# Order Lepidoptera—Moths



Lepidoptera, the second largest order of insects, includes the moths, butterflies, and skippers. This book covers 99 species of moths, the larvae of which are borers. Moths are best recognized by the minute scales more or less covering the wings and body, which rub off like dust when handled (Borror and others 1981, USDA FS 1985). The mouthparts, when present, are in the form of a long, slender tube carried coiled up beneath the head. Adults of many species have poorly developed mouthparts and do not take any nourishment. Antennae vary from threadlike to featherlike. The wings are folded rooflike on the abdomen, spread horizontally, or wrapped around the body when at rest. Moths vary greatly in size, with wing expanses ranging from 6 to 100 mm. Lepidopterous larvae, known as caterpillars, are usually cylindrical with a head and 13 (3 thoracic and 10 abdominal) segments. Each thoracic segment bears a pair of jointed legs, whereas the abdominal segments bear two to five pairs of fleshy unjointed prolegs, typically on segments 3 to 6 and 10. The prolegs of caterpillars have fine hooks, known as crochets, arranged in circles, bands, or rows at the apex.

### Family



## Family Hepialidae—Ghost Moths or Swifts

Hepialid moths are active for short periods at dusk or dawn and exhibit swift zigzag flights close to the ground near oviposition sites (USDA FS 1985, Wagner 1985). These moths have rather long, stout abdomens and are medium to large, with wingspans up to 100 mm. The best known species are yellowish to brown or ashy gray, and the wings are marked with silvery white spots. Larvae are longheaded and nearly naked, with long, cylindrical bodies and five pairs of prolegs. The larvae have cryptic habits and feed in the roots and lower trunk of host trees.

### Genus and Species



### *Sthenopis quadriguttatus* Grote

[poplar ghost moth] (figure 1)

**Hosts.** Poplar, willow. Native aspens (especially quaking aspen) and black cottonwood are preferred (Gross and Syme 1981, Prentice 1965). Numerous poplar hybrids in the taxonomic sections Aegeiros

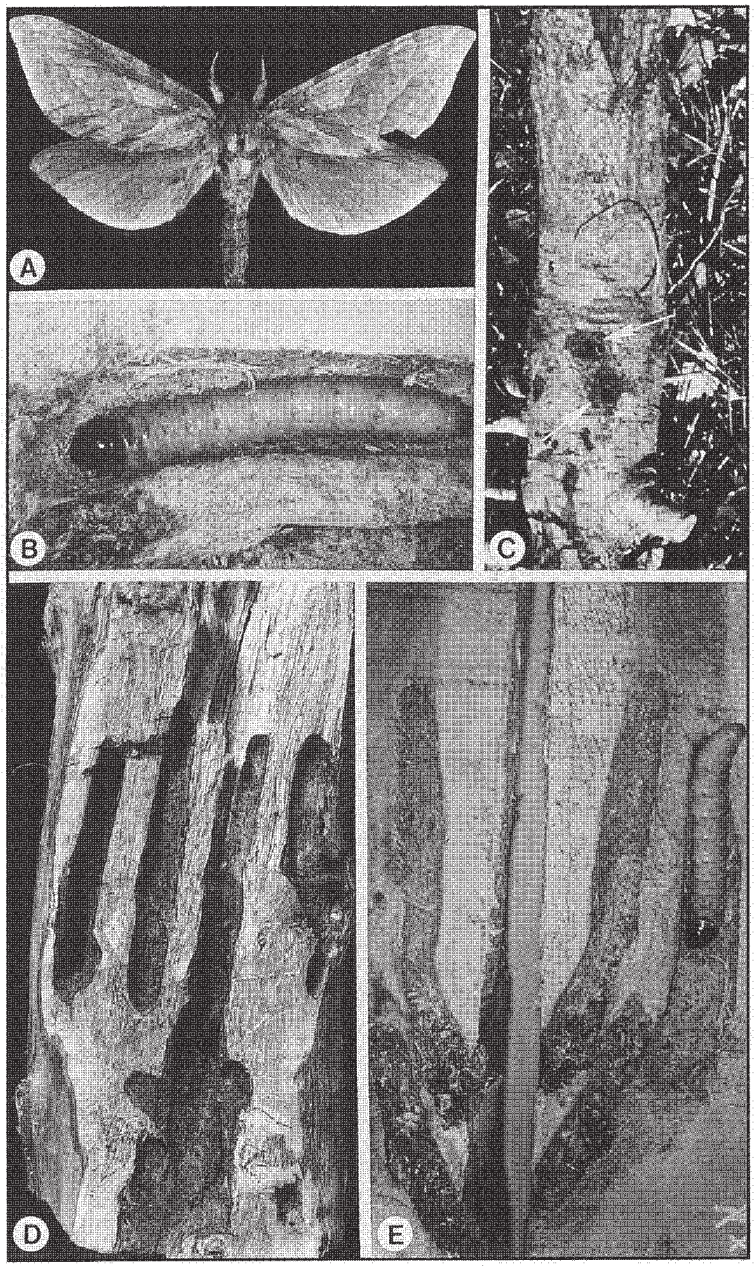


**Figure 1**—Sthenopis quadriguttatus, *[poplar ghost moth]: A, adult; B, larva in gallery; C, rootstock with entrance holes; D, multiple galleries in root collar; E, H-shaped gallery with larva (A, specimen courtesy R. Hodges; B-E, courtesy G. Vallee and R. Beique).*

and Tacamahaca also have been attacked (Vallee and Beique 1979).

**Range.** New England and northern New York and widely scattered in Canada from Quebec west to British Columbia (Forbes 1923, Prentice 1965). Uncommon in forest trees in its western range (Furniss and Carolin 1977). However, populations in hybrid poplars and native aspen are common at scattered locations, especially in high-yield energy plantations in southeastern Canada (Morris 1983).

**Description.** ***Adult***. Very large, brownish tan, heavy-bodied moth (figure 1A). Wingspan from 35 to 100 mm. Forewings mottled with tan, brown, and orange, with one or two silver spots at base of cell; hindwings salmon pink or brown (Forbes 1923). ***Egg.*** Spheroid with smooth, unornamented surface (Wagner 1985). ***Larva.*** Ranges from 33 to 57 mm long when mature (figure 1B). Unornamented, cream colored with reddish brown head, prothoracic shield extending below spiracle, and dorsal pinacula swollen and almost wartlike on abdominal segments 3 to 7 (Vallee and Beique 1979).

**Biology.** Adults are in flight from late June to mid-August (Prentice 1965). Moths captured in light traps have provided most of the recorded information on distribution. Typically, the moths fly at dusk, swiftly and close to the ground (Furniss and Carolin 1977). Larvae burrow in the xylem along the long axis, usually in the center of roots, where they continue to feed during winter, when temperatures reach 5 to 15 °C in the galleries (Vallee and Beique 1979). Larvae typically excavate galleries 10 to 12 mm in diameter and 10 to 15 cm long, but chambers within the galleries may be 25 to 30 mm in diameter (Vallee and Beique 1979). Larvae tunneling in the center of small roots can make tunnels up to 70 cm long (Gross and Syme 1981). Pupation occurs within the galleries in late May in British Columbia (Prentice 1965). Larvae of two sizes were found in infested roots in Ontario, indicating a life cycle of 1 to 2 years (Vallee and Beique 1979).

**Injury and damage.** Attacks occur at the groundline or below, and infestations are often difficult to diagnose (figure 1C). Excavation reveals long, narrow galleries in the small lateral roots (Gross and Syme 1981). In the root collar and taproot (and sometimes in large lateral roots) galleries are shorter and may have multiple channels (figure 1D), some of which are H-shaped (figure 1E) (Vallee and Beique 1979). Frass is bound loosely with fine silken threads and ejected from the galleries in clumps 1 to 2 cm in diameter. Gallery entrances are usually kept open but may be loosely plugged with frass. The large larvae are found singly in the galleries. In northern Ontario, a survey revealed root feeding in 47% of 45 aspen stands and in 8% of 450 root systems in the stands (Gross and Syme 1981). Rot fungi were associated with 47% of the larval galleries in trembling aspen. In another survey near Matane, Quebec, 30% of the native poplars were infested (Lavallee and others 1981).

**Control.** No resistance was found in an infested clonal planting in Ontario containing 12 hybrid poplar clones in the sections

Aegeiros and Tacamahaca (Vallee and Beique 1979). Systemic insecticides applied every 2 to 3 years in hybrid poplar plantations to control the ghost moth have been proposed (Vallee and Beique 1979). Nothing is known of natural controls.

### *Sthenopis argenteomaculatus* Harris

[alder ghost moth] (figure 2)

**Hosts.** Alder. Alders are the only well-documented hosts and only speckled alder has been named specifically (Forbes 1923, USDA FS 1985). Maple, chestnut, hazel, poplar, cherry, oak, willow, and blackberry have been listed as hosts (Tietz 1972, Weed 1889) but are not substantiated.

**Range.** New England and Long Island westward to Minnesota (Forbes 1923) and north into the southern parts of Canada (McDunnough 1939).

**Description.** ***Adult***. Large, tan, heavy-bodied moth with wingspan of 53 to 85 mm (figure 2A) (Forbes 1923). Forewings falcate; tan with prominent dark brown, pale-edged bands that originate near base and apex, converging toward inner wing margin. Base of forewings often with two silvery spots of orange scaling. Hindwings, tan to brown in male, have yellowish flush in female (Forbes 1923). Moths with small heads, short antennae, and long abdomens. ***Larva.*** Cream colored with reddish brown head, dark prothoracic shield, prominent dorsal pinacula on abdominal segments; may be 57 mm long at maturity (figure 2B).

**Biology.** Adults emerge in late May and early June (Packard 1895). Flight occurs for a brief period at sunset, often about 1 m above the ground. The moths, sometimes called swifts, perform unusual gyrations or dances in flight, particularly near where oviposition is to occur (Holland 1968). In northern New York, females oviposit mostly during early June (Packard 1895). The eggs incubate for about 23 days before hatching (Lyman 1903). The life and seasonal histories have not been studied in detail. Presumably, larvae burrow within roots for 2 years, then bore upward into the base of the tree trunk early in the last year of their development (Wagner 1985). By spring, they bore to the bark surface to make exit holes, which they then loosely plug with wood fragments. Pupation begins during early May in the gallery near the root collar, and the adults emerge through the preformed exit holes (Packard 1895). Published accounts indicate that larvae complete development in about 3 years (Kellicott 1888, Weed 1889), but recent unpublished evidence suggests a shorter development period of possibly 2 years.

**Injury and damage.** Pencil-sized holes, partially or loosely plugged with wood chips, sometimes can be seen at the base of infested trees (figure 2C) (Packard 1895). During early development, larvae burrow through the center of roots, even when roots are submerged in water (Covell 1984, USDA FS 1985). Older larvae usually reverse direction and bore mostly in the wood at the root collar of infested trees. Infestations are widely scattered, but populations can be abundant in some localities (Kellicott 1888). Little is known of the extent of damage

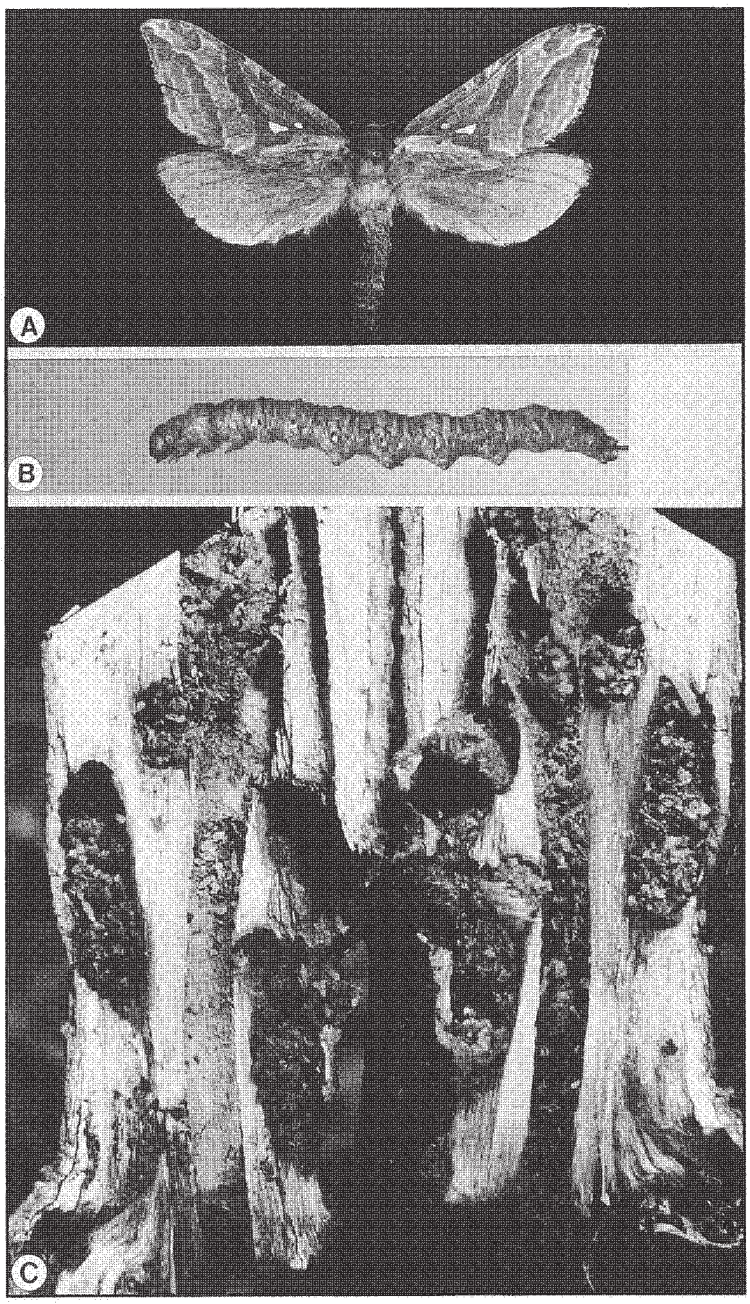


**Figure 2**—Sthenopis argenteomaculatus, *[alder ghost moth]: A, adult; B, mature larva; C, multiple galleries at base of trunk (specimens, courtesy R. Hodges).*

caused by this insect.

**Control.** Woodpeckers have been reported as predators (Kellicott 1888). Mature larvae are particularly susceptible to predation during fall, winter, and spring of their final months of development, as they prepare exit holes at the bark surface. Direct controls have not been investigated.

### *Sthenopis thule* Strecker

[willow ghost moth] (figure 3)

**Hosts.** Willow, maple. Low-growing willows such as meadow willow are preferred hosts (Winn 1909). Red, striped, and mountain maples may serve as hosts (Lyman 1893), but no direct observations have been made.

**Range.** New York west to Wisconsin and as far north as Hudson Bay in Canada (Forbes 1923). Populations are generally scarce, but years ago, they were moderately common in some localities near Montreal (Forbes 1923, Lyman 1893).

**Description.** ***Adult.*** Medium to large, brownish yellow moth with wingspan of 50 to 70 mm (figure 3A). Despite long, stout bodies, moths are swift, agile flyers. Forewings pale yellow to cream with brown patch running along leading edge from base to beyond middle. Apex of forewing forms almost sharp angle; upper half of margin of outer wing straight or slightly concave (Forbes 1923). ***Egg.*** Oval, about 0.6 mm in diameter. Surface smooth, dull, changing from honey yellow when deposited to black at maturity (Lyman 1893). ***Larva.*** Cylindrical, slightly humped thorax, yellowish white body, reddish brown head, and yellowish brown cervical shield. Measures up to 70 mm long (figure 3B) (Swaine 1909).

**Biology.** Adults emerge over about 10 days to 2 weeks from July 7 to 23 (Denny 1907, Forbes 1923) and are usually seen for only 15 to 20 minutes at twilight on cloudless evenings (Lyman 1893). The moths, sometimes called swifts, may fly rapidly back and forth or oscillate in a zigzag pattern just above the ground (Lyman 1893). From 1 to 20 males have been observed in dancing flight just above females that are resting on low-growing willows (Winn 1909). Females seldom fly until the male dances cease, but their flights are swift, only a meter or so above the ground, and usually in sweeping arcs. Females oviposit by dropping their eggs streamlike as they fly over and among host plants. They are prolific, sometimes laying over 2,000 eggs (Lyman 1893, Winn 1909). Newly hatched larvae seek tender roots to feed on and later bore into and tunnel within the roots and lower trunks. Mature larvae form cylindrical cocoons of frass and silk either in the mouth of the tunnel or in soil just beneath the ground surface (Swaine 1909). Pupal skins are often found among leaves and debris on the soil surface around infested willow clumps. The pupal stage lasts at least 12 days. The developmental time is unknown but lasts at least 2 years (Lyman 1893).

**Injury and damage.** Infestations occur locally within the range of this moth species and are generally sparse. Larvae bore in the roots (figure 3C) and basal portion of trees to about 0.3 m above

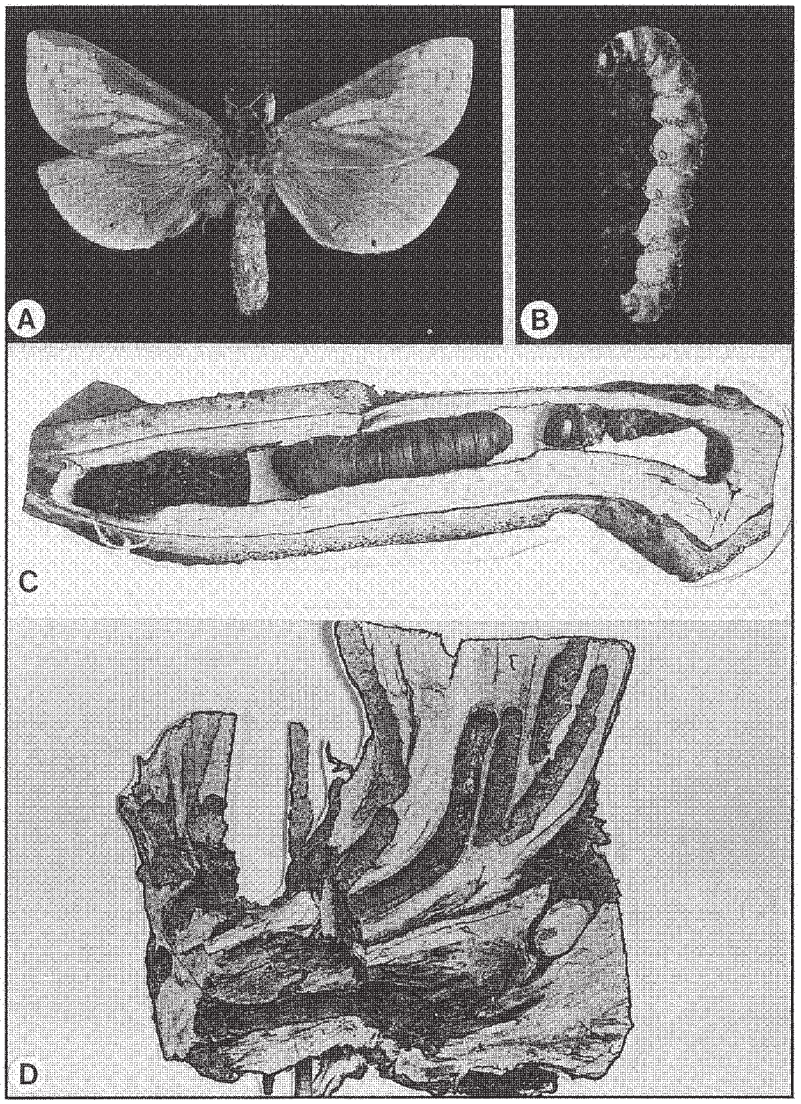


**Figure 3**—Sthenopis thule, *[willow ghost moth]: A, adult; B, larva; C, tunnel with pupa in root; D, root collar mass with multiple galleries (A, specimen courtesy R. Hodges; B-D, reproduced from Swaine [1909]).*

ground. Most tunnel openings are a few centimeters below ground level (Swaine 1909). Moths emerge through holes in the bark, usually located around the root collar (Lyman 1893). Frass fragments extend from just above the root collar down into the rootstock. A labyrinth of tunnels can be found when infested clumps of low-growing willows are excavated and split open (figure 3D) (Winn 1912). Individual galleries are cylindrical, up to 20 cm long, and usually kept free of frass (Swaine 1909). Larvae most often infest small stems 25 to 51 mm in diameter, but they will sometimes infest larger stems. Infestations have been recorded mostly in host trees growing on terraces extending down to flat, swampy tracts.

**Control.** Woodpeckers may be partially responsible for the rarity of this and other species of ghost moths (Lyman 1893). However, bats (Winn 1909), mice (Swaine 1909), an ichneumonid pupal parasite—*Pterocormus devinctor* (Say) (Winn 1912)—and a fungus (*Cordyceps* sp.) are probably more important than woodpeckers as natural enemies.

### *Hepialus californicus* (Boisduval)

[lupine ghost moth] (figure 4)

**Hosts.** Lupine, coyotebrush, dock, blackberry, apple, sneezeweed, bush penstemons, calceolaria, azalea, fern (Essig 1929, Opler 1968, Wagner 1985, Williams 1905a, 1905b). Tree lupine appears to be the major host.

**Range.** A western species known mainly along the Pacific Coast from Vancouver Island, British Columbia, south through Washington and Oregon to San Luis Obispo, California, and east to the Lake Tahoe area in the Sierra Nevada Mountains. Inland colonies are rare; most sightings are well within 80 km of the ocean (Wagner 1985). Many larval collections have been from tree lupine (Opler 1968, Wagner 1985, Williams 1905a, 1905b).

**Description.** ***Adult.*** Moderately large brown and gray moth with a wingspan of 24 to 59 mm (figure 4A) (Wagner 1985). Forewings range from nearly gray to boldly patterned with red, black, tan, white, or brown scales but frequently with two parallel oblique white bands of silvery spots; hindwings smoky gray (figure 4B). Head, thorax, and abdomen with buff to dark brown scales. ***Egg.*** Ovoid and comparatively very small for these large adults, ranging from 0.60 to 0.65 mm by 0.47 to 0.50 mm (Wagner 1985). When first released, eggs cream colored but darken to gray in 2 hours and to shiny black in 4 hours. ***Larva.*** Elongate, largely unpigmented except for brown head and thoracic shield, measuring 2.1 to 3.8 cm long at maturity (figure 4C) (Wagner 1985). Young larvae white; abdomen later becomes smoky gray. Freshly molted late-instar larvae bicolored, with white thorax and smoky gray abdomen. ***Pupa.*** Elongate, cylindrical, and spined, with all appendages firmly fused to the body (figure 4D).

**Biology.** Adults in the San Francisco Bay area emerge in late January through June (Wagner 1985). Adults lack functional mouthparts and live only about 7 days. The moths court and mate briefly at twilight.

