of vector's life history in pine wilt disease. *Formosan Entomologist* 33: 189–205.

Togashi, K., and H. Magira. 1981. Age-specific survival rate and fecundity of the adult Japanese pine sawyer, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae), at different emergence times. *Applied Entomology and Zoology* 16: 351–361.

Trägårdh, I. 1930. Some aspects in the biology of longicorn beetles. *Bulletin of Entomological Research.* 21: 1–8.

Troop, J. 1915. Cerambycid in bedstead (Col.). *Entomological News* 26: 281.

Turienzo, P. 2006. Definitive incorporation of *Callidiellum rufipenne* (Motschulsky, 1860) to the Argentinian fauna of Cerambycidae (Coleoptera). *Boletín de Sanidad Vegetal Plagas* 32: 155–156.

USDA Forest Service. 1991. *Pest risk assessment of the importation of larch from Siberia and the Soviet Far East.* Washington, DC: USDA Forest Service, Miscellaneous Publication No. 1495.

Van Meer, C., and C. Cocquempot. 2013. Découverte d'un foyer de *Callidiellum rufipenne* (Motschulsky, 1861) dans les Pyrénées Atlantiques (France) et correction nomenclaturale (Cerambycidae: Cerambycinae: Callidiini). *L'Entomologiste* 69: 87–95.

Vitali, F. 2015. Cerambycoidea.com: The first web-site about the world-wide Cerambycoidea. www.Cerambycoidea.com (accessed December 30, 2015).

Wagner, M. R., S. K. N. Atuahene, and J. R. Cobbinah. 1991. *Forest entomology in West Tropical Africa: Forest insects of Ghana*. Dordrecht, Netherlands, Kluwer Academic.

Wang, Q. 1995. A taxonomic revision of the Australian genus *Phoracantha* Newman (Coleoptera: Cerambycidae). *Invertebrate Taxonomy* 9: 865–958.

Wang, X.-H. 2011. *Studies on biology, ecology and biocontrol techniques of Apriona swainsoni Hope (Coleoptera: Cerambycidae).* Beijing: PhD. Thesis, Chinese Academy of Forestry.

Wang, X., Z. Yang, X. Wang, Y. Tang, and Y. Zhang, 2014. Biological control of *Apriona swainsoni* (Coleoptera: Cerambycidae) by applying three parasitoid species. *Scientia Silvae Sinicae* 50: 103–108.

Webb, J. L. 1909. *Some insects injurious to forests: The southern pine sawyer.* Washington, DC, US Government Printing Office: USDA Bureau of Entomology Bulletin 58(Part IV): 41–56.

Webster, F. M. 1889. Notes upon the longevity of the early stages of *Eburia quadrimaculata* (Say). *Insect Life* 1: 339.

Wylie, F. R. 1982. Insect problems of *Araucaria* plantations in Papua New Guinea and Australia. *Australian Forestry* 45: 125–131.

Wylie, F. R., and M. R. Speight. 2012. *Insect pests in tropical forestry*, 2nd edition Wallingford: CABI.

Xiao, G.-R., ed., 1992. *Forest insects of China* (2nd ed.). Beijing: China Forestry.

Yan, W. B. 2003. Researches on biological characters of *Semanotus bifasciatus*. *Journal of Anhui Agricultural College* 30: 57–60.

Yan, Z., J. Sun, D. Owen, Z. Zhang. 2005. The red turpentine beetle, *Dendroctonus valens* LeConte (Scolytidae): An exotic invasive pest of pine in China. *Biodiversity and Conservation* 14: 1735–1760.

Yuan, F., Y.-Q. Luo, J. Shi, et al. 2008. Invasive sequence and ecological niche of main insect borers of *Larix gmelinii* forest in Aershan, Inner Mongolia. *Forestry Studies in China* 10: 9–13.

Zhang, Q.-H., J. A. Byers, and X.-D. Zhang. 1993. Influence of bark thickness, trunk diameter and height on reproduction of the longhorned beetle, *Monochamus sutor* (Col., Cerambycidae) in burned larch and pine. *Journal of Applied Entomology* 115: 145–154.

Zhao, T. H., W. X. Zhao, R. T. Gao, Q. W. Zhang, G. H. Li, and X. X. Liu. 2007. Induced outbreaks of indigenous insect species by exotic tree species. *Acta Entomologica Sinica.* 20: 826–833.

Zhuravlev, I. I., and G. E. Osmolovskii. 1964. *Pests and Diseases of Shade Trees*. Jerusalem, Israel Program for Scientific Translations.