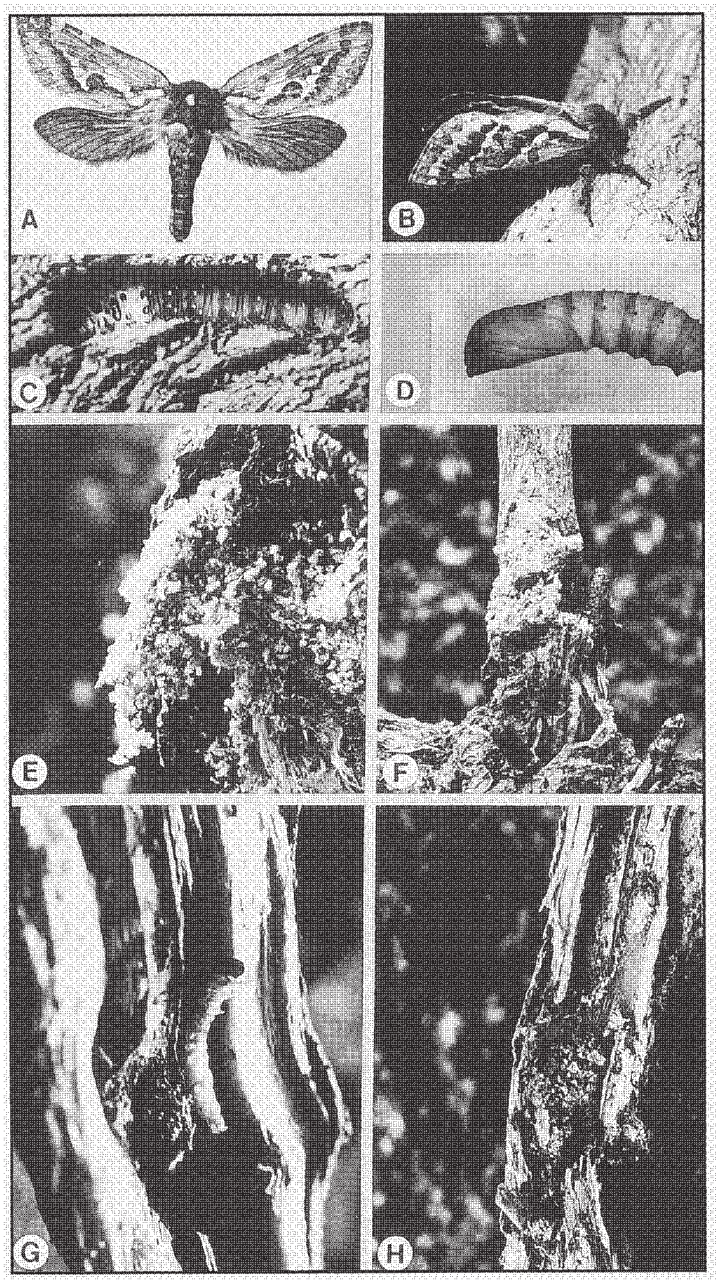


**Figure 4**—Hepialus californicus, *[lupine ghost moth]: A, adult; B, newly emerged moth in resting position; C, larva; D, pupa; E, frass clump; F, attack sites around branch crotches; G, split stem with galleries; H, protruding pupal skins (courtesy D. Wagner).*

When populations are high, adults swarm about suitable habitat in search of mates and oviposition sites; then 10 to 20 minutes later, they abruptly stop flying. Mated pairs remain coupled until a second flight just before dawn. Females oviposit during the two 15- to 25-minute flights (twilight and predawn) by broadcasting their eggs. During oviposition flights, females cast back and forth just under or above host plants and release 1,200 to 2,800 eggs from a few centimeters to 2 meters above ground. Eggs hatch in about 26 days. Almost nothing is known about the early larval instars, but observations of these and related hepialids suggest that they may feed on rootlets, leaf litter, and fungi. Older larvae bore into stems and roots, and unlike some other hepialids, they do not leave their tunnels to consume bark or callus tissue. Larvae in coastal California feed throughout winter. Before pupation, they line galleries with silk, constructing a silken cocoon four times the length of the pupa. Pupation lasts 17 to 35 days. Most evidence indicates one generation per year, but some observations suggest a 2-year generation (Wagner 1985).

**Injury and damage.** The first signs of attack may be weakened plants and dieback. Attacks commonly occur in the stems above ground and less frequently in roots. Although attacks are usually in stems 0.50 to 0.75 m above the ground, most tunneling is in lower boles and in decumbent stems lying in contact with leaf litter and soil. Inspection will reveal clumps of frass loosely bound with silk on bark (figure 4E) near entrance holes (Wagner 1985). Entrances mostly are at the juncture of two or more branches and are usually kept loosely plugged with moist tan frass (figure 4F). Galleries typically have single openings and extend into the xylem, then longitudinally in both directions (figure 4G). Completed galleries are 5 to 12 cm long and 5 to 6 mm in diameter. During spring and summer, brown pupal skins protruding from the bark are good evidence of infestation (figure 4H). Although not regarded as an economically damaging pest, heavy populations can riddle the stems of host plants (Wagner 1985). In a few cases, ornamentals such as azaleas, rhododendrons, bush penstemons, and *Calceolaria* spp. have been destroyed (Wagner 1985). Larval densities in tree lupine frequently reach 30 to 60 per plant and almost certainly contribute to the death of this early succession species (Opler 1968, Wagner 1985).

**Control.** Because of their small size, most first-instar larvae die before finding suitable food (Wagner 1985). Natural enemies, especially entomogenous pathogens, kill upwards of 50% of late-instar larvae (Williams 1905b). Cannibalism, the third most important mortality factor, accounts for moderate losses of late-instar larvae. Direct control action has not been necessary.

## Family Nepticulidae—Nepticulids

Species in this family include the smallest of the Lepidoptera; the adults of some species have wingspans ranging down to only 6 mm (Borror and others 1981, USDA FS 1985). Because of their minute size, retiring habits, and rapid, irregular flight, they are seldom seen. The wings are narrow and elongate with the margins bearing long hairlike scales. "Eye-caps" are formed from scales arising from the base of the antennae. Larvae are budminers and gallmakers.

### Genus and Species



### *Obrussa ochrefasciella*

hard maple budminer (figure 5)

**Hosts.** Maple. Commonly attacks hard maples, including sugar maple, black maple, and southern sugar maple (Kulman 1967). Soft maples, even when grown near infested sugar maple, have not been attacked.

**Range.** Recorded from southern Ontario and New England south to Florida and west to Mississippi and the Great Lakes region. Probably occurs throughout the range of hard maples in the eastern United States (Kulman 1967).

**Description.** ***Adult.*** Minute, brown and yellow moth (figure 5A). Wingspans 6.5 to 8.0 mm (Forbes 1923). Forewings and hindwings elongate, with margins bearing fringes of long scales and spinelike hairs. Forewings blackish brown with pale yellow band across basal third and scattered yellowish scales across apical half, which forms indistinct transverse line in females. Fringe of hairs on wing borders pale yellow (Forbes 1923). Long buff-colored scales rising from basal segment of antennae form caplike structures over the eyes. ***Egg.*** Flat, oval, measuring 0.8 to 1.0 mm by 0.4 mm with small projection from one end (figure 5B) (Kulman 1967). ***Larva.*** Slightly flattened with head rather deeply retracted into prothorax (figure 5C) (USDA FS 1985). Mature larvae 5 to 7 mm long (Kulman 1967).

**Biology.** Moths emerge during June in western Virginia (Kulman 1967). Females deposit most eggs in shallow grooves on the upper sides of leaf petioles attached to terminal buds. Typically, eggs are deposited singly within 3 cm of the petiole base, but petioles can have two to four eggs. Empty egg cases remain on leaf petioles as late as October. Hatching larvae bore directly through the bottoms of the eggs into the leaf petioles, plugging the entrance holes with frass. After mining toward the bases of leaf petioles, the larvae exit and tunnel into the nearest axillary buds. The entrance holes in axillary buds are also plugged with frass. Larvae develop slowly throughout the summer and fall and overwinter in axillary buds. Larvae resume feeding in spring, bore into the bases of terminal buds, and line the feeding cavities with silk. Once the larvae completely hollow the terminal buds, they exit through holes in the twigs about 1 mm below the points where the buds attach. Larvae drop to the ground and attach their

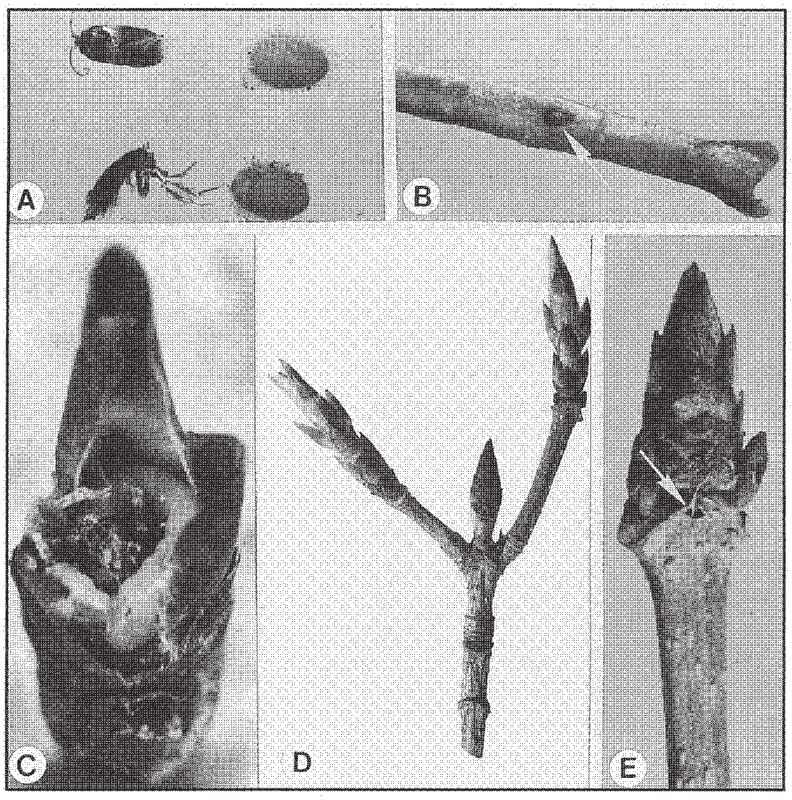


**Figure 5**—Obrussa ochrefasciella, *hard maple budminer: A, adults and cocoons; B, egg on leaf petiole; C, larva burrowing in maple bud; D, terminal bud killed allowing fork to develop; E, larval exit just below terminal bud (courtesy H. Kulman).*

small (3 by 1.5 mm), flat, tan-colored cocoons (figure 5A) to dead leaves. These miners have one generation per year (Kulman 1967).

**Injury and damage.** Excessive dichotomous branching and forking of the terminal leaders and branch tips on seedling and sapling hard maples are the most obvious signs of injury (figure 5D). The hard maple budminer prefers terminal buds over laterals. It first hollows out and kills a leaf petiole adjacent to the terminal bud, then mines into and kills one of the axillary buds before the bud can expand. By October, such small, easily detached buds can be detected. In spring, the larvae mine into second axillary buds and then into the terminal buds, killing them before bud elongation. This borer completely consumes the interiors of terminal buds (figure 5C) and leaves white, crusty, silken tubes. Larvae exit the terminals through small tunnels just beneath the buds (figure 5E) (Kulman 1967, Simmons and Knight 1973). Almost all terminal bud mortality on sugar maple seedlings and saplings in New York, Pennsylvania, Virginia, and West Virginia is caused by this budminer (Kulman 1967). Infestation of young sugar maples results in forking in the main stem and seriously reduces timber values by causing multiple stems and main-stem deformities (Simmons and Knight 1973).

**Control.** Up to 24% of full-grown larvae and 6% of pupae are commonly parasitized by the following hymenopterous insects—*Adelius* n. sp., *Echthrogonatopus* n. sp., and *Euderus argyresthiae* (Crawford). Although the hard maple budminer causes stem deformities that considerably reduce timber values in some stands, there is no information on the use of biological or artificial methods to control it.

### *Ectoedema populella* Busck

[aspen petiole gall moth] (figure 6)

**Hosts.** Poplar. Reared from bigtooth aspen and quaking aspen and appears to be most common in bigtooth aspen (Forbes 1923, MacAloney and Ewan 1964).

**Range.** North central and northeastern United States and from Manitoba to the Maritime Provinces in Canada (MacAloney and Ewan 1964, Martineau 1984).

**Description.** ***Adult.*** Tiny, brownish moth with wingspan of 6.2 to 9.6 mm (Forbes 1923, Martineau 1984). Head with reddish ochreous tuft and pale yellowish eye-caps. Forewings elongate, uniformly brown with coppery luster. ***Larva.*** Elongate, 3.5 to 5.0 mm long, very slightly flattened, slightly curved, yellowish green, with tan to light brown head deeply retracted into prothorax (figure 6A).

**Biology.** Adults emerge in May (Forbes 1923, Martineau 1984). Larvae bore in petioles and are active in the galls formed by boring from early July until fall. Larvae feed singly inside the galls and pack the brown frass into a firm, smooth mass on one side of the gall interior (figure 6B). By early fall, this frass mass, attached to the gall surface, becomes dark brown, round, flattened, and tabletlike in appearance. In October, mature larvae drop to the ground, spin cocoons in the duff, and overwinter. There is one generation per year (MacA-

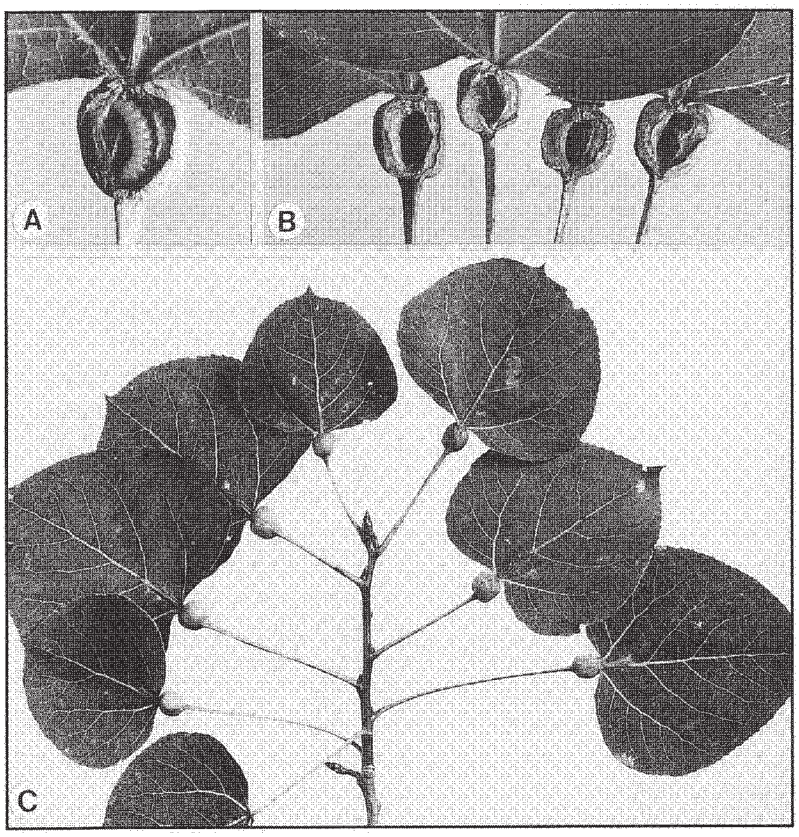


**Figure 6**—Ectoedemia populella, *[aspen petiole gall moth]: A, closeup of larva feeding inside gall; B, galls dissected to expose cavities and tabletlike frass mass on one side; C, pea-sized galls on petioles of aspen (specimens courtesy D. Wagner).*

loney and Ewan 1964).

**Injury and damage.** Globular to cylindrical, pea-sized galls form on the petioles just below the leaf blade (figure 6C) (MacAloney and Ewan 1964, Martineau 1984). Galls are the same color as the petiole and mostly 4 to 7 mm in diameter, but a few reach 10 mm in diameter. Heavily infested trees may have galls on nearly every leaf petiole. Heavy attacks cause early leaf fall in many shelterbelts or on shade and ornamental trees, but the impact generally is light.

**Control.** One unidentified larval parasite of the aspen petiole gall moth has been found in Canada (Martineau 1984). Cultural methods such as raking and burning fallen infested leaves during summer and early fall provide some control for shade and ornamental trees. A spring application of insecticide to the foliage can prevent oviposition.

## Family Momphidae—Momphids

These adult moths are very small, with wingspans ranging down to 7 mm (Forbes 1923). They can be distinguished by tufts of raised scales on their forewings. Wings are elongate and fringed with long scales. Immature larvae are usually reddish pink, but lose most of the pigment when mature. They bore in tender shoots.

### Genus and Species

*Mompha* n. sp. *17*

### *Mompha* n. sp.

[buttonbush shoot borer] (figure 7)

**Hosts.** Buttonbush. The only known host of this little-known species is buttonbush.

**Range.** Common in delta bottomlands of Arkansas, Louisiana, and Mississippi.

**Description.** ***Adult.*** Small, light and dark gray mottled moth (figure 7A). Head creamy white anteriorly. Wingspan 7 to 9 mm. Forewing gray with short, narrow, blackish gray lines edged with whitish gray at middle and near apex. These markings along with two grayish black dorsal tufts along inner margin at two-fifths and three-fourths distance to apex give distinct appearance to folded wings of resting moths (figure 7B). Long silvery gray fringe on forewings and hindwings. ***Larva.*** Mature larva, 5 to 6 mm long, slender, creamy white with light brown head (figure 7C). Immature larva with dorsal and lateral reddish pink lines, varying from moderately prominent in some specimens to almost

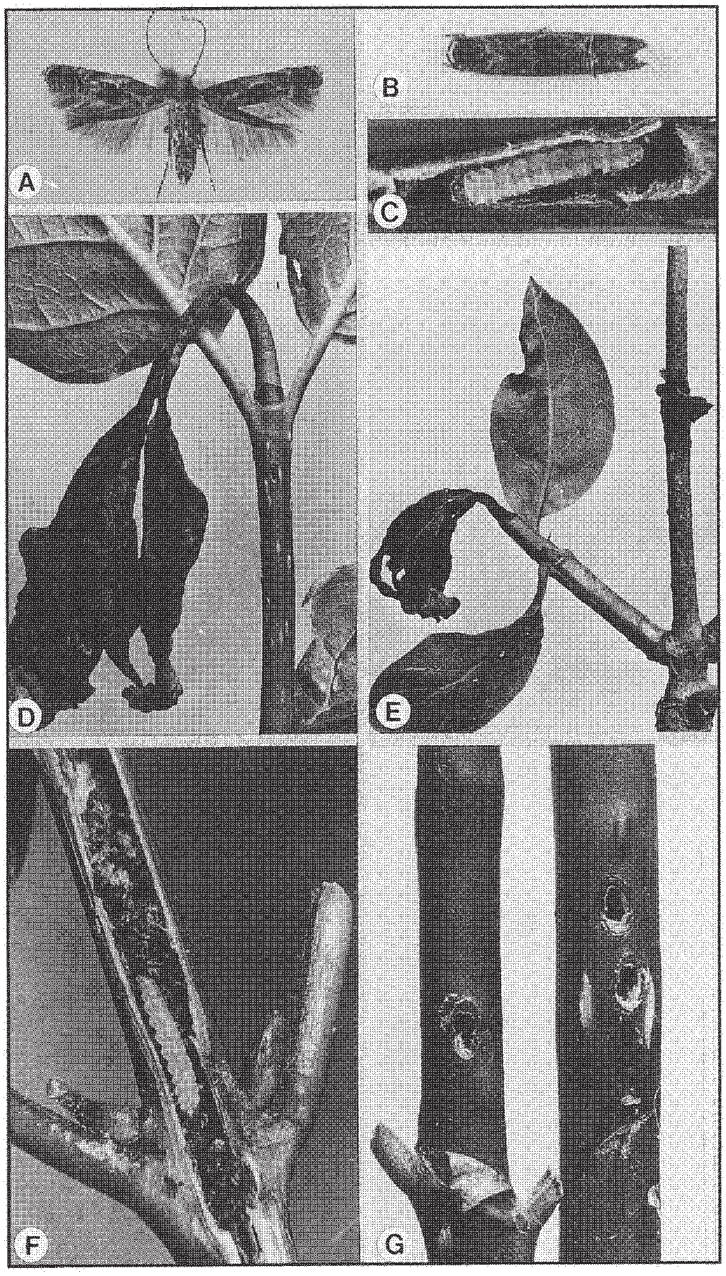


**Figure 7**—Mompha *n. sp., [buttonbush shoot borer]: A, adult; B, adult in resting position; C, larva in gallery; D, wilting, drooping terminal shoot; E, lateral shoot dieback; F, shoot hollowed out and loosely filled with frass; G, closeup of larval exit holes.*

indistinct in others.

**Biology.** In Mississippi, moths emerge at least from April 30 to May 20. Oviposition has not been observed, but it probably occurs on the new shoots or expanding leaves. Newly hatched larvae burrow into tender shoots a few millimeters below the apex and initially make tiny girdling burrows. Some larvae feed apically initially but then turn and tunnel basally down the shoots. Shoots usually contain one larva, though some have two, and up to three emergence holes can be found. Mature larvae cut tiny holes through the sides of the shoots and exit galleries to seek pupation sites. Most larvae from the spring brood mature and exit from April 16 to May 7. Pupation occurs in white, loosely spun, silken cocoons in and under debris and lasts 12 to 14 days. A few infested shoots found in June are evidence of a second generation. Although the new shoots become less succulent for internal feeding as the season progresses, the insect appears capable of one heavy and several sparse generations per year.

**Injury and damage.** Larva attacks only tender, new, terminal (figure 7D) and lateral (figure 7E) shoots, often killing them. First signs of attack are wilting and drooping shoot tips. Tips of affected shoots shrivel and darken, becoming black within days. Shoots may swell slightly just below the darkened portion. Dissection of shoots with early symptoms reveals tiny girdling tunnels. Later, the larvae excavate shoots, filling them loosely with frass consisting mostly of dark brown excrement pellets (figure 7F). Galleries range from 15 to 55 mm long. Tiny oval to elongate exit holes 1 to 2 mm long are left by emerging larvae (figure 7G). Damage, most noticeable from mid-April to early May, ranges from little or none to heavy infestation, killing every new shoot. When most of the shoots are killed on a plant, secondary shoots sometimes grow prolifically, giving a full bushy appearance.

**Control.** Natural controls are predaceous thrips and two insect parasites—*Bracon* sp. and *Pholetesor* sp. Direct controls have not been needed.

## Family Agonoxenidae—Agonoxenids

Adults of these moths are very small with a smooth-scaled head and very long labial palps (Covell 1984, USDA FS 1985). The wings are narrow and lancelike; hindwings have a broad fringe of long, hairlike scales. The light-colored larvae burrow in the bark.

### Genus and Species

*Glyphipteryx linneella* (Clerck) *20*

### *Glyphipteryx linneella* (Clerck)

[linden bark borer] (figure 8)

**Hosts.** Basswood. In Canada, the insect reportedly feeds only on planted European linden (Rose and Lindquist 1982).

**Range.** An introduced European species, first reported in New York in 1928 (USDA FS 1985). Since then, reported from New Jersey and Massachusetts west to Michigan and Ontario (Covell 1984, Rose and Lindquist 1982).

**Description.** ***Adult.*** Tiny, dusky moth with wingspan of about 10 mm (figure 8A) (Covell 1984, Rose and Lindquist 1982). Wings shiny black with large, elliptical, bright orange patch on each forewing that does not touch the margins and contains three silvery black spots. Hindwings have broad fringe. Antennae tipped with white. ***Larva.*** Full-grown larva white with light brown head; measures about 6 mm long when fully grown (figure 8B). ***Pupa.*** Tiny and pale yellow.

**Biology.** Moths fly from late May to July in the Northeast (Covell 1984, USDA FS 1985). In Ontario, moths are present mainly in June and some until early August (Rose and Lindquist 1982). Females lay eggs in bark fissures on branches of Hosts. Hatching larvae bore in the bark, making extensive burrows. Larvae occasionally honeycomb bark with tunnels. Larvae overwinter in bark and pupate from early spring to midsummer in cells in burrows close to the bark surface.

**Injury and damage.** The first evidence is fine grains of reddish orange larval frass in bark fissures (Rose and Lindquist 1982). Cutting away outer surface of bark reveals the mines and burrows (figure 8B). Honeycombed bark occurs from ground level to high in the crown. Old pupal skins and frass (mostly excrement pellets) are in many burrows. Larvae usually do not feed where bark is smooth and unfurrowed. Damage is not serious.

**Control.** As yet unneeded, but controls may become necessary for ornamental trees during heavy infestations.

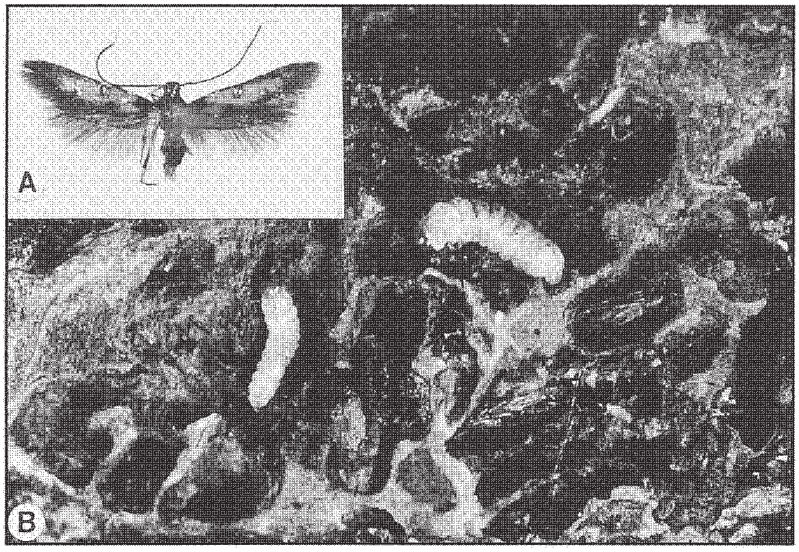


**Figure 8**—Glyphipteryx linneella, *[linden bark borer]: A, adult; B, outer bark removed to expose the larvae and burrows in the inner bark (A, specimen courtesy R. Hodges; B, courtesy Great Lakes Forestry Centre).*

## Family Gelechiidae—Gelechiids

Gelechiids are small moths that have noticeable labial palpi with terminal segments that are long and pointed and sometimes upcurved over the head like horns or tusks (Borror and others 1981, Craighead 1950). The wings are narrow, with the hindwings fringed and usually curved on the outer margin. Larvae feed in shoots, fruits, and galls; some members are economically damaging pests.

### Genus and Species



### *Anarsia lineatella* Zeller

peach twig borer (figure 9)

**Hosts.** The commercial fruit trees: peach, almond, apricot, plum (including prune varieties), cherry, and nectarine. Peach appears to be the principal host; however, apricot, almond, and plum are sometimes heavily attacked (Bailey 1948).

**Range.** Introduced into California from Asia (probably Japan) over 100 years ago (Bailey 1948, Holland 1968). Now occurs throughout the United States and Canada, wherever its hosts grow (Slingerland and Crosby 1919).

**Description.** ***Adult.*** Dark gray moth with irregular spots and streaks of light and dark gray (figure 9A). Head bluntly rounded. Wingspan 10 to 16 mm; wings held rooflike over body when at rest. Labial palpi upcurved over face, resembling tusks or horns. Male slightly smaller than female (Bailey 1948). ***Egg.*** Oval with reticulated surface. Yellowish white, 0.4 mm in length by 0.2 mm in diameter (Bailey 1948), becomes orange before hatching. ***Larva.*** Newly hatched larva light yellowish brown with black head; about 0.5 mm long. Gradually becomes reddish brown with black heads and dark cervical and anal plates. Yellowish white intersegmental membranes that contrast sharply with darker segments. Mature larvae average 10 mm long (figure 9B) (Bailey 1948). ***Pupa***. Naked and smooth, light to dark yellow, gradually becoming dark brown, measuring about 6 mm in length (Bailey 1948).

**Biology.** Young larvae overwinter in hibernacula beneath the outer bark. During early spring as new growth of hosts begins, they emerge from hibernacula and attack shoots. Full-grown larvae vacate tunnels in shoots and crawl to the larger branches or trunks to construct cocoons and pupate within curled flakes of bark. In California, first-generation adults appear in early May and live 3 to 20 days. Mating and egg laying last about 2 weeks. Moths deposit up to 115 eggs, usually in batches of 1 to 10. Eggs are laid primarily on stems and leaves and incubate for 5 to 7 days (extremes are 4 and 18 days) before hatching. Larvae develop in 10 to 20 days (Bailey 1948). Second-generation larvae attack tips of growing branches in late May and fruit in early June. They pupate during July and August in the stem ends of fruit (Slingerland and Crosby 1919). Pupal stage lasts 6 to 7 days, except on apricots, where it lasts 10 to 15 days

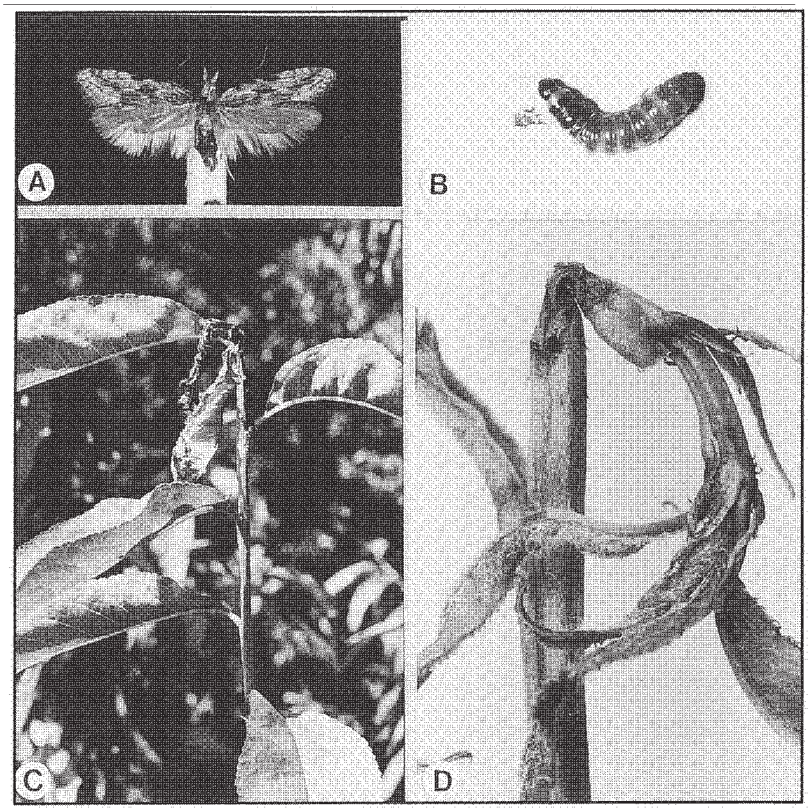


**Figure 9**—Anarsia lineatella, *peach twig borer: A, adult; B, larva; C, peach shoot wilting and drooping; D, dying shoot with hole in stem (A, specimen courtesy R. Hodges; B, courtesy L. Smith).*

(Bailey 1948). Adults appear during late summer and lay eggs on the fruit. In warmer climates, a third (and sometimes a fourth) generation develops; in the North, only one generation is possible (Metcalf and others 1962). During fall, first- and second-instar larvae move to the rough bark or cracks in crotches of branches to form hibernacula for overwintering. In California, overwintering lasts from mid-September or October to April.

**Injury and damage.** The insect causes two kinds of injury—death of terminals and twigs, which can misshape trees and kill nursery stock (generally of minor concern), and injury to fruit (often of major economic impact). During spring and early summer, infested terminals and branch ends wilt, turn brown to black, and begin to die back (figure 9C and D). Twigs often exude small masses of gum. Succulent growth is attacked from the tip downward for 12 to 51 mm. Succulent and vigorous hosts have more wilted shoots than less vigorous varieties. Larvae from the May brood (second brood) attack lateral shoots stimulated to grow by the death of terminal and branch-end buds (Bailey 1948). Heavily infested trees appear fire-scorched (Slingerland and Crosby 1919). Injury to the fruit starts with the May brood as evidenced by sap droplets on green fruits. Most larvae enter fruits at the stem end along the suture and excavate a considerable cavity in the flesh, which they fill with excrement and gum. Infestation in fruit is evident from entrance hole, gum exudate, excrement, and decay. Late-maturing varieties are damaged worst. Overwintering larvae chew hibernating cavities beneath the outer bark, usually in branch crotches at the base of new growth. These hibernacula can be recognized by small reddish brown mounds of bits of bark webbed together with silk. Up to 80 hibernacula have been found on a 2-year-old tree. Losses of 50% of the crop are common in untreated orchards. Damage is generally light in regularly sprayed, well-managed orchards. Although sometimes troublesome in the eastern United States, peach twig borer impact has been greatest along the Pacific Coast (Metcalf and others 1962).

**Control.** Clipping and burning infested shoots in spring, picking up and destroying fallen fruit and prunings, and sterilizing lug boxes around orchards are controls (Bailey 1948). Natural enemies include *Leptothrips mali* (Fitch), a thrips that consumes large numbers of eggs and young larvae. A predaceous mite—*Pediculoides ventricosus* (Newport)—is abundant in some areas and destroys the hibernating larvae. Two beetles—*Hydnocera scobia* LeConte and *Notoxus constrictus* Casey—also are predaceous on the hibernating larvae. In all, 28 parasites have been listed for the peach twig borer (Bailey 1948). During some years, insect parasites destroy up to 80% of the population. *Hyperteles lividus* (Ashmead) has been the most effective larval parasite along the Pacific Coast. Insecticides are useful in controlling the pest. Dormant oil applications during winter are moderately effective against hibernating larvae. Pheromones are hepful for monitoring populations to help predict and time insecticide applications (Hathaway 1981).

### *Gnorimoschema baccharisella* Busck
[coyote brush gall moth] (figure 10)

**Hosts.** Coyote brush (Busck 1903, Tilden 1951).

**Range.** Has a very limited known distribution in the San Francisco and Berkeley areas and southern Monterey County in California (Busck 1903, Tilden 1951).

**Description.** ***Adult.*** Moth has light clay brown face, head, and thorax (figure 10A). Antennae reddish brown with each joint tipped with black and two small black dots. Labial palpi reddish white; extreme tip whitish with black shading. Wingspan varies from 11 to 20 mm (Busck 1903). Forewings yellow with slight brown tinge and reddish spot near middle and some streaking near apex. Base of forewings light brown with small, dark brown dot below costa at extreme base. Few black dots along apical edge. Hindwings shiny silver with yellowish cilia. Abdomen robust, reddish yellow, with transparent ovipositor in female.

**Biology.** Moths emerge in September and lay eggs on outer portions of shrubs (Busck 1903, Tilden 1951). Eggs overwinter and young larvae invade the nearest shoots soon after hatching, as early as February. Larvae bore into the tips of the growing terminals. Galls first form in March. Larvae feed on granular tissue that is continually regenerated inside the galls for 4 to 5 months. Before maturing, larvae outstrip their food supply and eat much of the gall interiors. Toward the end of their development, larvae feed deeply in one spot, usually near the top of the gall. When ready to leave the gall, they eat through the thin wall, exiting through round holes and crawling down stems to the ground in July. They enter the soil, usually under the duff, just deep enough to cover themselves. Here, they pupate in silken cells (Tilden 1951). There is one generation per year.

**Injury and damage.** The larva bores into the apex of the growing terminal for a short distance and seals the entrance completely with frass. A hollow gall forms around the larva, beginning at the farthest point of the larval entry. The twig usually continues to grow, leaving the mature gall some distance from the tip. The gall is short, cylindrical, often spindle shaped, and may persist for several years (figure 10B). Its outside wall resembles and is confluent with the bark of the stem. Mature galls are 17 to 36 mm long. Later, the larva chews an exit hole in the gall (figure 10C). The larva deposits frass at the apical end of the gall during most of its development (Tilden 1951). Galls are prevalent and can be found on nearly all plants in heavily infested areas (Tilden 1951). Infested twigs die and fall off, causing noticeable pruning.

**Control.** Ten species of coyote brush gall moth parasites have been reared (Tilden 1951). A clerid predator has been found in the galls feeding on hymenopterous parasites and probably feeds on the gall-making larvae as well.

### *Coleotechnites bacchariella* (Keifer)
[coyote brush twig borer]

**Hosts**. Coyote brush (Keifer 1933, Tilden 1951).

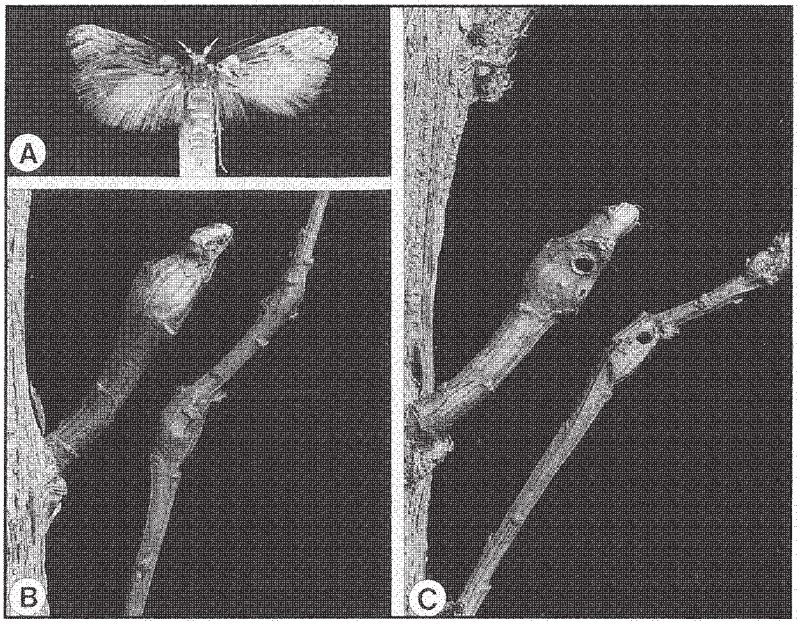


**Figure 10**—Gnorimoschema baccharisella, *[coyote brush gall moth]: A, adult; B, galls on shoots; C, exit holes in shoot galls (A, specimen courtesy R. Hodges).*

**Range.** Known only in the San Francisco area of California (Keifer 1927, Tilden 1951).

**Description.** ***Adult.*** Moth creamy white with dark brown and red to black marks. Second joint of labial palpi suffused with dark brown; terminal joint has blackish rings. Light brown head; face overlaid with dark brown. Antennae ringed with dark brown. Thorax and forewings dark brown with black markings on wings. Wingspan averages 14 mm in males and 12 mm in females. Forewings have five noticeable scale tufts. Hindwings brown and cilia brownish yellow tinged. Dark brown legs. ***Larva.*** Yellow with pink longitudinal subdorsal stripe and reddish yellow head (Keifer 1933). Full-grown larvae 8 to 9 mm long.

**Biology.** Moths begin emerging in June, but most emerge in August and September (Keifer 1933, Tilden 1951). Larvae become active in March and live in and feed from their webbed-leaf shelters around terminal shoots until late summer (Keifer 1933). Larvae mature slowly and typically use the same shelter during their entire development. Larvae do not appear to feed continuously, which is perhaps important in their slow development. In most cases, they form a feeding tube and molt then stop feeding for 4 to 10 days before resuming. Mature larvae rest for about 2 weeks before pupation (Tilden 1951). Pupation begins in May and June and occurs within the galleries (Keifer 1933, Tilden 1951). There is one generation per year.

**Injury and damage.** Larvae tie terminal leaves together with silken threads, feed on the terminal bud, and spin a silken tube where the bud is removed. Larvae wrap the leaves around the tube and bore a short distance into the tender shoot. The terminal leaves dry and form a short tunnel with the silken tube. As the larvae extend their tunnels into the terminals, more leaves are webbed together, making structures bulky and conspicuous. Destruction of the terminal tissue stops stem elongation (Tilden 1951). Considerable pruning of plants occurs when the insect is abundant.

**Control.** Natural enemies include three insect parasites—*Apanteles* sp., *Scambus aplopappi* (Ashmead), and most commonly, *Goniozus* sp. (Tilden 1951). Direct controls have not been needed.

## Family Argyresthiidae—Argyresthiids

Adults are small moths that are usually brightly patterned and have rather broad wings (USDA FS 1985). The larvae feed as miners and borers in shoots, fruits, or leaves.

### Genus and Species

*Argyresthia oreasella* Clemens *28*

### *Argyresthia oreasella* Clemens

[cherry shootborer]

**Hosts.** Cherry, serviceberry, hawthorn, oak. Cherry appears to be favored (Covell 1984, Forbes 1923, Rose and Lindquist 1982).

**Range.** A little-known pest reported from Quebec to Manitoba and Alberta and in the northeastern United States south to Missouri (Covell 1984, Forbes 1923, Rose and Lindquist 1982).

**Description.** ***Adult.*** Tiny, silvery white moth with wingspan varying from 10 to 13 mm (Forbes 1923). Forewings white streaked with oblique, irregular, gold and brown bands; terminal band near apex encloses two white dots. Hindwings gray (Covell 1984, Rose and Lindquist 1982). ***Larva.*** Very small; measures about 7 mm long when fully grown.

**Biology.** Moths emerge and fly in late June and July (Rose and Lindquist 1982). Larvae tunnel and feed inside succulent shoots from May to mid-June. They pupate in June and early July.

**Injury and damage.** Infested plants can usually be detected when young leaves at tips of tender shoots begin to wilt, droop, and darken in late spring and early summer (Rose and Lindquist 1982). Infestation can be confirmed by dissecting infested shoots to find galleries and larvae. This shoot borer occasionally becomes abundant in localized areas of Ontario, where it damages cherry.

**Control.** This shootborer can be controlled in urban plantings and recreational areas by clipping and destroying infested new shoots in late May (Rose and Lindquist 1982).

## Family Sesiidae—Clearwing Moths

The sesiids are best known as clearwing moths because in most species the greater part of one or both pairs of wings is without scales and transparent (Duckworth and Eichlin 1977a, USDA FS 1985). Forewings are long and narrow; the hindwings are somewhat broader. The body is often brightly banded, and the two sexes are frequently colored differently. Adults are swift fliers, often seen around flowers, and many species strikingly resemble bees and wasps. Most larvae are white and without markings, except for a pigmented head and lighter thoracic shield. They bore in branches, trunks, root collars, or roots of trees, shrubs, and vines, or in the stems, canes, and roots of herbaceous plants. Many species make their own entrances, but some inhabit injured areas. A few form galls, and others are inquilines in galls. Some are economically damaging pests of forest and shade trees and ornamentals.

### Genus and Species

### *Podosesia syringae* (Harris)

ash borer (figure 11)

**Hosts.** Ash, lilac, fringetree, privet, mountain-ash. Green ash, white ash, and lilac are the major hosts; but red, European, and Carolina ash are also commonly infested (Solomon 1975). Fringetree, privet, olive, and mountain-ash mentioned infrequently as hosts.

**Range.** Saskatchewan and Manitoba (Engelhardt 1946) southward through Washington and the Rocky Mountains to Texas and throughout much of the eastern United States (Eichlin and Duckworth 1988).

**Description.** ***Adult.*** Reddish clearwing moth (figure 11A) closely mimics *Polistes* wasps in appearance and flight. Wingspan of males 26 to 32 mm; of females, 32 to 38 mm. Opaque forewings, dull black, and more or less shaded with chestnut red; hindwings transparent with yellowish iridescence. Head dark brown with reddish posterior fringe near neck; thorax brownish black, marked with chestnut red laterally and posteriorly. Legs marked with black, orange, and yellow; hindlegs noticeably longer than middle and forelegs (Engelhardt 1946). Pale ochreous form with black and yellow banding on abdominal segments occurs in western range. ***Egg.*** Light brown, elliptical, and about 0.8 mm long and 0.4 mm wide (figure 11B) (Solomon 1975). Irregular, hexagonally shaped reticulations on the surface of the egg shell more pronounced than on egg of banded ash clearwing, *P. aureocincta* Purrington and Nielsen, a closely related species (Purrington and Nielsen 1977). ***Larva.*** White except for amber-colored head, thoracic shield, and spiracles (figure 11C). Larvae average about 1 mm long when newly hatched and 26 to 34 mm at maturity (Solomon 1975). Each thoracic segment has one pair of jointed legs and abdominal segments 3 to 6 and 10 have fleshy lobes (prolegs) ending in rows of small hooked spines (crochets). ***Pupa.*** Reddish brown; measuring 18 to 24 mm long (figure 11D).

**Biology.** Adults emerge as early as mid-December in southern Florida (Eichlin and Duckworth 1988), February in northern Florida (Purrington and Nielsen 1977), mid-March to mid-July in west central Mississippi (Solomon 1975), May through July in North Dakota (Dix and others 1978), and May through June in the Canadian Prairie Provinces (Peterson 1964). Emergence in all areas is complete by July 31. This borer has one generation per year over most of its range (USDA FS 1985), but a 2-year life cycle has been reported in Canada (Peterson 1964). Adults emerge between 8 a.m. and 11:30 a.m.; mating and oviposition follow rapidly (Solomon 1975). Most eggs are deposited singly or in small clusters in bark crevices or beside bark ridges; rarely laid on smooth surfaces. Eggs are laid over about 5 days; incubate from 9 to 13 days; and adults live an average of 5.5 days (Solomon 1975). Initially, young larvae make cavities in the phloem and cambium about 1 to 3 cm wide and 2 to 5 cm long. Then they excavate galleries in the wood for 2 to 4 cm inward, tunnel vertically for varying distances, and finally return to

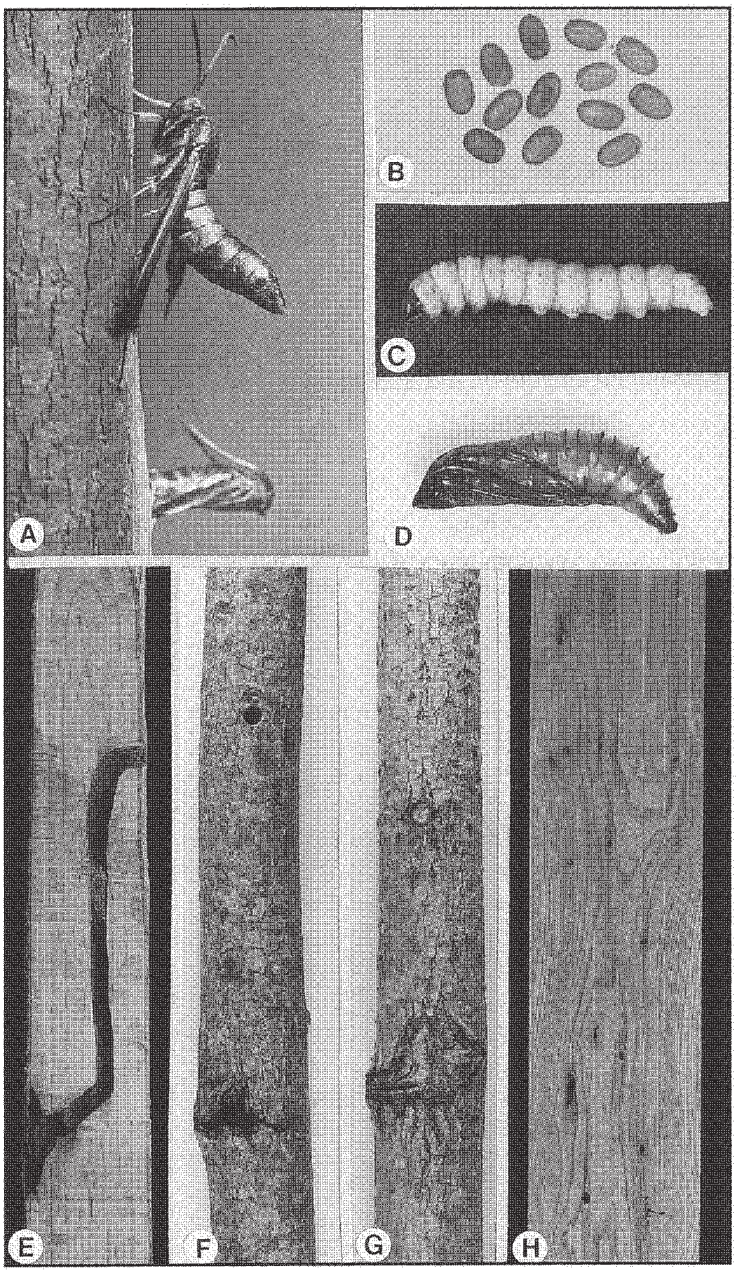


**Figure 11**—Podosesia syringae, *ash borer: A, newly emerged adult, pupal skin below; B, eggs; C, larva; D, pupa; E, completed gallery; F, entrance hole below, round exit hole above; G, bark scars of healed entrance and exit; H, wormhole defects in ash lumber.*

the surface. Completed galleries are 5 to 7 mm in diameter and 7 to 32 cm long. Galleries intersect in heavily infested trees, but only one larva occurs in each gallery. Before pupation, galleries are extended to the bark surface except for paper-thin covers. The larvae enclose themselves in pupal chambers in the uppermost portion of galleries by plugging the tunnels tightly with frass. The pupal stage requires about 3 weeks.

**Injury and damage.** This borer is one of the most destructive insects of ash and lilac in North America. The first evidence of attack, during spring and summer, is sap mixed with fine frass oozing from small irregularly shaped holes in the bark of trunks and larger branches. Later in the year, frass in small clumps is extruded from the entrance hole; frass catches in bark crevices as it falls to the base of the tree, where it often accumulates. Pencil-sized tunnels in the wood are common (figure 11E). Adults exit from circular holes several centimeters above entrance holes, on the same or opposite side as the entrance hole (figure 11F). Entrance holes eventually heal to form L-shaped scars, and exit holes heal to resemble small branch-stub scars (figure 11G). Infestation is usually greatest in the lower trunk, but attacks can occur on trunk and branches to 9 m. In green ash, the number of attacks is often proportional to a tree's diameter (Roberts 1956). Open-grown trees generally are more susceptible than trees in dense stands (Solomon 1975). Lumber sawn from infested trees may have numerous dark-stained, pencil-size holes (figure 11H). In northeast Ohio, this borer causes an estimated loss in lilac nurseries of $12,345 per hectare per 5-year crop cycle and has precluded the culture of ash in the area (Nielsen and others 1973). Infestations of 50% among green ash used as shade trees and windbreaks are common throughout the Canadian Prairie Provinces and northern Great Plains (McKnight and Tunnock 1973, Peterson 1964). Reforestation and intensive management of green ash, a valuable timber species in the South, have been hampered by this borer (Solomon 1975). Trees intended for wood products are reduced in value by the holes and associated decay. Shade and ornamental trees may be disfigured, scarred, seriously weakened, or even killed.

**Control.** Woodpeckers are important in natural control (Solomon 1975). The insect parasites *Apanteles* sp., *Lissonota* sp., and *Phorocera signata* Aldrich and Webber are natural enemies in Mississippi (Solomon 1975); *Macrocentrus marginator* (Nees) in North Dakota (McKnight and Tunnock 1973); *Lampronota pleuralis* Cresson and *Phaeogenes ater* Cresson in Illinois (Appleby 1973); *Agonocryptus discoidaloides* (Viereck), *Bracon sanninoideae* (Gahan), and *Coccygomimus annulipes* (Brulle), in other areas (Carlson 1979). The ant *Crematogaster clara* Mayr preys upon the pupae, and a fungus (*Beauveria* sp.) infects the larvae (Solomon 1975). Because the borer prefers wound sites, tree injuries should be minimized. In forests, brood trees should be removed (Solomon 1975) and vigorous tree growth maintained by eliminating competing vegetation (Dix and

others 1978). For ornamental trees, trunks can be wrapped with burlap before adults emerge (Peterson 1964). In green ash shelterbelt trees in North Dakota (Dix and others 1978), in street trees (ornamental variety) in Ohio (Nielsen and others 1973), and in privet hedges in Illinois (Appleby 1973), ash borer has been controlled effectively with insecticides.

### *Podosesia aureocincta* Purrington and Nielsen

banded ash clearwing (figure 12)

**Hosts.** Ash. A recently described species reared only from white and green ashes; probably occurs in other *Fraxinus* species and possibly other *Oleaceae*.

**Range.** New York south to Florida and west to Oklahoma and Texas (Purrington and Nielsen 1977, 1979).

**Description.** In 1946, the genus *Podosesia* was revised to include two subspecies, *P. syringae syringae* (Harris) and *P. syringae fraxini* (Lugger), which became generally known as the lilac and ash borers (Engelhardt 1946). Later, when sesiid taxonomy was reworked, both borers were combined under one name *P. syringae* Harris (ash borer) (Duckworth and Eichlin 1977a). Subsequently, *P. aureocincta* was described and distinguished from *P. syringae* (Purrington and Nielsen 1977, 1979). ***Adult.*** Reddish clearwing moth with wingspan about 39 mm in female and 33 mm in male. Narrow forewings violet-brown and mostly opaque except near base; hindwings mostly transparent. Head and thorax grayish, except for orange-yellow and chestnut red markings. Abdomen mostly brownish black, except upper surface of fourth abdominal segment bordered posteriorly with distinct, narrow, dorsally tapering, bright, orange-yellow band (figure 12A). *Podosesia syringae* lacks such coloration of the fourth abdominal segment (Purrington and Nielsen 1977). Black, orange, yellow, and brown legs long; hindlegs held wasplike in flight and at rest. Genitalia of male differ morphologically from *P. syringae* (Purrington and Nielsen 1979). ***Egg.*** Blackish, elliptical, and about 1.00 by 0.67 mm (Purrington and Nielsen 1977). Color and size distinguish it from egg of *P. syringae*, which is tan and markedly smaller at 0.69 by 0.44 mm. Irregular, hexagonally shaped network of raised ridges (reticulations) on surface shallower than those of *P. syringae*. ***Larva.*** White except for brown head; about 26 to 34 mm long at maturity. Mature larva resembles *P. syringae* in every respect except the number of crochets (tiny hooks) on the abdominal prolegs ($14 \pm 2$ crochets per row in *P. aureocincta* and $18 \pm 2$ in *P. syringae*).

**Biology.** Adults emerge in August and September in Ohio and Virginia (Grayson 1943, Purrington and Nielson 1977), September and October in Mississippi, and July to December in Florida (Eichlin and Duckworth 1988). Late-season emergence distinguishes this species from *P. syringae*, which emerges during spring and summer. Moths emerge in late morning and mate from late morning until midday. Eggs are deposited in bark crevices of hosts. Young larvae bore into bark and mine in the phloem-cambium

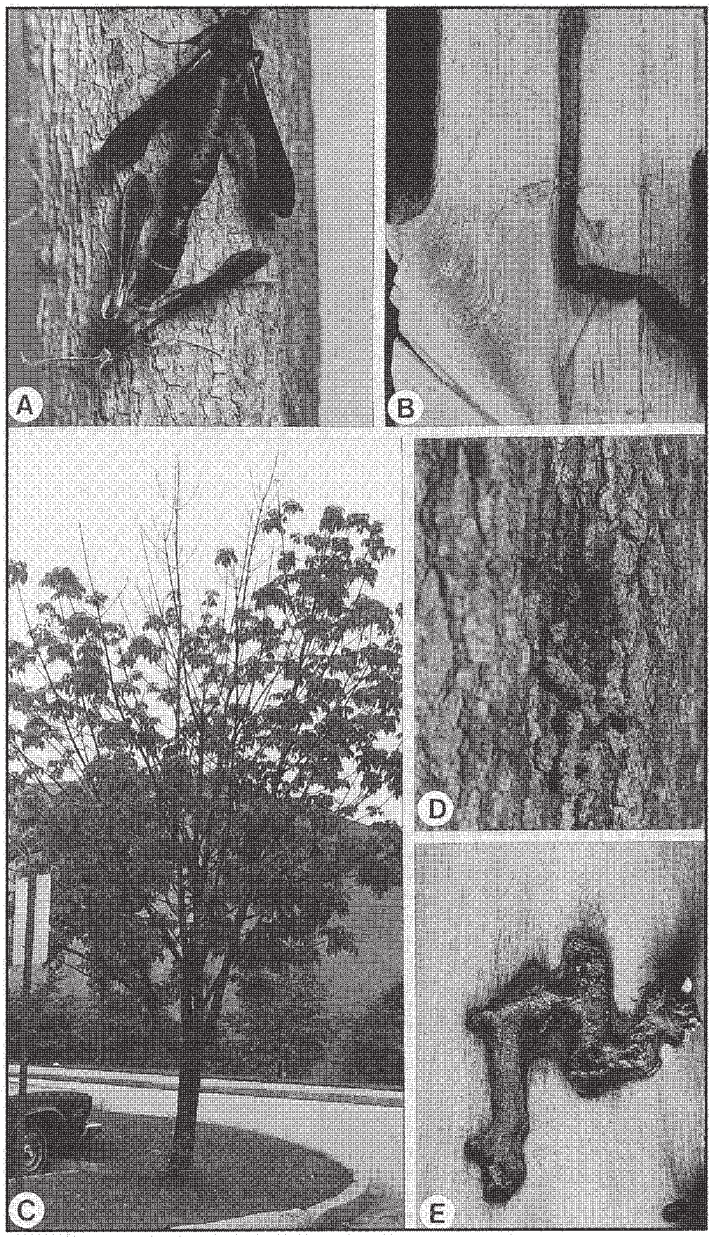


**Figure 12**—Podosesia aureocincta, *banded ash clearwing: A, mating adults; B, gallery with cambial cavity; C, tree under heavy attack with crown dieback and basal sprouts; D, active attack site with sapstained bark and frass; E, cambial burrow on surface of sapwood.*

area. They overwinter in the mines as second-instar larvae (Purrington and Nielsen 1977). In spring, they continue to enlarge the cambial mines and begin excavating galleries into the wood. Head measurements for 152 larvae indicated 6 to 8 larval instars (Grayson 1943). Cambial cavities, like those of *P. syringae*, are 1 to 3 cm wide and 2 to 5 cm long. Galleries extend obliquely upward in the wood 2 to 4 cm, vertically for varying distances (figure 12B) and finally back to the surface. Completed galleries are 5 to 7 mm in diameter and 7 to 32 cm long. Mature larvae enclose in a pupal chamber at the uppermost part of the gallery by plugging the tunnel tightly with frass. They pupate from midsummer to fall (about 3 weeks). There is one generation per year.

**Injury and damage.** Injuries (figure 12B) resemble those of *P. syringae*. Crown dieback and basal sprouts often indicate attack (figure 12C). Oozing sap and fine frass are extruded from attack sites beginning in late summer and continue into fall. By spring and summer, frass becomes coarse and granular and is extruded in small clumps from entrance holes (figure 12D), may be present in bark crevices, and often accumulates in piles around the tree's base. Maximum accumulation of frass occurs during May and June (Grayson 1943). Cambial burrows can be exposed by removing the bark (figure 12E). Pupal skins protrude from exit holes in bark from late summer to winter. The seasonal evidence, irregularly shaped entrance holes, 4- to 5-mm round exit holes, together with associated overgrown bark scars indicate current and past infestation. This borer is very destructive to ornamental and timber trees but seems less populous and more scattered than *P. syringae*.

**Control.** Woodpeckers are among the most important natural enemies. A fungus disease (caused by *Beauveria* sp.) has killed a high percentage of larvae in Virginia (Grayson 1943). Good cultural practices that promote tree vigor help minimize losses. Insecticides have effectively controlled *P. syringae* (Dix and others 1979, Nielsen and others 1973) and undoubtedly would control the banded ash clearwing. However, insecticides should be applied in late summer to fall rather than in spring and summer as recommended for *P. syringae*.

### *Paranthrene simulans* (Grote)

[red oak clearwing borer] (figure 13)

**Hosts.** Red oaks, white oaks, American chestnut. Red oaks (especially Nuttall, Shumard, cherrybark, and black oaks) are preferred hosts in the South; northern red, pin, and black oaks favored in the North (Engelhardt 1946, Solomon and Morris 1966). Deciduous and evergreen scrub oaks in Florida also have been mentioned as hosts.

**Range.** Eastern Canada and throughout the eastern United States westward to Texas in the South and Minnesota in the North (Engelhardt 1946).

**Description.** ***Adult.*** Colorful yellowish orange and black clearwing moth (figure 13A) closely resembling queen yellowjacket wasps (Solomon and Morris 1966). Wingspan of females from 30 to 40 mm and males

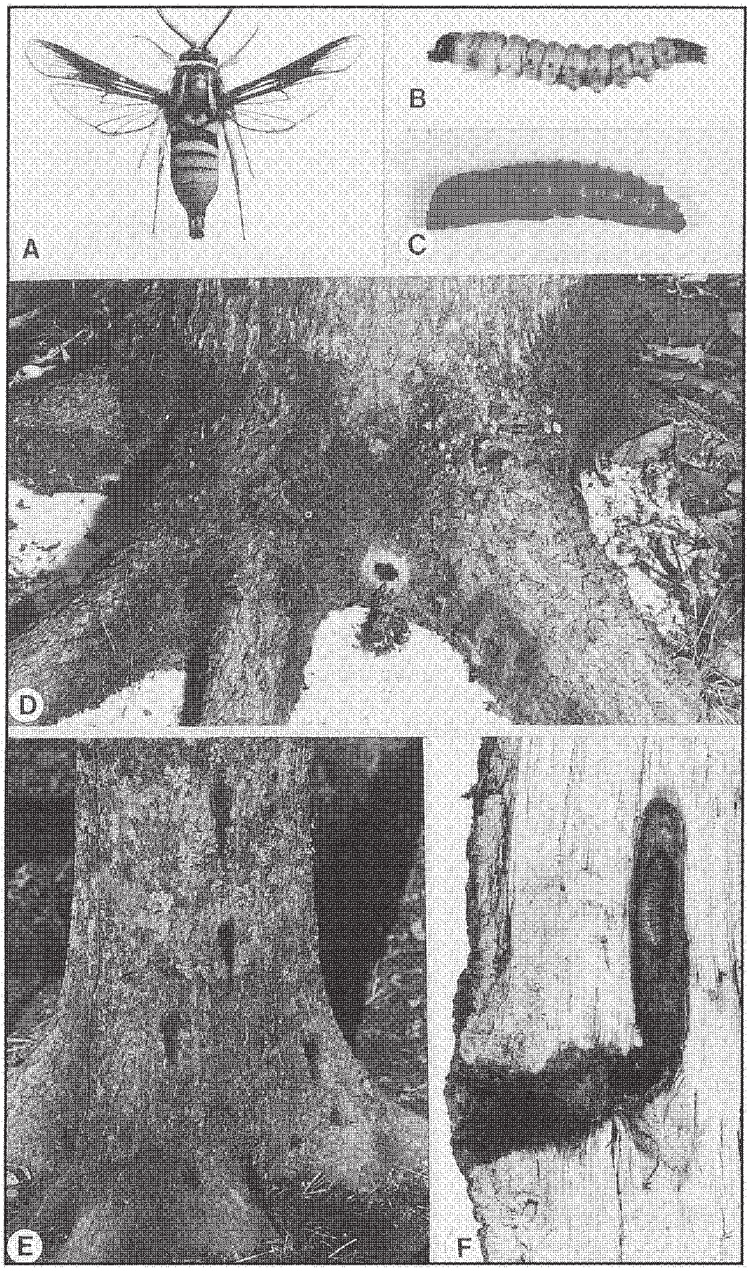


**Figure 13**—Paranthrene simulans, *[red oak clearwing borer]: A, adult; B, larva; C, pupa; D, entrance hole and frass pile between root flanges; E, sap spots indicating new attack sites; F, completed gallery.*

27 to 36 mm (Engelhardt 1946). Forewings with brownish black scales near leading edges but otherwise transparent; hindwings entirely clear, with opalescent reflections and narrow, brown, marginal fringe. Females larger and more robust than males but general body color similar. Females with simple antennae touched with yellow at inner base; males with bipectinate antennae, black, and brown at tips (Engelhardt 1946). Head black; eyes with broad margin of yellow scales in front. Leg segments alternately colored black and yellow. Thorax black with yellow spots and streaks. Abdomen black with wide bright yellow band on posterior edge of each segment. In some locations, yellow markings shade to orange. ***Egg.*** Oval, light brown, 1 by 0.5 mm, finely reticulated surface (Solomon and Morris 1966). ***Larva.*** Black head, yellowish brown thoracic shield, purplish brown abdomen (figure 13B) (Solomon and Morris 1966); 22 to 30 mm long at maturity (MacKay 1968). Three pairs of small jointed legs on thorax. Ventral prolegs on abdominal segments 3 to 6 bear two transverse rows of well-developed uniordinal crochets; anal prolegs with one row of crochets. Elliptical spiracles on the abdomen prominent. ***Pupa.*** Brown to black and approximately length of mature larva (figure 13C). Maxillary palpi of mouthparts well developed. Most abdominal segments with two dorsal, parallel transverse rows of spines, tips pointing toward rear; cremaster consists of tuft of spines (Solomon and Morris 1966).

**Biology.** Most adults emerge from April to June in southern range and in June and July in the more northern latitudes (Engelhardt 1946, Snow and others 1989). Males have been captured in pheromone-baited traps in Georgia from early May to July (Snow and others 1985) and in west central Mississippi from June 1 through August 3 (Solomon and others 1982). Moths mate late in the afternoon on the day of emergence, and average life is 6 days (Solomon and Morris 1966). Females lay up to 459 eggs over 5 days; eggs hatch in 15 to 18 days (Solomon and Morris 1966). Eggs are laid in bark crevices, mostly around the base of trees. Young larvae bore ovoid chambers in the inner bark. As larvae grow, they extend galleries into the wood, usually at an upward angle for 3.8 to 4.5 cm, then turning straight upward for another 5 to 6 cm. Completed galleries are 9 to 10 cm long and up to 9.5 mm in diameter (figure 13F) (Solomon and Morris 1966). Galleries resemble those of carpenterworms but are much narrower and shorter. During the second fall after hatching, mature larvae construct slightly enlarged areas in their innermost galleries in which they overwinter. In spring, they enlarge the galleries to the bark surface and cap them with an almost colorless, parchment-like material that pupae can easily rupture just before the adults emerge. Empty pupal skins, partially protruding from exit holes, often remain for months after moths emerge. The life cycle is completed in 2 years. Heavier emergence occurs in odd-numbered years, and light emergence in even-numbered years.

**Injury and damage.** Principal external evidence is larval entrance holes, 9.5 to 16 mm in diameter, usually within the basal

0.3 to 0.6 m of the bole and between root flanges (figure 13D). Loose clumps of frass held together by silken strands often hang from the entrance holes or in small piles on the ground when holes are near the ground. In early stages of attack, wet spots occur at entrance holes (figure 13E). Larval tunneling may produce gall-like swellings on small saplings and branches, often causing death of the stem beyond the injury (Engelhardt 1946). Larval tunnels on larger tree trunks may be indicated by swellings covered with blistered bark (Engelhardt 1946). Empty pupal skins protruding from entrance holes are common from late spring until early fall. This borer is reported to seriously damage young oak shoots, branches, and saplings (Engelhardt 1946) and can cause the cull of oak nursery stock (Solomon and others 1987). Economic impact in oak forests is usually minimal because most larval galleries are confined to the stumps of trees below the first merchantable log. In some areas, rot and stain in the butt log caused by the larval galleries can lead to significant monetary loss (Solomon and Morris 1966). This borer is frequently troublesome in farm woodlots, parks, and street trees, where one larva can open a tree to decay fungi, and heavy infestations can kill small trees (Johnson and Lyon 1988).

**Control.** Woodpeckers are important natural enemies; predation is heaviest during winter (Solomon and Morris 1966). One hymenopterous parasite—*Pterocormus saucius* (Cresson)—has been recorded (Carlson 1979). Direct control on yard, park, and street trees can be accomplished by inserting a stiff wire into the galleries to kill larvae and pupae. Fumigants can be injected into individual galleries and the openings then sealed. Applying a long-residual insecticide to the base of valuable trees during the oviposition period prevents larval entry (Solomon and others 1987).

### *Paranthrene pellucida* Greenfield and Karandinos

[pin oak clearwing] (figure 14)

**Hosts.** Oaks. Only pin oak and black oak have been recorded as hosts, but other oak species undoubtedly are hosts (Greenfield and Karandinos 1979a, 1979b).

**Range.** A newly described species recorded in Connecticut, New York, Ohio, Wisconsin (Greenfield and Karandinos 1979a), Indiana (Reed and others 1981), Maryland (Neal and Eichlin 1983), and Missouri (Eichlin and Duckworth 1988). Distribution is likely much more widespread than currently reported.

**Description.** ***Adult.*** Yellowish clearwing moth with long, narrow, clear wings; long legs; and black-and-yellow-banded abdomen; mimics vespid wasps (figure 14A) (Greenfield and Karandinos 1979a). Wingspan averages 29 mm for males and 32 mm for females. Forewings and hindwings long, narrow, almost completely devoid of scales, except on brownish black veins and fringes. Distinguished by hyaline forewings; the sibling species *P. simulans* (Grote) has marked scale suffusion on forewing with region beyond the discal spot covered with brown scales. Antennae bipectinate-ciliate in male and simple in female. Legs long and yellow

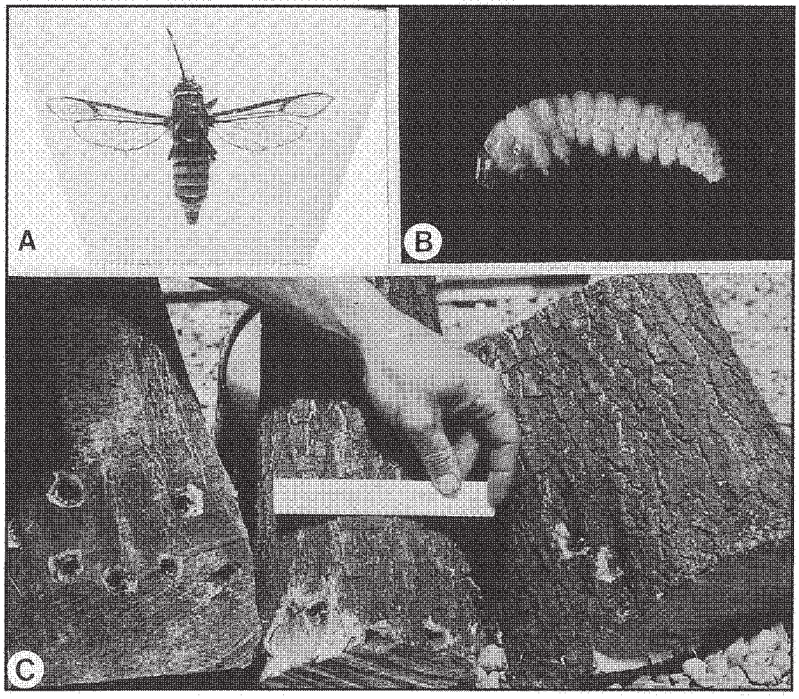


**Figure 14**—Paranthrene pellucida, *[pin oak clearwing]: A, adult; B, larva; C, entrance holes in oak trunk sections (courtesy F. Purrington).*

orange, marked with black. Dorsum of abdomen banded with alternating yellow and black. Less yellow on dorsum of abdomen than *P. simulans*. ***Larva.*** Brown head, light brown thoracic shield, grayish body; reaches about 25 mm long at maturity (figure 14B).

**Biology.** Adults emerge from June to July in Wisconsin (Greenfield and Karandinos 1979b) and July to August in Maryland (Neal and Eichlin 1983). Males are drawn to synthetic sex attractants between 5 p.m. and 7 p.m. and apparently mate with females at the time. Females deposit eggs on the bark of host trees. The eggs hatch and larvae bore through the bark and extend galleries into the wood. This species has a 2-year life cycle; in Wisconsin, adults emerge in odd-numbered years (Greenfield and Karandinos 1979b).

**Injury and damage.** Wet spots on bark, followed initially by fine, moist frass ejected from the entrance holes. Later, clumps of brown granular frass are found in the bark crevices and on the ground at the base of the tree. Irregularly round exit holes 8 to 14 mm in diameter are left in the bark (figure 14C). Brown pupal skins protrude from exit holes in the summer through early fall. The insect has been reared from galleries in oak cuttings and probably causes damage similar to its sibling species, *P. simulans*. Preliminary information indicates that it is restricted mostly to xeric oak barrens and occurs in small numbers, making its damage less important than that of *P. simulans*.

**Control.** Natural or other controls have not been reported.

### *Paranthrene asilipennis* (Boisduval)

oak clearwing moth (figure 15)

**Hosts.** Oak, ash, alder. Oaks (particularly red oak species) are the favored hosts. Black, red, and pin oaks have been listed specifically (MacKay 1968), and the author has collected it from scarlet oak. No recorded collection from white oaks, but it reportedly does not discriminate among the oaks (Engelhardt 1946). Ash and alder are mentioned, but unconfirmed, hosts (Doane and others 1936).

**Range.** Recorded from scattered locations in southeastern Canada and through the eastern United States from New Hampshire south to Florida and west to Minnesota and Texas (Beutenmuller 1901, Doane and others 1936, MacKay 1968). Range reportedly extends through the temperate and subtropical regions of Mexico and Central America (Engelhardt 1946).

**Description.** ***Adult.*** Yellowish black clearwing moth with wingspan 28 to 38 mm in male and 32 to 46 mm in female (figure 15A and B) (Beutenmuller 1901, Engelhardt 1946). Forewings and hindwings transparent, except forewing in female slightly opaque. Wings fringed with black and dull red; hindwing with small orange discal mark. Head black, edged narrowly with yellow, and thorax mostly brownish black with wing base edged in yellow and shoulder in chestnut red. Blackish abdomen in male to chestnut brown in female, with segments 2 through 7 narrowly banded with pale yellow. Extent of abdominal banding variable among specimens. Short anal tuft, blunt and brown. Male antennae reddish brown, orange at tips, strong and

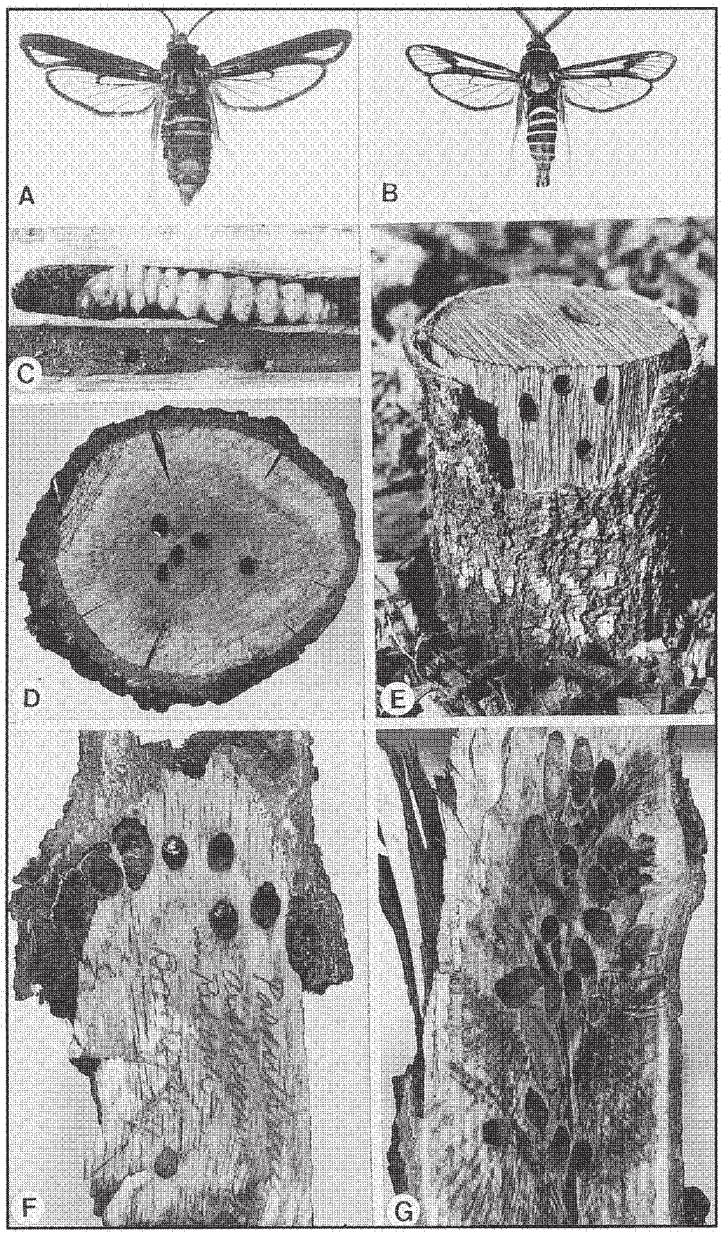


**Figure 15**—Paranthrene asilipennis, *oak clearwing moth: A, adult female; B, adult male; C, larva; D, cross section of galleries; E, entrance holes in stump; F, bark slab removed to expose holes; G, stump split to expose multiple galleries (A, B, F, & G, specimens courtesy R. Hodges).*

broadly bipectinate (Beutenmuller 1901). Female antennae simple, rufous, becoming dark at tips. Legs rufous and marked with black and chestnut red. ***Larva.*** White with brown head, light brown thoracic shield, and brownish black mandibles (figure 15C) (MacKay 1968). Mature larvae 23 to 36 mm long, reaching their largest size in warm or subtropical part of range.

**Biology.** Adults emerge in late February through March in Florida, April in North Carolina, May in West Virginia, and May and June in New York (Engelhardt 1946, Kimball 1965, Snow and others 1989). Soon after emerging, females attract males and mate. Eggs are deposited in bark crevices and around wounds on living trees and particularly on exposed wood of recently cut stumps. Larvae bore through the bark and into the wood. Galleries 6 to 10 mm in diameter and up to 15.2 cm long have been dissected from stumps. Galleries are generally kept open but may contain some loose frass and fungus mycelia. They pupate during the second spring in chambers within galleries that are capped lightly above and below. Exits are well hidden by minute bark and wood particles. When an adult emerges, about half of the pupal case is left protruding from the bark entrance or from the cut stump surface. A generation requires 2 years.

**Injury and damage.** Attack sites are indicated by moist sap spots on bark and fine moist frass extruded from tiny entrance holes. Frass becomes coarse and granular as larvae grow. Lower trunk and roots preferred, particularly exposed roots (Doane and others 1936). Pencil-sized tunnels extend several centimeters deep into the solid wood (figure 15D). Recently cut stumps sometimes become heavily infested (figure 15E). Galleries may extend through the bark into the stump or may be initiated on the cut surface and extend into the wood (figure 15F). Dissection of infested trees or cut stumps will reveal extensive galleries (figure 15G) along with the white larvae (Engelhardt 1946). Borers cause structural injury and breakage in young trees, especially in recently thinned stands where they spread from stumps to young trees. However, sparse populations over widely scattered areas make the overall impact of this moth (except for individual trees or locations) generally light to negligible.

**Control.** Little is known about control (Engelhardt 1946). Parasitism is reportedly heavy (Engelhardt 1946), but only the hymenopterous parasite, *Apanteles paranthrenidis* Muesebeck, has been named (Marsh 1979). In recently cutover areas where the pest is a problem, chemical treatment of stumps should help prevent population buildup.

### *Paranthrene tabaniformis* (Rottemburg)

[dusky clearwing] (figure 16)

**Hosts.** Poplar, willow. The willows—preferably shrubby, low-growing species—are principal hosts in the northern range of this insect (Beutenmuller 1901, Engelhardt 1946). In its southern range, cottonwood is favored. At least a dozen species of poplars are listed as hosts in Europe (Dafauce 1966). Alder, birch, and hawthorn are

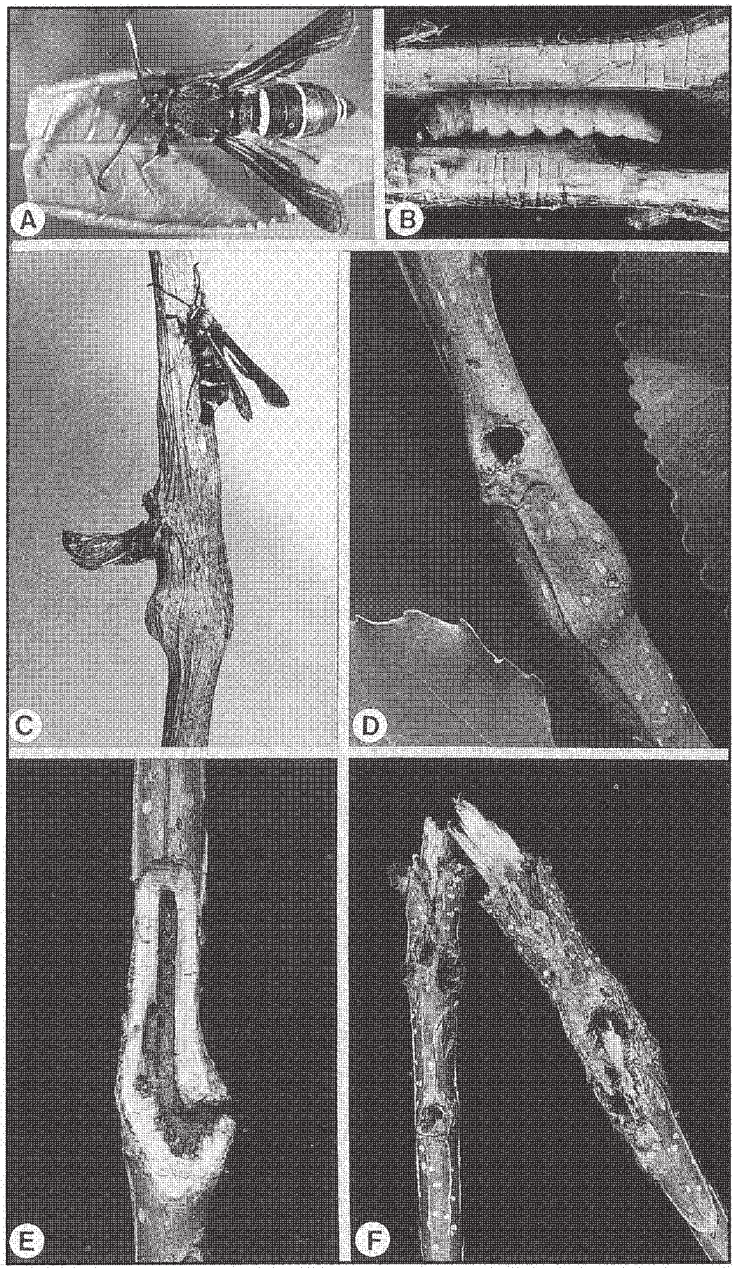


**Figure 16**—Paranthrene tabaniformis, *[dusky clearwing]: A, adult; B, larva; C, newly emerged adult, pupal skin below; D, swollen branch with exit hole; E, completed gallery; F, stem broken at site of attack.*

mentioned as hosts in Europe (Anonymous 1961) but not confirmed in North America.

**Range.** An introduced species from Europe, now a taxonomic combination of the European species *P. tabaniformis* and what was formerly known in North America as *P. tricincta* (Harris) and its varietal forms (Duckworth and Eichlin 1977a). In North America, ranges from Newfoundland south to Florida, west to the Rocky Mountain region, and northwest to Alaska (Engelhardt 1946).

**Description.** ***Adult.*** Bluish black clearwing moth with wingspan of 24 to 28 mm in male and 26 to 32 mm in female (figure 16A). Forewings narrowly elongate, opaque, and generally reddish brown to violet black; hindwings somewhat broader than forewings, opaque, and bordered with narrow fringe of dull coppery brown scales. General color bluish black. Sexes easily distinguished by bipectinate antennae and yellow banding of abdominal segments 2, 4, 6, and 7 in male; female antennae simple, smooth, dilated at apex, and abdominal segment 7 not banded with yellow (Engelhardt 1946). Anal tuft contains mixed yellow and black hairs in male and black median line in female (Anonymous 1961). ***Egg.*** Dark brown to dull black, oval, somewhat depressed on two surfaces, and about 0.6 by 1 mm. Surface with polygonal reticulations (Anonymous 1961). ***Larva.*** At maturity, measures up to 24 mm long (figure 16B). Head pale yellowish brown and body ivory. Prothorax somewhat wider than other segments; dorsal surface yellowish, marked by two brown furrows that converge toward the head. Jointed thoracic legs yellowish brown. Fleshy prolegs on abdominal segments 3 to 6 bear two transverse rows of chestnut uniordinal crochets; last segment with one row of uniordinal crochets. Prominent elliptical spiracles present along the side of each body segment.

**Biology.** Based on pheromone-baited trap catches in Mississippi, moths are active continuously from mid-April to early November (Solomon and others 1982). Adults live 8 to 10 days and usually mate the day they emerge; females oviposit on terminals and branch tips (Dafauce 1966). Eggs are glued singly to the bark near rough scars and often at vacated exit holes of other borers. Females can deposit 50 to 100 eggs. Newly hatched larvae initially feed in the inner bark, creating irregular chambers, and later tunnel in the stem pith. As larvae extend galleries, they keep them clear by expelling frass and debris from the entrance holes, which they gradually enlarge (Dafauce 1966). Galleries are about 10 cm long by larval maturity. As pupation approaches, larvae make short galleries to the surface and cut thin flaps almost through the bark. Larvae return to the main galleries and enclose themselves in chambers of silken threads and small wood chips in which they overwinter. The pupal period is 15 to 25 days (Dafauce 1966). Developed pupae rupture the walls of their chambers and squirm to the exit holes by means of rows of spines on their abdomen.

**Injury and damage.** Excessive dying and breaking of terminal and lateral branches most noticeably indicates infestation. Severe infestations result in multiple forking of the trunk and in bushiness. Close inspection of branches often reveals small swellings (figure 16C). A ragged-edged circular larval

entrance hole occurs near the swelling (figure 16D) and a conspicuous plug of frass usually protrudes from the hole; reddish sap characteristically percolates through the plug (Anonymous 1961). A round adult exit hole, with the empty pupal skin projecting, may be several centimeters from the larval entrance hole (figure 16C). Splitting stems reveals the galleries (figure 16E). Stem breakage is common at tunneled sites (figure 16F). This clearwing has been a serious pest of cultivated and planted poplars since the 18th century in Europe, where it particularly damages 1-year-old and, less commonly, 2-year-old plants in nurseries (Anonymous 1979). Since 1960, in the United States, it has become a threat to more than 20,000 ha of cottonwoods used for reforestation in the lower Mississippi River Valley. Infestation of terminals and lateral branches of 1- to 3-year-old cottonwoods is commonly so severe that the trees are more like bushes than straight, single-stemmed, merchantable crop trees. In the North, it is often found associated with galls of longhorn beetles, *Saperda* spp., on aspen and other poplars (Beutenmuller 1901).

**Control.** Woodpeckers destroy many overwintering borers in Mississippi, but little is known about parasites and other natural enemies in North America. In Spain, about 5% of *P. tabaniformis* eggs were parasitized by the encyrtid wasp (*Ooencyrtus* sp.), and 23% of the larvae were killed by the braconid wasp (*Apanteles hoplites* Ratz.) (Dafauce 1966). Chemical control has been investigated intensively in Europe. Effective methods of pesticide application include fumigation of cuttings and young trees in nurseries, spraying larger trees to prevent the entrance of newly hatched larvae, and injection of chemicals into larval galleries. *Beauveria bassiana* (Bals.) Vuill. injected into larval galleries in young poplars in Poland provided 98% control (Schnaiderowa and Swieznyska 1977). In the United States, applying a systemic insecticide in soil in nurseries and plantations has provided some control.

### *Paranthrene dollii* (Neumoegen)

[cottonwood clearwing borer] (figure 17)

**Hosts.** Poplar, willow. Eastern cottonwood is the major host, but balsam poplar and the hybrid poplars are also attacked. Many other poplars probably susceptible. Observed occasionally in black willow; probably occurs in other willow species.

**Range.** Throughout the eastern half of the United States westward to the edge of the Great Plains (Engelhardt 1946); most destructive in the South (Solomon 1988a).

**Description.** ***Adult.*** Reddish clearwing moth with opaque, dark brown forewings with violet or coppery reflections (figure 17A). Hindwings semitransparent and reddish brown. Wingspans from 30 to 40 mm. Male antennae robust, bipectinate, and strongly dilated at tips; female antennae simple. Head black and shiny with rust red fringe just behind top. Thorax black with lateral buff and reddish tufts. Abdominal segments 1, 2, and 3 black; 4, 5, 6, and 7 reddish; and segments 2 and 4 narrowly ringed with reddish yellow. Legs pale red with black femora (Engelhardt 1946). ***Egg.***

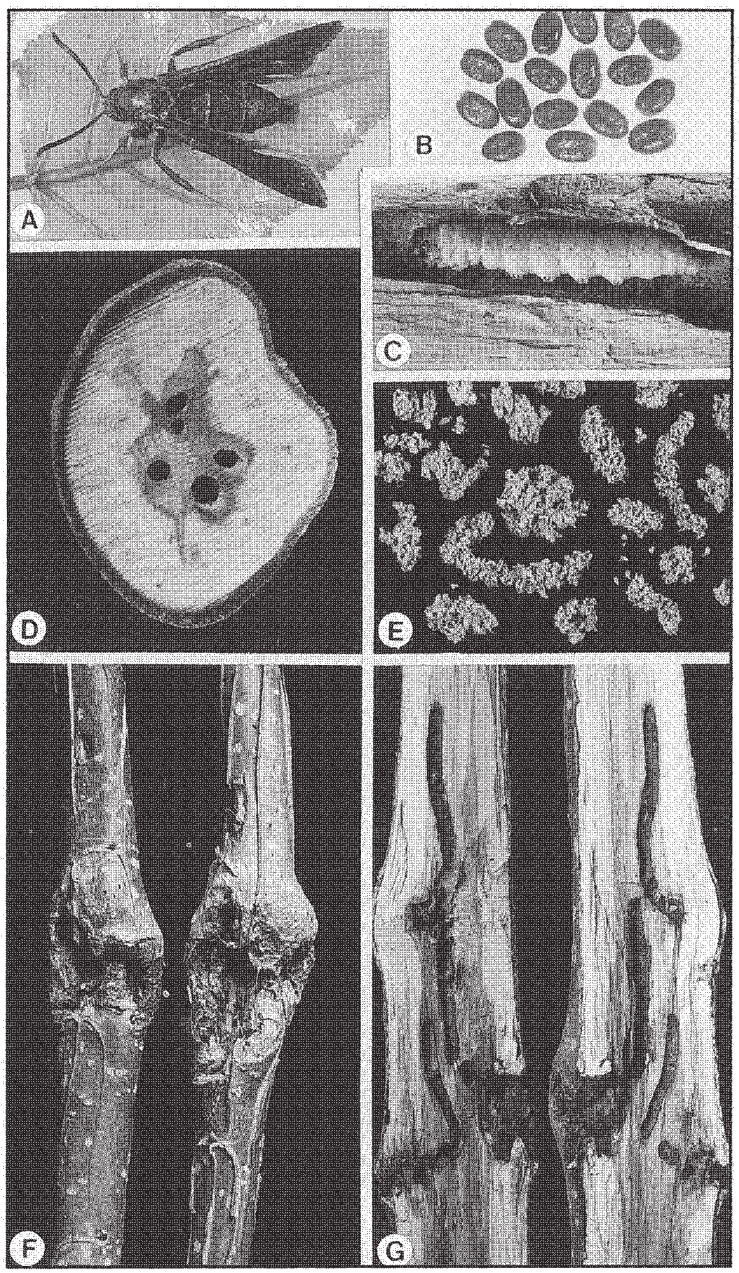


**Figure 17**—Paranthrene dollii, *[cottonwood clearwing borer]: A, adult; B, eggs; C, larva; D, cross section of galleries; E, frass clumps; F, active attack sites on nursery switches; G, stem split exposing galleries.*

Oval and dark brown (figure 17B) (Morris and others 1975), measuring 0.7 to 0.9 mm wide and 1.0 to 1.2 mm long (Eroles-Harkins 1983). ***Larva.*** White to light pink with brown head and thoracic shield; 25 to 32 mm long and 4 to 5 mm wide at maturity (figure 17C) (MacKay 1968, Morris and others 1975). Thoracic and abdominal spiracles elliptical, former being larger than latter. Ventral prolegs on abdominal segments 3 to 6 bear parallel rows of well-developed uniordinal crochets; anal prolegs possess only one row of crochets (Peterson 1962). ***Pupa.*** Brown, smooth, shiny, and 20 to 25 mm long. Upper surface of each abdominal segment with two parallel transverse rows of spines.

**Biology.** Adult life span is 10 to 18 days (Eroles-Harkins 1983). Adult males were caught in pheromone-baited sticky traps in north central Florida from early April to late June and from mid-September to mid-November (Sharp and others 1978). Similar trapping by Eroles-Harkins (1983) in west central Mississippi showed three peaks: mid-April to mid-May, late June to mid-July, and mid-August to early September. Moths are diurnal; males confine their flight mostly to 12 noon to 4 p.m. (Solomon and others 1982). Females oviposit for 2 to 6 days in deep cracks, crevices, and other cavities, usually in the basal meter of the tree. Larvae have 12 instars in the field and 15 to 17 instars in the laboratory (Eroles-Harkins 1983). Upon hatching, larvae feed initially in bark and later enter the wood. Galleries in wood at the tree base meander, whereas those made higher on the trunk tend to follow the pith. Several larvae often infest a stump, but galleries generally do not intersect. Galleries are about 10 cm long for mature larvae. Mature larvae, before constructing silk-lined pupal chambers near the distal end of the galleries, make short tunnels almost to the bark surface, keeping exit holes closed with flimsy bark flaps. When the pupal stage nears completion, the pupae work their way up the galleries with the aid of abdominal spines and protrude through exit holes for emergence. In its northern range, this species requires 2 years for its life cycle (Engelhardt 1946), whereas, in Mississippi, one or two generations may be completed in 1 year (Cook and Solomon 1976). Biological observations are confounded by the occurrence of various-sized larvae in trees throughout the growing season and the occurrence of at least three peak male moth catches in pheromone-baited traps.

**Injury and damage.** Early signs of attack are sap flow and frass pushed from the entrance holes; attacks may occur at almost any point on the stem but are most common at the base (Morris and others 1975). Stems may have multiple tunnels from repeated attacks (figure 17D). As larvae grow, clumps of granular frass accumulate at the base (figure 17E). Galleries are partially filled with small, round, reddish pellets of excrement and woody fragments (Engelhardt 1946). Stems less than 4 cm in diameter frequently develop galled or cankerlike swellings (figure 17F). Large stems exhibit only slight (or no) swellings (figure 17G) (Cook and Solomon 1976). A survey revealed that 12% of

1- and 2-year-old trees in cottonwood plantations in Mississippi River bottoms of Arkansas and Mississippi were infested (Abrahamson and Newsome 1972). In nurseries, populations in 1-year-old plants are seldom heavy; sizeable infestations build up in 2-year-old and older rootstocks. After several harvests, every rootstock may be attacked, requiring clearing and destruction of stumps. Infested trees are weakened and sometimes break off or may be killed by fungi that invade entrance holes. Plantation trees occasionally are deformed or killed. In nurseries, losses average about 12% from culling of infested cuttings (Cook and Solomon 1976).

**Control.** Woodpeckers are one of the most important natural enemies of the cottonwood clearwing borer, particularly of overwintering larvae, but the holes they excavate may aggravate infestations by providing more oviposition sites and entrance courts for fungi (Cook and Solomon 1976). The parasite *Apanteles paranthrenidis* Muesebeck has been recorded, but nothing is known of its effectiveness (Marsh 1979). In heavily infested nurseries, the rootstocks should be rogued out and burned about every 3 years to destroy the borers (Solomon 1988a). Systemic insecticides incorporated into soil provide some control (Cook and Solomon 1976).

### *Paranthrene robiniae* (Hy. Edwards)

western poplar clearwing (figure 18)

**Hosts.** Poplar, willow, birch. Poplars are generally favored. Black cottonwood, balsam poplar, and white poplar, as well as several hybrid poplars, are recorded hosts (Beutenmuller 1901, Engelhardt 1946). Many other species of poplars are probably susceptible. Willows seem preferred in some areas of California and Oregon (Thompson 1927). Birch is occasionally attacked, and black locust has been listed as a host but needs to be confirmed (Beutenmuller 1901, Duckworth and Eichlin 1978).

**Range.** From sea level to near timberline (Duckworth and Eichlin 1978), Alaska southward along the Pacific Coast to southern California and throughout the Rocky Mountains into the desert Southwest and as far east as Kansas and North Dakota (Engelhardt 1946).

**Description.** ***Adult.*** Yellow-black clearwing moth. Male wingspan 23 to 30 mm and female wingspan 30 to 36 mm (figure 18A) (Engelhardt 1946). Forewings orange brown with somewhat darker veins (Beutenmuller 1901). Hindwings transparent with conspicuous deep yellow discal mark; fringed with dark brown scales (Engelhardt 1946). Orange-brown antennae (Beutenmuller 1901), bipectinate in male and simple in female (Engelhardt 1946). Black head with yellow face and collar of depressed black and yellow scales (Engelhardt 1946). First three abdominal segments black; segments 2 and 3 with narrow yellow bands on posterior edges; remaining segments essentially yellow (Beutenmuller 1901). Coxae and femora of legs black and tibiae and tarsi yellow (Engelhardt 1946).
***Egg.*** Oval and brown with reticulated surface, 1.0 to 1.2 mm across greatest axis.
***Larva.*** White to grayish white with brown

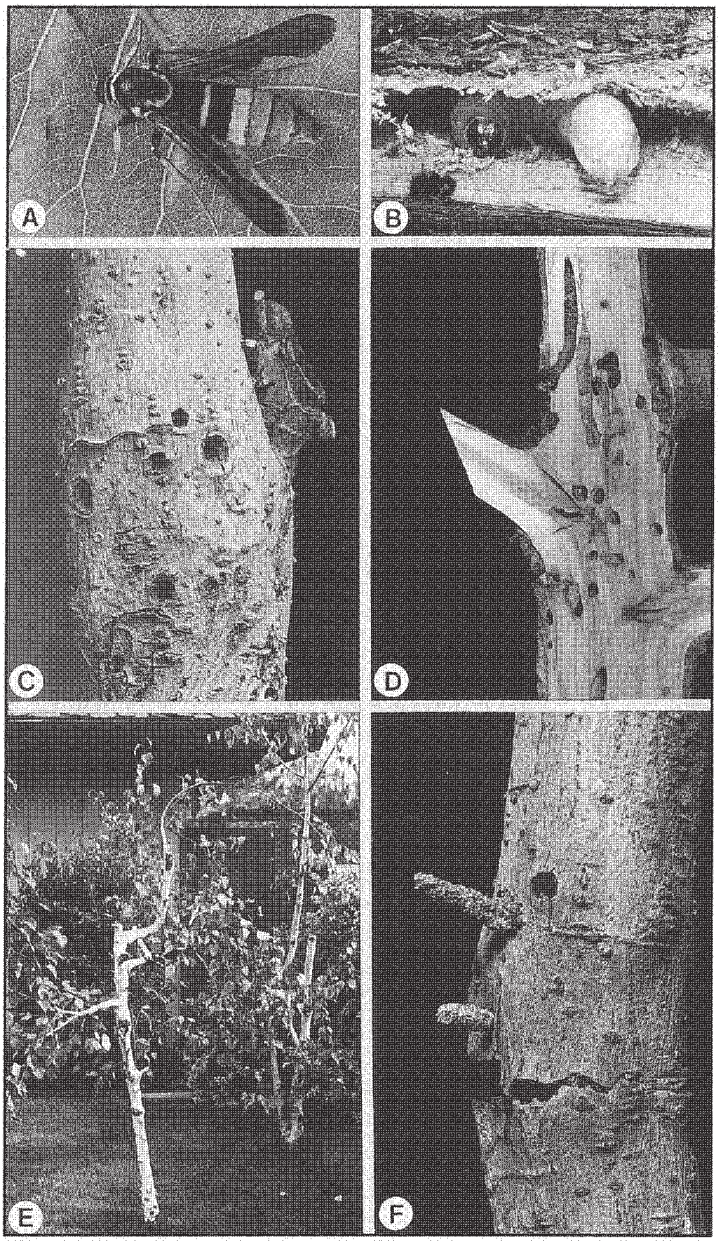


**Figure 18**—Paranthrene robiniae, *western poplar clearwing: A, adult; B, larva; C, exit holes in willow trunk; D, split to expose galleries; E, infested birch; F, frass tubes over exit holes (B, courtesy T. Eichlin; C & F, specimens courtesy J. Donahue; D, specimen courtesy R. Hodges; E, courtesy H. Kaya).*

head and thoracic shield (figure 18B). Larva with pair of jointed legs on each thoracic segment and reachs 23 to 30 mm long. A setal map of body chaetotaxy can distinguish *P. robiniae* larva from closely related *P. dollii* (Eroles-Harkins 1983).

***Pupa.*** Brown, shiny, and 18 to 20 mm long.

**Biology.** Adults emerge mostly March to August, depending on location (Doane and others 1936). In central California, most emerge by mid-June; in eastern Washington, as late as mid-September (Thompson 1927). In the species' extreme southern range in California, specimens have been taken from February through May and again in November (Duckworth and Eichlin 1978). Females oviposit singly in bark crevices, around knots and wounds, and on other rough places of the bark of trunks and large limbs (Thompson 1927). Eggs hatch after about 20 days. Newly hatched larvae crawl over the bark for a few hours before selecting suitable sites to begin feeding. The larvae initially excavate cavities in the phloem and cambium and later galleries into the wood. Galleries are 5 to 10 cm long. Larvae feed during two successive summer and fall seasons; the first winter in galleries loosely packed with frass and the second winter in pupal chambers near the distal ends of the galleries. Distal ends are capped with silk, but no cocoons are formed. Pupation lasts 2 to 3 weeks (Duckworth and Eichlin 1978) to 30 days (Thompson 1927), depending on range. A generation requires 2 years over most of its range but may be of shorter duration in its southern range (Duckworth and Eichlin 1978).

**Injury and damage.** Trunks and larger branches (particularly of young trees) are most apt to be attacked (Duckworth and Eichlin 1978). Sap oozing from the bark and light brown granular frass ejected from bark are good evidence of infestation. Heavily infested trunks may become swollen and appear galled and cankered and have numerous entrance and exit holes (figure 18C). Dissection of infested stems reveals irregularly shaped cavities in the cambium and galleries extending into wood (figure 18D). Trees weakened or stressed by planting or transplanting, disease, wounds, and poor sites are most susceptible (figure 18E). Repeatedly attacked trees have open entrances and bark scars in all degrees of healing. Branches broken at tunneled sites and cast pupal cases protruding from exit sites are good evidence of infestation (figure 18F). The western poplar clearwing is a serious pest of ornamental trees in residential areas and parks in the West, where it kills and seriously deforms many trees. More recently this borer has damaged nurseries and young plantations.

**Control.** Little is known about natural and cultural controls. One hymenopterous parasite—*Apanteles paranthrenidis* Muesebeck—has been recorded (Marsh 1979); woodpeckers take large numbers of the larvae in some areas. The nematode *Steinernema feltiae* Filipjev has been used experimentally and has given 88 to 90% control of natural infestations (Kaya and Lindegren 1983). Because the borer prefers weakened trees, infestations could undoubt-

edly be reduced and injury minimized by cultural practices that promote tree health and vigor. Preliminary trials with chemical sprays have provided some control.

### *Sesia tibialis* (Harris)

American hornet moth (figure 19)

**Hosts.** Poplars, aspens, and willows. Eastern cottonwood is attacked most often, but other species—including white poplar, balsam poplar, Fremont cottonwood, black cottonwood, and quaking aspen—are readily infested (Duckworth and Eichlin 1978, Engelhardt 1946, Underhill and others 1978). Willows are occasionally attacked.

**Range.** Widely distributed from Nova Scotia and New England along the northern Atlantic Coast westward across the northern United States and southern Canada, south in the Rocky Mountains, and west to the Pacific Coast (Engelhardt 1946). In the West, to southern California and New Mexico (Duckworth and Eichlin 1978).

**Description.** ***Adult.*** Yellow and black clearwing moth, resembles wasps in appearance and flight because of narrow clear wings, long legs, contrasting black and yellow body colors, and slightly constricted base of abdomen (figure 19A). Wingspans 30 to 32 mm in males and 34 to 38 mm in females. Forewings and hindwings transparent and veins covered with orange-brown scales (Engelhardt 1946). Female antennae black, somewhat dilated over apical half, and pointed at tip. Male antennae black and unipectinate (like teeth of a comb on each segment). Head black on top and front with yellow markings along sides; eyes bordered with yellow scales. Thorax variably marked with black and yellow. Generally, abdominal segments 1 and 2 brownish black; segment 3 yellow, narrowly edged with brown black posteriorly; segment 4 brown black; and segments 5 through 7 yellow with narrow brown-black posterior margins. Male abdomens end in tuft of short brownish yellow scales; ovipositor of females usually projects beyond tip of abdomen. Legs long and variously shaded with yellow and brown. ***Egg.*** Light to moderately brown, oval, and covered with fine surface reticulations. ***Larva.*** Moderately robust and white with amber head and thoracic shield (figure 19B). When newly hatched, 1.3 mm long, but growing to about 40 mm at maturity. Crochets on abdominal prolegs poorly developed. Larva resembles that of hornet moth, but surface of head distinctly more wrinkled. ***Pupa.*** Light brown but becomes nearly black with age.

**Biology.** Adults emerge from late May to early August. In California, most adults have been taken during June (Duckworth and Eichlin 1978), whereas, in Saskatchewan, greatest adult activity is mid- to late July (Neill and Reynard 1986). Emergence and mating occur during morning and early afternoon (Engelhardt 1946). However, in Canada, males have been attracted to females only during early morning (Underhill and others 1978). After mating, females deposit 200 to 600 eggs around the base of host trees and live for 4 to 10 days. Females are poor fliers but readily make short flights to nearby trees to disperse their eggs. Eggs

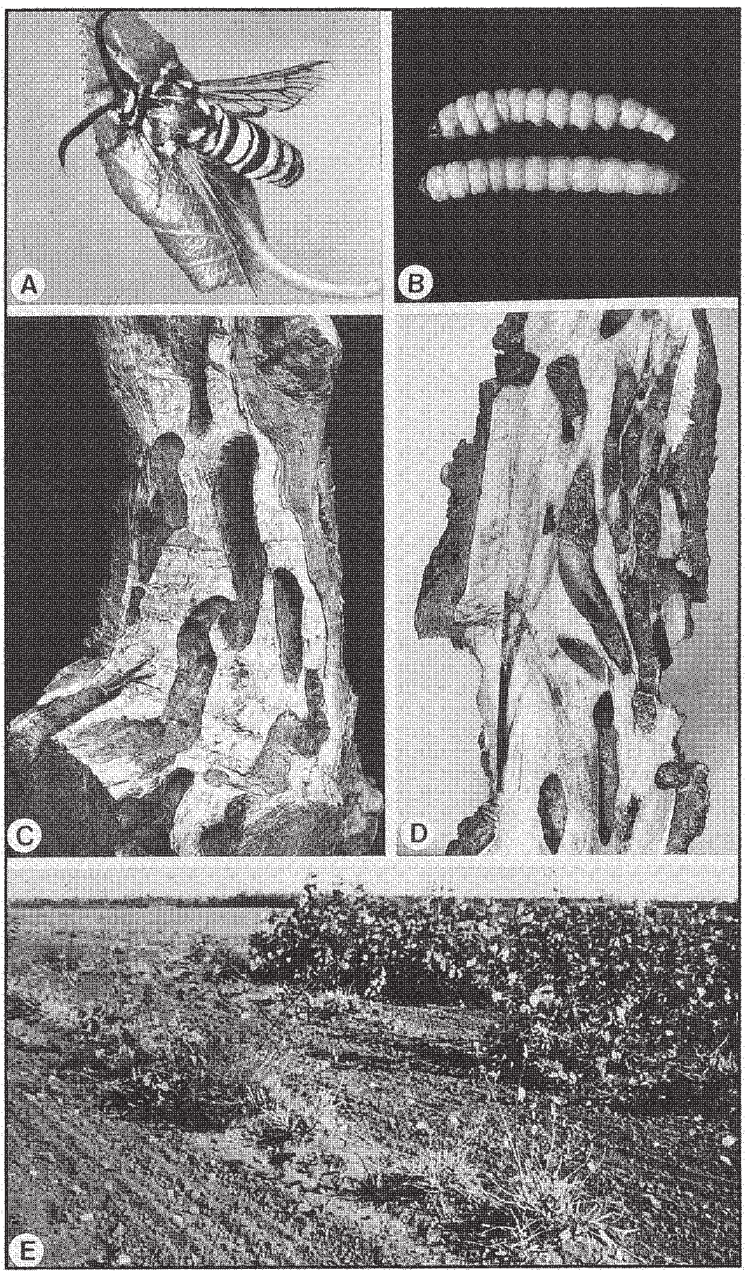


**Figure 19**—Sesia tibialis, *American hornet moth: A, adult; B, larvae; C, surface removed from poplar rootstock exposing galleries; D, split poplar rootstock showing heavy damage; E, poplar stocks in portion of nursery killed by borers (courtesy G. Neill).*

held at 23 °C incubate in 24 days. Newly hatched larvae seek out thin bark or injured sites, preferably around the root collar, to enter. Young larvae mine for a time in the inner bark and cambium. Early development occurs in shallow mines and burrows just under the bark; later galleries extend into the wood. Galleries and mines vary in shape but frequently extend vertically up or down from the root collar or groundline. Vertical galleries 76 to 127 mm long and 9.7 mm in diameter occur most often on smooth areas of the root collar. Burrows occurring mostly at root crotches or other rough areas are oval, patchlike, and highly irregular in shape. Galleries are mostly free of frass, but the ends or sides of burrows sometimes contain packed frass. Before pupation, larvae prepare galleries for easy exit. Pupation occurs within the galleries, and pupae move to the exit holes for moth emergence. A life cycle of 2 years is required.

**Injury and damage.** Attack sites are limited mostly to the lower trunk, root collar, and exposed roots (figure 19C) (Underhill and others 1978). Oozing sap and fine frass in bark crevices around the base are good early evidence of infestations. This species infests trees of all sizes, but young trees suffer most and are sometimes killed. Bark irregularities, holes, and clumps of frass appear later during an infestation. Dissection of badly infested plants reveals extensive tunneling (figure 19D) and sometimes larvae within galleries. Cast pupal skins protruding from bark openings near the base are common during summer and early fall. Nurseries seem particularly susceptible, where populations gradually build up to damaging levels in stools and rootstocks and sometimes kill portions of a nursery (figure 19E). Damage is difficult to distinguish from that of the hornet moth, but the two species can usually be separated by their ranges. Larvae do not bore as deeply into large roots as do those of the hornet moth. In the northern Great Plains and Prairie Provinces of Canada, where poplars are commonly used as shade trees and windbreaks, the species frequently weakens and kills trees. In poplar nurseries, larvae completely girdle and hollow out stools in cutting beds allowing the entry of decay organisms. Also, damage reduces the yield of vegetative cuttings and limits the life of stool beds to less than 10 years. Shade and windbreak plantings may be severely damaged. All poplar species and clones appear to be susceptible (Underhill and others 1978). An average of seven larvae per plant has been found in hybrid poplar cutting beds.

**Control.** In nurseries, the reproductive stools left from year to year become heavily infested and build up populations. Although stools may produce cutting material for 10 years or more, it would be wise to rogue out and plow up infested stools every 4 to 6 years. The lifted stumps should be destroyed before May to kill overwintering borers. Any infested or culled cuttings and trimmings should also be destroyed. Little is known of natural enemies; only one hymenopterous parasite—*Meringopus relativus* (Cresson)—has been recorded (Carlson 1979).

Insecticides reduce infestations if properly timed (Neill and Reynard 1986). Synthetic pheromones show promise for monitoring adult male populations to improve timing of insecticide application (Underhill and others 1978).

### *Sesia apiformis* (Clerck)

hornet moth (figure 20)

**Hosts.** Poplars and willows. Some preference for Carolina and silver or white poplars, but balsam poplar, eastern cottonwood, black cottonwood, other poplars, and *Salix* spp. are commonly attacked (Engelhardt 1946, Tietz 1945).

**Range.** Was introduced into the northeastern United States, apparently from Europe, in the mid-1800's. Became so destructive of willow and poplar shade trees in the New York City area between 1900 and 1920 that these species were replaced with maples (Engelhardt 1946). Recorded in Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, and Newfoundland (Morris 1986). Its western distribution is questionable and probably confused with other closely related sesiids.

**Description.** ***Adult.*** Yellow and black clearwing moth. Wingspan of 34 to 43 mm in male and 40 to 44 mm in female (figure 20A). Forewing transparent, outer margins and fringes dark brown, and wing base with yellow spot. Hindwings transparent and narrowly margined with brownish black. Female antennae dilated toward tip (clavate); male antennal segments unipectinate (single, long, parallel, comblike projections on each segment) and pectinations rusty brown. Head with rough yellowish brush on top. Thorax brownish black with patches of yellow or pale orange. Abdominal segments 2 through 7 yellow to orange yellow and edged with black. Male abdomen ends with short, rounded tuft of yellow hairs tipped with orange; female abdomen without tuft (figure 20B) (Engelhardt 1946). ***Egg.*** Brown and oval to elliptical. Surface of chorion (shell) with irregular, hexagonal reticulations (network of raised lines). ***Larva.*** Robust and white with reddish brown head and light brown thoracic shield, legs, and spiracles (figure 20C). Newly hatched larvae are 1.5 mm long but reach 30 to 50 mm when grown. ***Pupa.*** Brown, becoming blackish brown with age and enclosed in cocoon covered with frass.

**Biology.** Moths fly May through June and, in the northernmost range, possibly into July (Engelhardt 1946, Srot 1969). They emerge at night and early morning and prefer full sunlight for mating. Except for oviposition, much adult life is spent in tree crowns. Males are short lived, but females live 7 to 20 days, depositing 500 to 1,800 eggs. Females drop eggs on the substrate, which can be the tree or the soil under the tree. Females fly clumsily from one tree to another, depositing small groups of eggs. Newly hatched larvae readily bore through the thin bark of young trees; however, on thicker bark of older trees, particularly the trunk and branches, mechanical injury is usually required for entry. Larval galleries are found mostly in the root collar area below ground and along the sides of roots near their origin at the trunk but have been

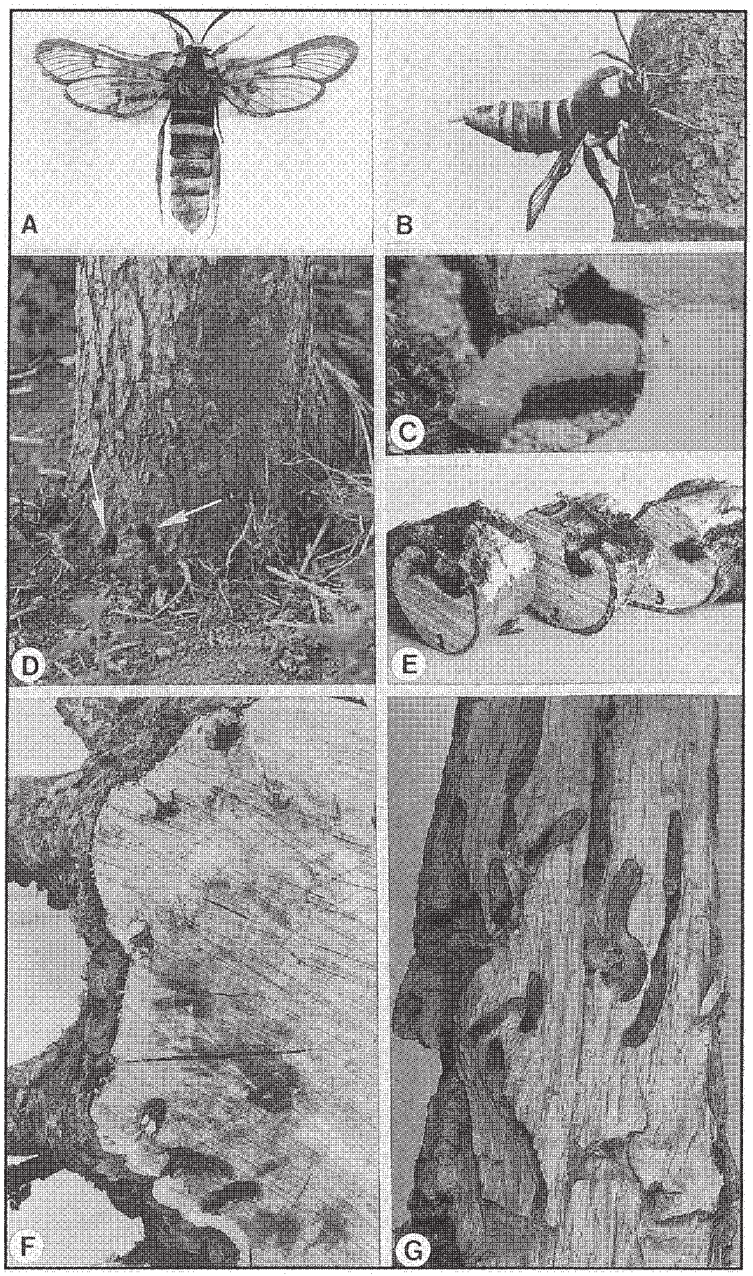


**Figure 20**—Sesia apiformis, *hornet moth: A, adult; B, calling female; C, larva; D, entrance holes and frass at root collar; E, gallery in root; F, stump cross section showing galleries; G, stem split to expose galleries (A & G, specimens courtesy R. Hodges; B, courtesy J. Burzynski; C & D, courtesy J. Abgrall; E & F, courtesy L. Nef).*

observed in roots 20 cm below soil surface (Anonymous 1979, Schnaider 1971). By fall of the first year, larval galleries are irregular, elongate, gradually broadening into patch-like areas in the succulent inner bark. Frass is expelled from the galleries rarely and only when they occur in aboveground parts. During the second year, larvae enlarge the bark cavity and make narrow vertical galleries 5 to 30 cm long and 7 mm in diameter, which terminate in slightly enlarged areas for pupation. Larvae feeding in the roots sometimes vacate their galleries and burrow upward in the soil, pupating just below the soil surface. Pupation occurs in loosely constructed cocoons. Pupal skins may be found protruding from gallery exits or the soil. Pupation in the laboratory lasts 21 to 35 days. It has a 2-year life cycle (Duckworth and Eichlin 1977a).

**Injury and damage.** Infestation is readily recognized by empty pupal skins projecting from exit holes on bark of exposed roots, lower trunks, and sometimes soil (figure 20D). In the absence of pupal skins, the inner bark and outermost sapwood of the roots (figure 20E) and root collar (figure 20F) must be cut open to expose the irregularly shaped larval tunnels. Trees of all sizes may be infested, even large mature trees. On roots with thin bark, larval galleries are indicated by irregular dark swellings on the bark surface. Galleries in inner bark, made by larvae during their first year, heal over rapidly with scar tissue, but second-year larvae may penetrate the sapwood more deeply and are more easily identified (figure 20G). Little frass is pushed out of entrance holes, but withering foliage is a clue to heavy infestation. Heavily infested trees are sometimes girdled and killed. Continuous reinfestation creates favorable conditions for the development of fungal and bacterial infections (Schnaider 1971). The hornet moth has long been a serious threat to fast-growing hybrid poplar clones in Europe and Asia, where damage has been particularly severe to young trees and coppice growth (Anonymous 1979). Few specific references cite the importance of this introduced pest in North American poplar plantings, probably because its injury to trees is easily confused with damage caused by other species of clearwing borers.

**Control.** Excessive soil humidity or prolonged drought are major factors in the mortality of eggs and early larval stages; ants are also important natural enemies during these stages (Srot 1969). Woodpeckers are predators of larvae that feed in the aboveground portions of trees (Schnaider 1971). Three applications of insecticide at 3-week intervals during the adult flight period applied to the lower trunks and root collars have provided good control in Czechoslovakia (Srot 1969). Eggs and newly hatched larvae have been controlled in poplar cutting beds with insecticides applied to the soil. Root-collar treatments with fumigants and sticky compounds have also shown some promise for control.

### *Sannina uroceriformis* Walker

persimmon borer (figure 21)

**Hosts.** Persimmon. Persimmon is the only known host. Native wild persimmon is

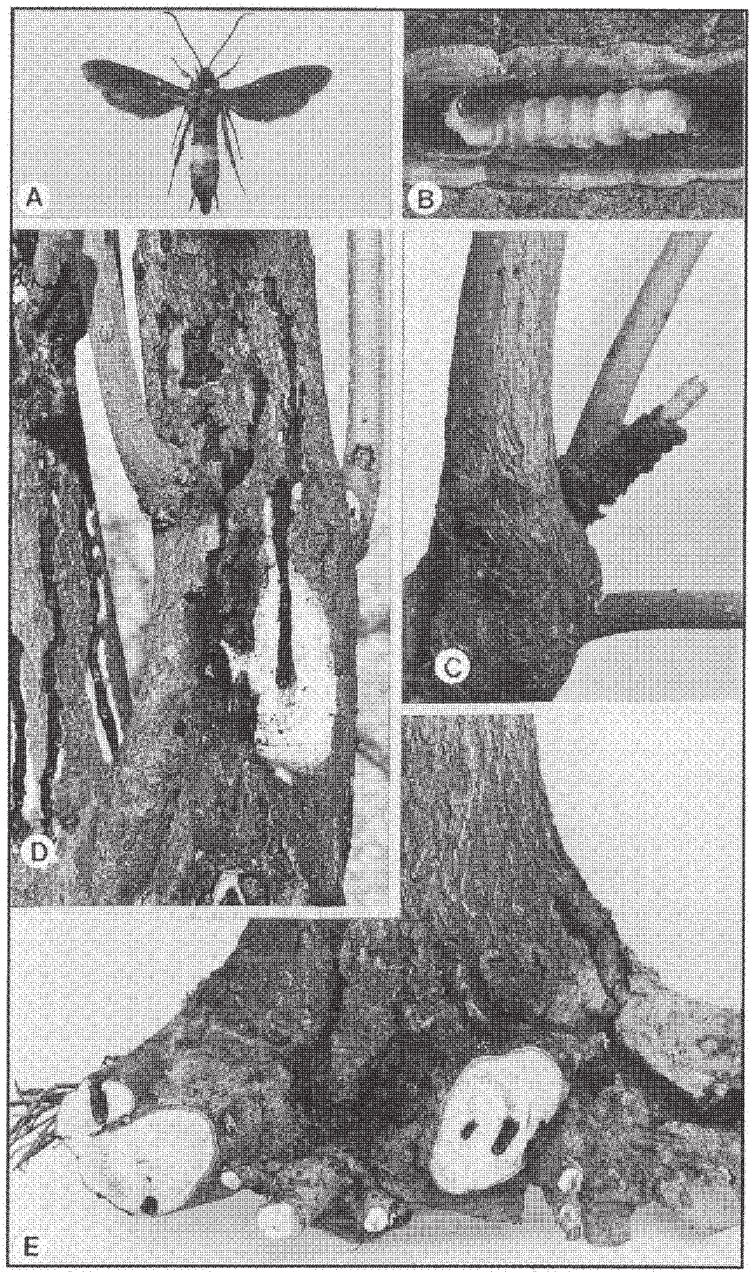


**Figure 21**—Sannina uroceriformis, *persimmon borer: A, adult; B, larva; C, frass tube with protruding pupal skin at base of tree; D, galleries in lower trunk; E, galleries at root collar and in roots.*

preferred; introduced Japanese persimmons grafted onto native persimmon rootstocks are sometimes attacked. Improved varieties are probably susceptible.

**Range.** Throughout the range of its host along the Atlantic Coast from New Jersey to Florida and westward to Texas, Oklahoma, Missouri, Kansas, Ohio, and Indiana (Engelhardt 1946).

**Description.** ***Adult.*** Bluish black, wasplike, clearwing moth with wingspan of 28 to 32 mm; female slightly larger than male (figure 21A). Typically, distinctive orange band across abdomen, though lacking in some. The blue-black color and orange abdominal band cause this species to be confused with the female of the more common peachtree borer. Opaque forewings, somewhat opaque hindwings with small transparent areas between veins at base of wings (Engelhardt 1946). Distinctive anal tuft in male with five long hair pencils on segment 8, consisting of two lateral pairs and one anal. ***Larva.*** Young larva dull or grayish white; later becomes almost white, except for brown head and light brown sclerotized area dorsally on prothorax. Mature larva about 24 to 30 mm long (figure 21B) (MacKay 1968). ***Pupa.*** Light brown becoming darker with age and found in a dark frass-covered cocoon 25 to 63 mm long (figure 21C) (Herrick 1907).

**Biology.** Moths emerge April to early July in the Gulf Coast region and mostly in June and July in the northern range (Engelhardt 1946). Over 400 males were captured between May 12 and July 16 in Mississippi in pheromone-baited traps (Solomon and others 1982). Moths emerge in the morning and mate from late morning until noon. Females deposit eggs on the bark of the lower trunks of hosts or sometimes drop their eggs on the ground around the base of hosts. On hatching, larvae move to suitable sites, usually at or near the root collar, to bore into the bark, but attacks sometimes are initiated 30 to 60 cm above ground. Young larvae begin feeding and mine downward in the cambium. Mines occasionally meander but usually extend essentially straight down. At or slightly below the groundline, larvae extend tunnels into the wood, sometimes to the center of both the lateral and tap roots. Root galleries most commonly extend down to a depth of 20 to 25 cm (Herrick 1907), but can reach 43 to 56 cm in the taproots (Riley and Howard 1892). Larvae overwinter in their galleries below the soil line and pupate during spring. When ready to pupate, larvae extend their galleries upward in the roots to groundline or just above. They chew through the bark and construct large cocoons upward and outward from the bark (figure 21C). These tubelike cases are made of dark frass, bits of bark, and silk; they are 25 to 62 mm long (Herrick 1907). Pupation occurs in the galleries. In about 3 weeks, the pupae become active and work their way up through the tubelike cocoons to project through the covers for adult emergence. The life cycle requires 2 to 3 years (USDA FS 1985).

**Injury and damage.** Damage is sometimes difficult to diagnose, as most tunneling occurs below ground. However, many attacks initiate at or slightly above the root collar, providing some evidence for diagno-

sis (figure 21D). Black gum exudate, particles of bark, and frass are often present, especially during early stages of attack on the base of the trunks. Sometimes, bark loosens at mined or burrowed sites, exposing tunnels leading down and extending below ground. Most aboveground mines on trunks are just under the bark in the cambium but extend into the wood at or near ground level. Damage can be readily identified by excavating roots (figure 21E). Small roots may be hollowed out, leaving only a shell, or may be severed. Large roots may have two or more galleries. Repeatedly attacked roots will be heavily scarred from previous injury. Heaviest populations occur in young trees 12 to 50 mm in diameter, but trees up to 20 cm at the root collar have been found to be moderately infested (Herrick 1907). Seedlings and young trees may have their taproots tunneled out, causing them to break off and die. Trees that appear weak and in decline should be examined for this borer. Seedlings and sprouts growing on abandoned fields, roadsides, and ditch banks seem particularly susceptible to attack. Larvae are voracious feeders that tunnel extensively and deeply into roots, weakening and sometimes girdling and killing them. Larval feeding causes seedlings and young saplings to wilt and break. Usually, larvae injure large trees less seriously (Engelhardt 1946), but populations sometimes are large enough to cause weakening.

**Control.** Little is known of natural enemies. Evidence of woodpecker and rodent excavations of larvae around the base of trees has been observed, but no parasites have been found. No direct controls have been developed, but measures recommended for the peachtree borer would probably be effective (Engelhardt 1946).

### *Synanthedon exitiosa* (Say)

peachtree borer (figure 22)

**Hosts.** The commercial fruit trees—peach, plum (including prune varieties), nectarine, cherry, apricot, and almond—as well as black cherry. Original host plants were wild cherry and wild plum until early settlers introduced the peach (Gossard and King 1918, Snapp and Thomson 1943). Now, it is a major pest of both fruit-bearing and flowering varieties of the genus *Prunus* (Russell and Stanley 1969). Although this borer attacks several kinds of fruit and ornamental trees and shrubs, the peach tree is its most common host (Russell and Stanley 1969).

**Range.** A native of the United States found in most peach-growing areas of the United States. Occurs mainly east of the Rocky Mountains from Canada to the Gulf of Mexico, where it is more important as an economic pest than it is in the Rocky Mountain and Pacific Coast regions (Snapp and Thomson 1943).

**Description**. ***Adult***. Bluish black clearwing moth (figure 22A) with wingspan of 27 to 38 mm and body length of 17 to 23 mm. Body scales of males bright steel blue; pale yellow to white narrow banding around abdomen; forewings and hindwings clear. In females, front wings, legs, and body, except for broad band of orange to reddish scales on fourth abdominal segment, covered with

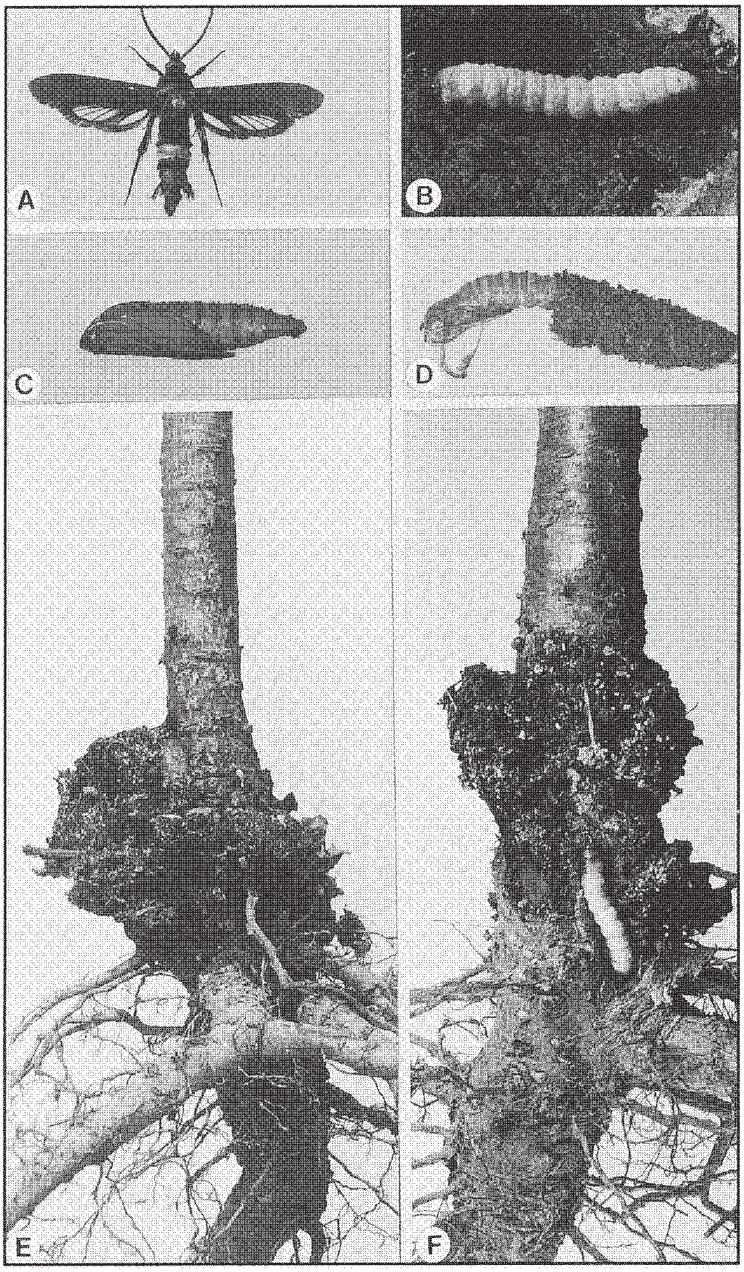


**Figure 22**—Synanthedon exitiosa, *peachtree borer: A, adult; B, larva; C, pupa; D, frass-covered cocoon with pupal skin protruding; E, young tree with large frass-jelly mass at root collar; F, frass-jelly mass pulled back to expose burrow and larva.*

dark steel-blue scales; hindwings of females clear. Several color forms with variations in wing scaling and abdominal banding exist over its range (Engelhardt 1946). ***Egg.*** Dark to light brown, somewhat flattened, depressed or concave on one side, with one end slightly broader than other. Eggs measure about 0.7 mm long, 0.5 mm wide, and 0.3 mm thick (Snapp and Thomson 1943). ***Larva.*** Young larva, grayish white with brown head; older larva, white or cream colored with dark brown head and sclerotized area dorsally on prothorax and another on last segment of abdomen (figure 22B). Young larvae 1.5 to 1.7 mm long; mature larvae 32 to 38 mm long. ***Pupa.*** White when first formed but soon changing to bright brown; 19 to 24 mm long (figure 22C) (Snapp and Thomson 1943). Protected inside frass- or soil-coated cocoons, from which they exit for moth emergence (figure 22D).

**Biology.** Adults emerge in May to October, with peaks in early and late summer. Moths mate soon after emergence and live only a few days. Adults have not been observed to feed in the field (Russell and Stanley 1969). Oviposition typically begins the day of emergence but occasionally does not start until the second day. Females typically deposit from 200 to 800 eggs, but a few lay more than 1,200 eggs. Eggs are usually deposited singly in small groups, mostly on host trees adjacent to or near the emergence site. Sometimes, eggs are laid on all parts of a tree and occasionally on weeds, grass, debris, and bare soil around the trunk. Most eggs, however, are laid on the lower 15 cm of the trunk and on the soil nearby (Snapp and Thomson 1943). At 27 °C, eggs hatch in about a week. Newly hatched larvae move to the base of trees, usually near the soil line, where they chew through the bark to the cambium. Wounds or breaks in the bark are not needed for entry (Russell and Stanley 1969). The peachtree borer usually has one generation per year (King and Morris 1956, Russell and Stanley 1969) but sometimes it has two generations (Snapp and Thomson 1943). After overwintering, larvae usually build cocoons beneath the bark, on the trunk just below the groundline, or at the soil surface under gum exudates. Pupation occurs inside cocoons and lasts about 3 weeks (figure 22D) (Russell and Stanley 1969).

**Injury and damage.** Large masses of gum exudate, particles of bark, and frass at the base of a tree are evidence of infestation (figure 22E). Damage results from larvae feeding on the cambium and inner bark of the lower trunk, usually just below the soil but sometimes just above ground (figure 22F). Feeding also may injure the larger roots (Snapp and Thomson 1943). Larvae usually attack only after trees are about 50 mm or greater in diameter (Dorn and Auchmoody 1974). They sometimes girdle young trees (and less commonly girdle older trees) and damage is often severe. In some areas, only one or two borers inhabit an infested tree; in other areas, many borers may be in a tree. Trees with old damage are more susceptible to repeated attacks and to invasion by fungi (Russell and Stanley 1969).

Occasionally the peachtree borer has killed young black cherry trees in seed orchards in the Allegheny and Monongahela National Forests (Dorn and Auchmoody 1974). More recently this borer has injured trees in black cherry seed orchards in North Carolina. It also causes minor defects in sawtimber trees.

**Control.** Natural enemies include the egg parasite *Telenomus quaintancei* Girault (Muesebeck 1979) and the following larval hymenopterous parasites—*Macrocentrus marginator* (Nees), *Microbracon sanninoideae* (Gahan) (Marsh 1979), *Cryptus rufovinctus* Pratt, *Phaeogenes ater* Cresson (Carlson 1979), *Hyssopus sanninoideae* (Girault), *Syntomosphyrum clisiocampae* (Ashmead), and *Venturia nigricoxalis* (Cushman) (Burks 1979)—and the pupal dipterous parasite *Anthrax lateralis* Say (Arnaud 1978). Important predators are field mice and rats, which sometimes greatly reduce populations by destroying pupae. Other predators include ants, chrysopid larvae, spiders, moles, and skunks (Snapp and Thomson 1943). Several insecticides effectively reduce populations (Dorn and Auchmoody 1974, Russell and Stanley 1969, Wylie 1968). Disruption of mating communication with synthetic pheromone has been very effective in field trials.

### *Synanthedon pictipes* (Grote and Robinson)

lesser peachtree borer (figure 23)

**Hosts.** Peach, plum, cherry, beach plum, black cherry. Peach is the major cultivated plant host (Bobb 1969). Plum, cherry, and other cultivated stone fruits are attacked as well (Engelhardt 1946). Principal native wild plants attacked are cherry and plum, which may serve as an infestation reservoir for spreading to cultivated plants (Beutenmuller 1901). Serviceberry and chestnut have also been mentioned as hosts (Beutenmuller 1901) but are questionable (Engelhardt 1946).

**Range.** Eastern half of Canada and the United States westward to Minnesota in the north and eastern Texas in the south. Reported as far west as the Rocky Mountains and Pacific Coast but doubtful (Engelhardt 1946).

**Description.** ***Adult.*** Black clearwing moth with a metallic sheen and whitish yellowish markings on head, thorax, and narrow band on abdomen (figure 23A) (Engelhardt 1946). Wings transparent and span 18 to 25 mm. Males and females similar but male more slender with finely tufted antennae. ***Egg.*** Small, about 0.4 by 0.6 mm, reddish brown and very hard; chorion keeps shape after eclosion. ***Larva.*** Newly hatched larvae small and difficult to see, especially in bark crevices of trees (Bobb 1959). Twelve-day-old larvae measure 2.5 to 5.0 mm long and reach 20 mm when grown (figure 23B) (King 1914). Cocoons are just beneath the bark or near debris around the wound (Bobb 1959).

**Biology.** Moths emerge over the entire growing season, peaking in spring and early summer (Dupree 1972, King 1914, Rings 1960). Spring broods emerge from early April until late July; summer broods emerge early July through November (Bobb 1959).

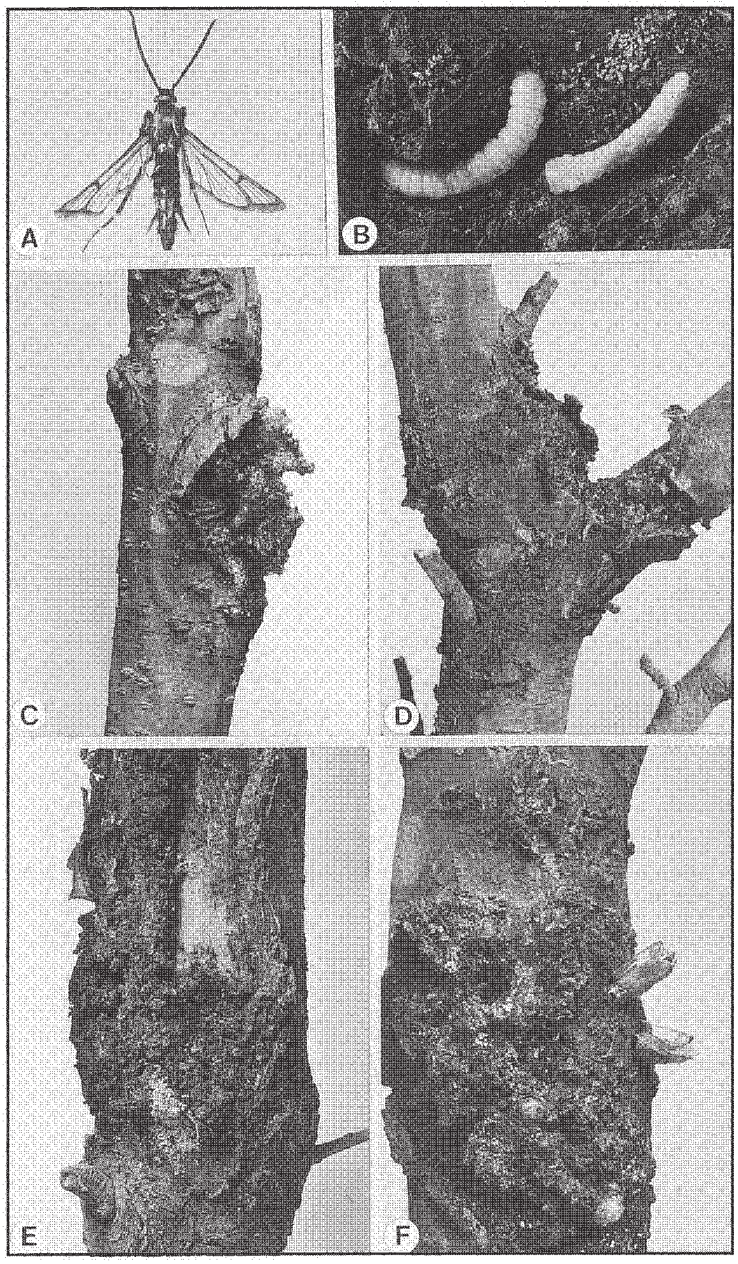


**Figure 23**—Synanthedon pictipes, *lesser peachtree borer: A, adult; B, larvae; C, frass adhering to bark; D, active attack site at branch crotch; E, attack sites with frass at cankered site; F, pupal skins protruding from infested bark.*

Females deposit eggs in broken bark, usually near wounds on vigorous trees. Eggs are deposited singly, but several females may lay large numbers of eggs in and around a wound. Eggs hatch in about 20 days during early season but require as few as 8 days later in the season (Bobb 1959). Larvae usually establish in bark cavities around wound margins and may infest old uninjured trees that have rough bark. *Cytospora* spp. cankers are particularly favorable for invasion (Swift 1986). Numbers of larvae may increase rapidly in a wound and many may feed in a small area. First-brood larvae develop in 40 to 50 days; second-brood larvae overwinter and complete development in about 240 days (Bobb 1959). Larvae overwinter in instars 2 through 6 (Dupree 1972). When development is completed, larvae construct cocoons and pupate in 3 to 7 days. Depending on the time of year, pupation requires 15 to 28 days. Two generations develop each year in the South (Bobb 1959); one (and sometimes a partial second) generation occurs in the North (King 1914).

**Injury and damage.** Attacks are indicated by accumulation of reddish frass (figure 23C), usually near wounds such as split limbs and crotches (figure 23D), pruning scars, abrasions caused by machines, and winter injuries to bark (Bobb 1959). Cankers produced by the peach canker fungus are also infested (figure 23E). Larvae prefer to feed on living tissue at the edges of such injuries. Over several years, feeding can girdle the trunk or limb. Larvae concentrate on trunks 30 to 60 cm above ground and rarely occur at heights above 2.5 m (Rings 1960). A few larvae may be found below ground in association with the peachtree borer (Bobb 1959). After becoming established in a wound, larvae feed on the cambium and inner bark but do not bore into wood. Larvae are often very active and, in large numbers, can kill a tree or branch. Because this borer is not cannibalistic, many survive in even small wounds, increasing the possibility of severe injury to the tree (Bobb 1959). Pupal skins commonly protrude from the bark at infested areas (figure 23F). Before the 1950's and 1960's, this moth was not considered a problem in healthy, well-kept plantings (Bobb 1969). It was found mainly in larger limbs where injuries provided favorable sites for attack. However, in the past 20 to 30 years, it has gained greatly in importance by attacking trunks from ground level to branch crotches. In Virginia, it kills more peach trees than the peachtree borer (Bobb 1969). In Georgia, up to 97% of the trees in some older orchards are infested (Dupree 1972). Economic losses occur when trees die, lose scaffold branches, or are weakened by the borers (Rings 1960). It seriously damages young trees in black cherry seed orchards in Tennessee and North Carolina, necessitating chemical control in some areas.

**Control.** Cultural practices that minimize mechanical injuries from cultivation, mowing, and harvesting reduce incidence. Diseases such as peach canker and black knot, which result in rough, healed areas, create infestation sites; the diseases should

be controlled. Insect injury can be minimized by properly pruning and shaping trees when limbs are small and heal quickly (Rings 1960). Three hymenopterous parasites—*Coccygomimus annulipes* (Brulle), *Macrocentrus marginator* (Nees) (Marsh 1979), and *Venturia nigricoxalis* (Cushman) (Carlson 1979)—have been reported. It can be effectively controlled by applying insecticides periodically during the season to trunks and lower limbs (Bobb 1969, Rings 1960). Disruption of mating communication with sex pheromone appears feasible.

### *Synanthedon scitula* (Harris)

dogwood borer(figure 24)

**Hosts.** Dogwood, pecan, hickory, oak, chestnut, beech, birch, black cherry, elm, mountain-ash, viburnum, willow, apple, loquat, ninebark, bayberry. It is a notorious pest on flowering dogwoods and pecans and is also extremely adaptable (more so than any other species in the family Sesiidae) to different unrelated food plants, including deciduous trees, shrubs, and occasionally vines (Engelhardt 1946).

**Range.** Generally distributed from southeastern Canada throughout the eastern United States westward to Texas and Minnesota (Engelhardt 1946).

**Description.** ***Adult.*** Bluish black and yellow clearwing moth. Forewings narrow and nearly devoid of scales, except dorsally where larger veins are marked with black scales (figure 24A). Body length of adults 8 to 10 mm and wingspan 16 to 18 mm. Overall body color variable, but generally dark blue to black, with second and fourth abdominal segments yellow dorsally (additional yellow banding in southern populations). Femora dark but remaining leg segments mostly yellow. Noticeable anal tufts marked laterally with yellow. ***Egg.*** Pale yellow, elliptical, about 0.5 mm long by 0.4 mm wide, covered with fine reticulations. ***Larva.*** Cream colored with reddish brown head and resinous appearance (figure 24B). Prothoracic shield with two dorsal reddish brown spots. Larvae from 1 mm or less at hatching to 15 mm when mature (Pless and Stanley 1967). ***Pupa.*** Brown; remains inside frass-covered cocoon under bark until adult emerges.

**Biology.** Adults emerge over a 4-month period. Emergence begins in March (Engelhardt 1946) in the extreme South, in late April in eastern Tennessee (Pless and Stanley 1967), in mid-May in Virginia (Underhill 1935), and late in May in Connecticut (Schread 1965). Emergence continues through September. Adults live 7 to 9 days. Eggs frequently are laid next to wounds or on frass produced by other borers (Pless and Stanley 1967). Newly hatched larvae are small, fragile, and very sensitive to low humidity; many die from desiccation before locating suitable niches. Young larvae can move only short distances, usually seeking wounds, fresh grafts, and mines of other borers to become established, although some successfully burrow in uninjured sites. Small larvae may feed for several weeks in the bark before reaching the cambium. Throughout development (six instars), larvae feed in an irregular course

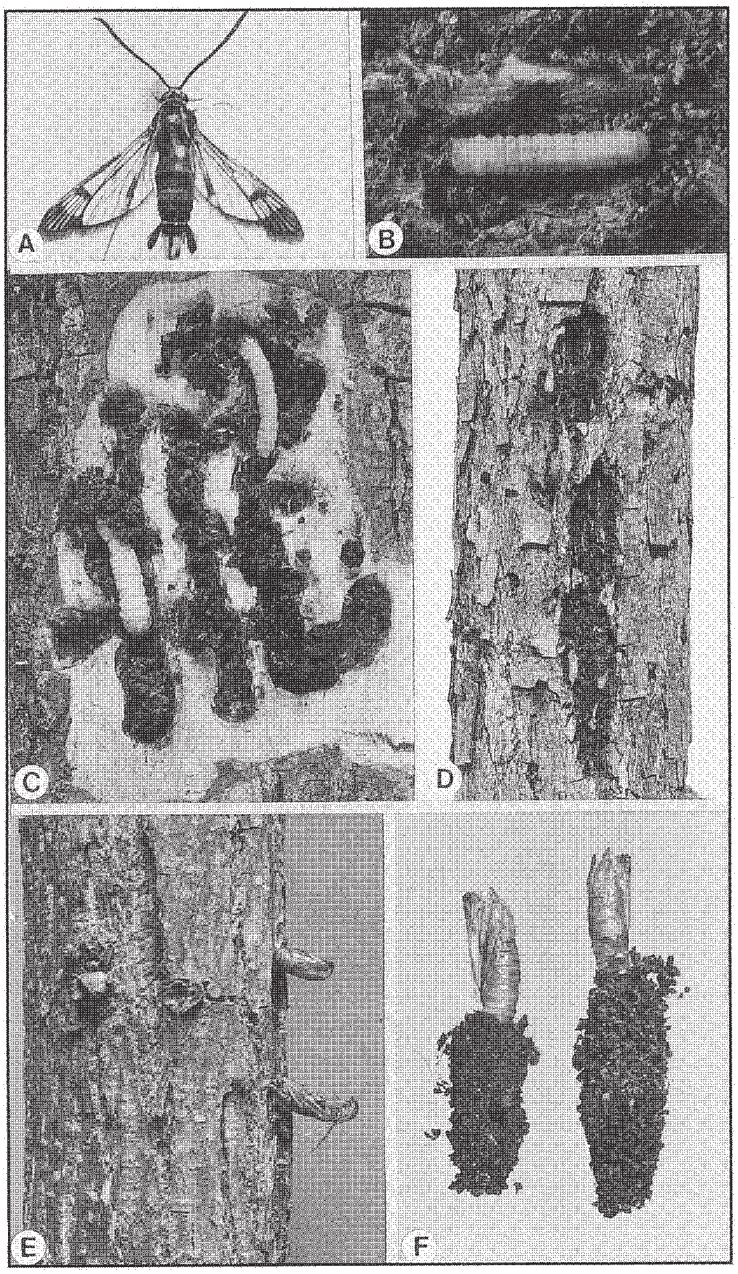


**Figure 24**—Synanthedon scitula, *dogwood borer: A, adult; B, larva; C, burrows under bark of pecan; D, sapstained bark and frass at site of attack; E, pupal skins protruding from bark; F, frass-covered cocoons with pupal skins.*

in the cambium (figure 24C). They may etch the surface of the sapwood but excavate no galleries in it. Generally, only one larva occupies a gallery; when more than one is present, cannibalism may occur. Because larvae are present in trees throughout the year, some entomologists have suggested more than one brood per year, though most report one generation. Pupation normally occurs just beneath the bark within the larval mines and lasts 8 to 12 days. Pupae develop in cocoons made of frass and bark particles held together with silken strands.

**Injury and damage.** Presence of borers usually is indicated by sapstain and fine frass on the trunk and branches in late summer (figure 24D) (Coleman 1968). Sloughing of loose bark is another early symptom of attack (Johnson and Lyon 1988). By fall and winter, coarse brown frass is extruded from galleries. Removal of outer bark reveals larval burrows in the cambium. Infested trees often have swollen, knotty, callused, or gall-like areas on the lower trunk (Schread 1965). Borer injuries sometimes are prevalent at the juncture of trunk and primary branches or smaller twigs and branches. After 1 year of infestation, dead bark over galleries begins to peel, exposing the wood (Pless and Stanley 1967). These borers often infest abnormal growths on stems and branches, such as insect galls, disease-caused galls and cankers, and mechanically caused wounds (Engelhardt 1946). In Kentucky, infestation increased significantly with exposure to sunlight and stem wounds (Potter and Timmons 1981), suggesting why dogwoods in the forest understory are much less subject to attack than open-grown ornamentals. Badly infested trees usually appear unhealthy and may have dieback in parts of the crown and sprouts near the groundline. Small brown pupal skins may protrude from bark (figure 24E) and from frass-covered cocoons beneath the bark (figure 24F) from spring to fall. Before the 1930's, when this species was known as the pecan-tree borer, it was so destructive to buds that it seriously hindered efforts to reproduce pecan varieties vegetatively. It destroys much of the cambium and callus in grafted and budded pecans, preventing the union of scion and stock. Feeding larvae reduce leaf area, change leaf morphology, and hasten leaf senescence in flowering dogwood (Heichel and Turner 1973). Thousands of dogwoods in Tennessee nurseries have been rendered worthless by one generation of this insect (Pless and Stanley 1967). In Virginia, 4,000 dogwoods were killed or badly damaged in nurseries over 4 years (Underhill 1935). In New York, 30 apple trees in 83 orchards were infested (Riedl and others 1985).

**Control.** Internal insect parasites are important natural enemies. Up to 50% of larvae were reported to be parasitized by the braconid wasp, *Apanteles sesiae* Viereck (Underhill 1935). Other insect parasites include *Agathus buttricki* Viereck, *Hyssopus sanninoideae* Girault, *Microbracon mellitor* Say, *M. sanninoidae* Gahan, *Phaeogenes ater* Cresson, and *Scambus (Itoplectis) conquisitor* Say. A fungus, *Cordyceps* sp., has been found but is not prevalent. Predators, including birds, are of

some value as natural controls. Excessive sap flow in spring kills many young larvae (Underhill 1935), and both larvae and pupae are highly susceptible to desiccation during drought (Pless and Stanley 1967). Control on dogwoods is not practical or economically feasible in forests. On ornamental dogwoods, monthly applications of insecticide to trunks and lower branches, from late April to mid-September, prevent attack (Coleman 1968). Cultural practices that keep trees vigorous and free of bark injuries are most important.

### *Synanthedon acerni* (Clemens)

maple callus borer (figure 25)

**Hosts.** Maple. Silver maple is preferred; red maple and sugar maple are readily attacked, and other maples are probably susceptible. Mountain-ash has been listed as a host (Beutenmuller 1901), but this record needs to be confirmed.

**Range.** Occurs in Canada, New England, mid-Atlantic region, Midwest, the Mississippi River Valley south through Mississippi (Engelhardt 1946), and west to Nebraska (Holland 1968).

**Description.** ***Adult.*** Black and orange clearwing moth. Wasplike with wingspan of 18 to 22 mm in male and 22 to 27 mm in female (figure 25A) (Engelhardt 1946). Wings largely transparent, except for bluish black markings. Head and thorax reddish orange with white and black markings and bluish black antennae. Abdomen and prominent anal tuft vary from mostly black with orange markings to mostly orange with black markings (Beal and others 1952, Engelhardt 1946). ***Larva.*** White with dark brown head and light brown thoracic shield and spiracles (figure 25B). Mature larvae 12 to 19 mm long (Felt 1905). ***Pupa.*** Brown and enclosed in small cocoon of silken threads with excrement pellets and debris interwoven on surface (figure 25C) (Holland 1968).

**Biology.** Moths emerge early in the morning from April to July and swarm about tree trunks, ovipositing on the bark (Holland 1968). Eggs are laid on roughened bark, especially wounds (Felt 1905). Young larvae burrow in bark and cambium and prefer succulent callus tissue at the interface of healing wounds. Tunnels are kept partially filled with frass (Saunders 1881). Each larva maintains its own feeding niche, but several often feed near each other. Larvae overwinter within burrows and make cocoons under bark in spring (Engelhardt 1946). After enclosing themselves in cocoons, the larvae transform to brown pupae. Shortly before moths emerge, the pupae wriggle forward, rupture the thin, papery layers of bark over the tunnel exits, and protrude partly out of the trunk. Soon after, the moths emerge onto the bark. There is one generation each year (Saunders 1881).

**Injury and damage.** Round exit holes 3 to 4 mm in diameter in bark typically adjacent to wounds are good evidence of infestation (figure 25D). Brown frass, mostly consisting of small excrement pellets, may be visible at wounds, in bark crevices, or in other rough areas of the bark (Beal and others 1952, MacAloney and

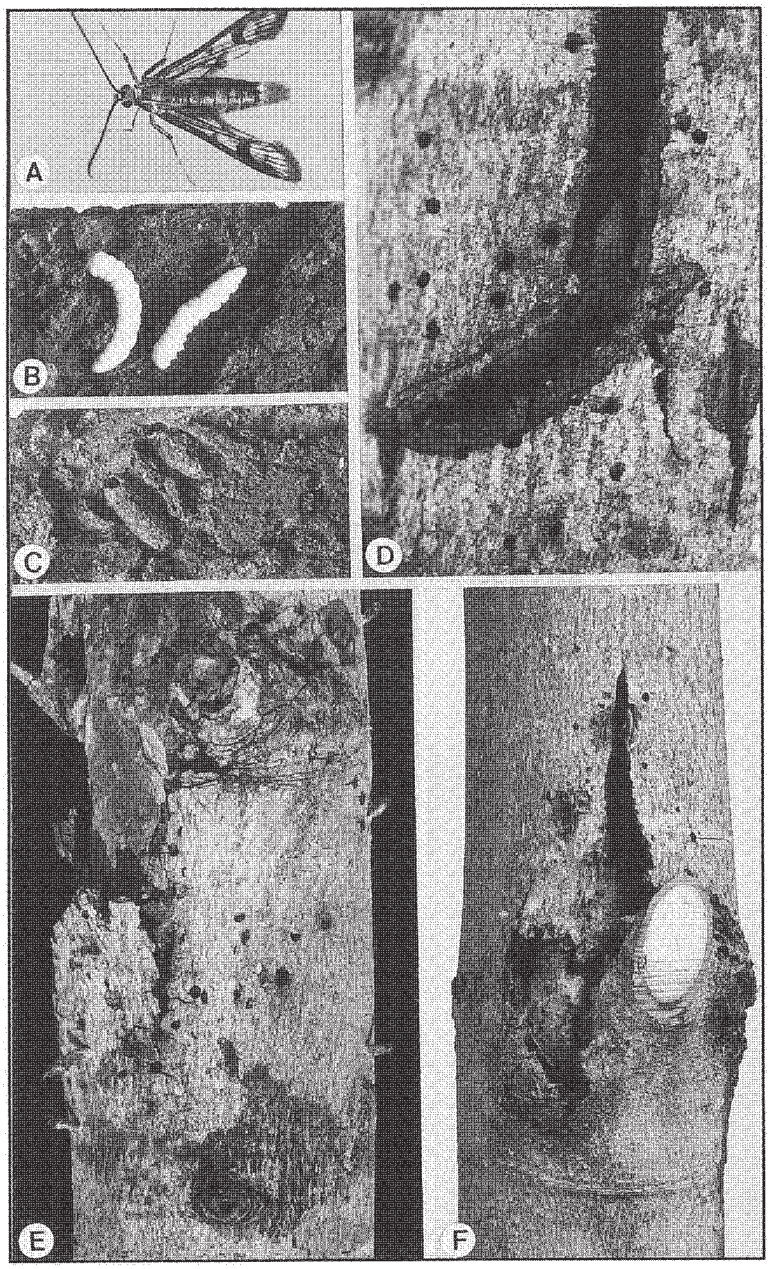


**Figure 25**—Synanthedon acerni, *maple callus borer: A, adult; B, larvae; C, frass-covered cocoons under bark; D, exit holes around ax wound; E, pupal skins protruding from bark; F, infested site with exit holes at branch crotch.*

Ewan 1964). Borers are found most frequently at the boundary of live callus tissue and dead areas in scars and wounds on the trunks and large branches of ornamentals. Once infested, even minor wounds are kept from healing properly, and heavy infestations can enlarge wounds. Repeated attacks can cause disfigured, gnarled areas on the bark that sometimes ruin the appearance of ornamentals (Felt 1905). Infestations are sometimes recognizable by empty pupal skins sticking out of the bark (figure 25E). Open or loose bark at branch crotches and around pruning wounds may indicate attack (figure 25F). Feeding on the inner bark and sapwood, the larvae, once established, attack year after year, leading to a gradual decline of the tree (Engelhardt 1946). Trees may be girdled or killed by the burrows or weakened so that they are more susceptible to decay and wind damage (Holland 1968). The injuries cause deformities and unsightly scar tissue, sometimes resulting in serious defects in forest stands (Beal and others 1952).

**Control.** Woodpeckers help to reduce populations in both forests and urban areas (Felt 1905). Artificial control in forests usually is not feasible (Beal and others 1952), but controls commonly are recommended for shade and ornamental plantings. Infested areas on the trunk should be trimmed and cleaned in spring, then painted with tree-wound paint (USDA FS 1985). Insecticides applied to the trunk during emergence and oviposition can prevent reinfestation. In areas of high infestation, planting less susceptible species, such as Norway maple, is recommended (Engelhardt 1946).

### *Synanthedon acerrubri* Engelhardt

[maple clearwing] (figure 26)

**Hosts.** Maple, boxelder. Red and sugar maples are favored hosts; other maples may also serve as hosts (Engelhardt 1946, Tietz 1945).

**Range.** Found along Atlantic Coast through the eastern half of the United States and northward into Canada (Engelhardt 1946, MacKay 1968).

**Description.** ***Adult.*** Bluish black and yellow clearwing moth. Transparent wings with black scales along veins; wingspan 16 to 22 mm (figure 26A) (Engelhardt 1946). Head black with silvery white markings, orange palpi, and orange collar; thorax violet black, marked with yellow scales and pale yellow beneath. Abdomen bluish violet with narrow, pale yellow bands on segments 2, 4, 6, and 7 in male and segments 2, 4, and 6 in female. Anal tuft in male distinctly fan shaped and black mixed with red; female tuft short, round, and bright red. ***Larva.*** Dull white with brown head and about 12 mm long (figure 26B) (MacKay 1968). Head smaller than prothorax, and abdomen with rather deep segmental folds. Spiracles light brown and elliptical.

**Biology.** Adults emerge mostly during March and June (Engelhardt 1946, Snow and others 1989) but have been taken as late as July and August in Missouri (Adams 1984), Pennsylvania (Tietz 1945), Arkansas, and Mississippi. Moth activity is greatest

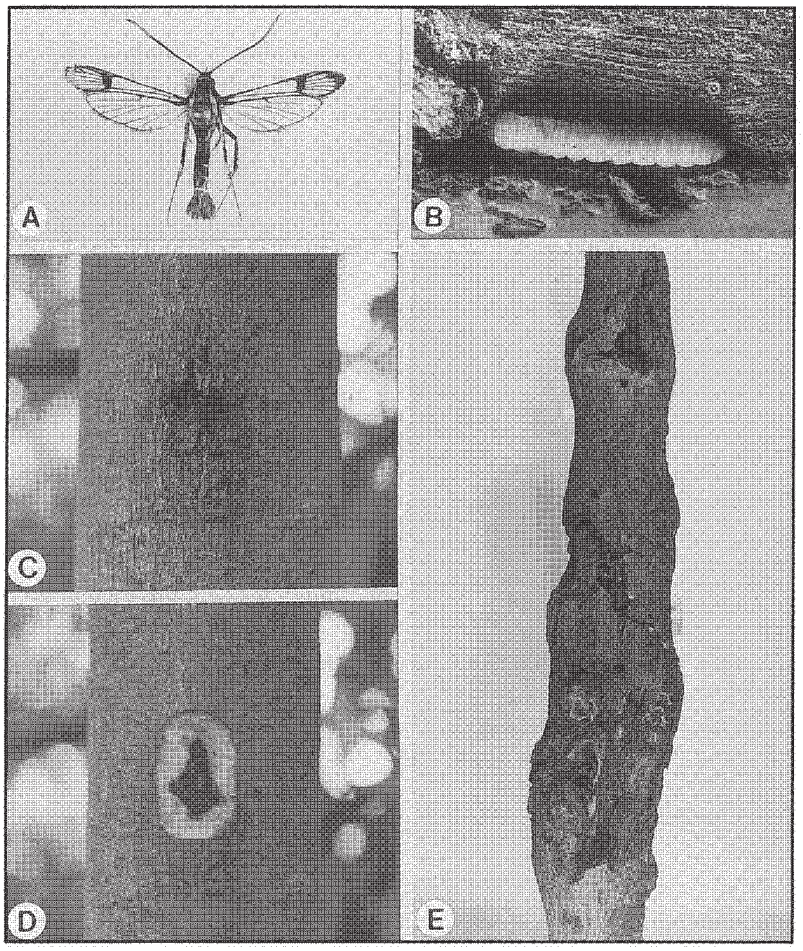


**Figure 26**—Synanthedon acerrubri, *[maple clearwing]: A, adult; B, larva; C, sapstained bark at site of attack; D, bark removed to expose burrow; E, gnarled, swollen stem from repeated attacks.*

between 2:30 and 8:20 p.m. (Adams 1984). Females deposit eggs on bark, mostly around wounds and scars caused by other boring insects, and preferably on branches of weakened host trees (Adams 1984, Engelhardt 1946). Larvae mine the inner bark and etch the sapwood but do not construct galleries in the wood. Several larvae may feed around the periphery of a single wound. Larvae overwinter in their burrows, resume feeding in spring, then cut exit holes nearly through the bark, leaving only thin circular flaps that are ruptured by the pupae just before emergence. Pupation occurs in oblong cocoons of frass and silken threads in the feeding cavity under the bark. The maple clearwing has one generation yearly.

**Injury and damage.** Larvae often invade wounds made by cossid, cerambycid, and buprestid borers. Invasion prevents or slows callus formation and sometimes enlarges wounds. Sap-stained, sunken, and swollen areas on the bark of branches and trunks of hosts often indicate infestation (figure 26C) (Engelhardt 1946). Wounds in bark that are slow to close should be inspected. Prying open bark at infested sites will reveal feeding cavities (figure 26D) and often tunneling larvae—sometimes six or more at a site. Although some frass may be ejected, much of it is packed in cavities under the bark. Branches are sometimes badly scarred and gnarled with numerous round exit holes in the bark (figure 26E). Repeated attacks can girdle and kill branches, but infestations are less common than those of the related maple callus borer.

**Control.** Good tree maintenance that minimizes mechanical wounds and attacks by other borers is the most important means of prevention. Little is known of natural enemies; controls recommended for the maple callus borer should be effective.

### *Synanthedon resplendens* (Hy. Edwards)

[sycamore borer] (figure 27)

**Hosts.** Sycamore, oak, avocado. The preferred host is California sycamore (Brown and Eads 1965b). Coast live oak heavily damaged in some localities (Brown and Eads 1965b). Reported occasionally in avocado (Duckworth and Eichlin 1978, Ryan 1928).

**Range.** A western species of major importance to host trees, particularly in low areas along the Pacific Coast. Occurs throughout California (Brown and Eads 1965b) north to Washington and Idaho (Duckworth and Eichlin 1978) and east to New Mexico (Engelhardt 1946).

**Description.** ***Adult.*** Bluish black and yellow clearwing moth. Blue-black head and antennae, yellow palpi, and yellow collar (figure 27A). Thorax blue black, with nearly parallel yellow lines on sides. Forewings with iridescent blue-black veins and yellow scales on apical cells; hindwings completely transparent and brownish black fringes with inner yellow scales. Wingspan ranges from 20 to 24 mm. ***Egg.*** Ovoid, golden, slightly reticulated on surface, and about 0.8 mm long (figure 27B) (Brown and Eads 1965a). ***Larva.*** About 18 mm long at maturity, without conspicuous hairs, pinkish

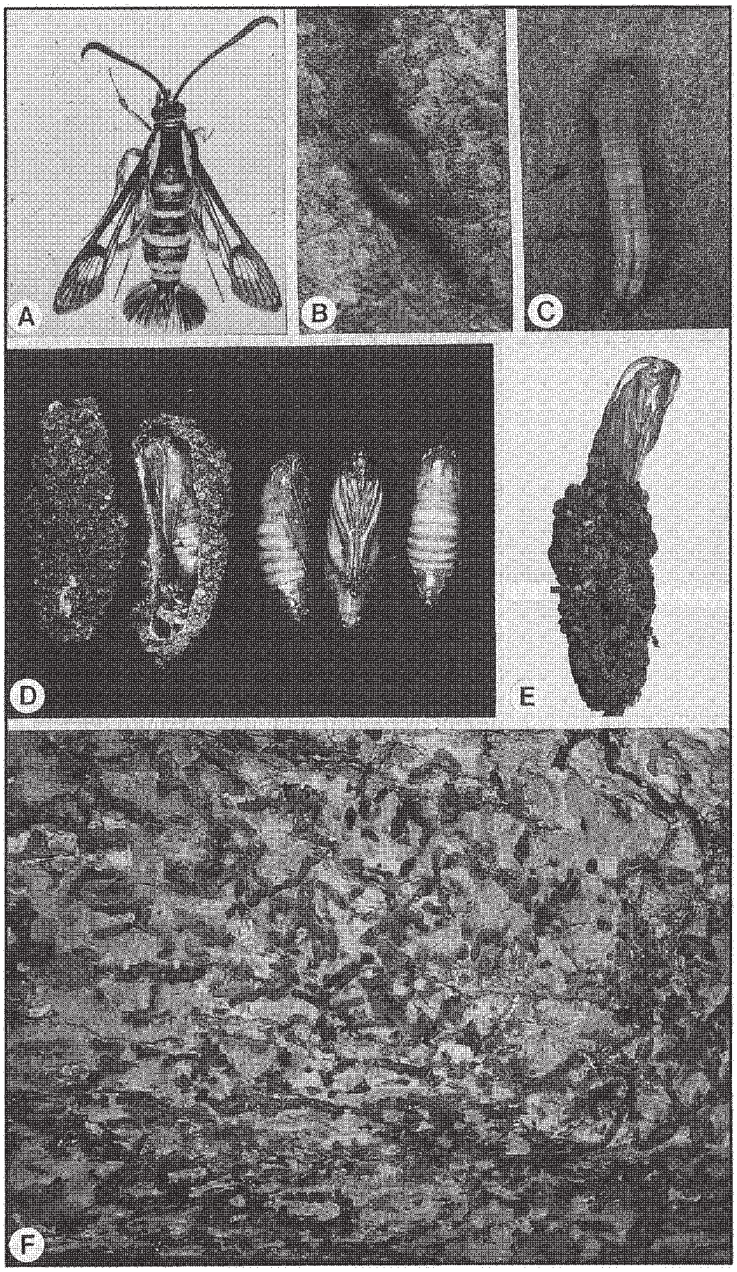


**Figure 27**—Synanthedon resplendens, *[sycamore borer]: A, adult; B, egg; C, larva; D, pupae and cocoons; E, cocoon with pupal skin protruding; F, outer bark removed exposing extensive tunneling (courtesy L. Brown).*

white to dark pink, and with reddish brown head (figure 27C). ***Pupa.*** About 10 mm long, shining mahogany brown, and found in white to brownish silken cocoon (figure 27D and E) (Brown and Eads 1965a).

**Biology.** Adults emerge from April to early August, but peak emergence occurs in June and July. Except for emergence and oviposition, adults confine most activities to the crowns of trees (Duckworth and Eichlin 1978). Oviposition begins soon after moths emerge and mate. Eggs are laid singly, mostly in small openings such as bark crevices and depressions or against some irregularity of the trunk bark. When eggs hatch, young larvae tunnel in the bark and cambium. Galleries are generally serpentine. Larvae overwinter within galleries but resume feeding in spring, enlarging and extending their burrows (Brown and Eads 1965b). Before pupating, larvae bore almost through the bark to the outside, leaving only paper-thin coverings of bark, and then they crawl a few centimeters back into the tunnel to pupate. As emergence approaches, pupae leave the cocoons and work their way through the thin layer of bark that previously covered the tunnel. Pupal skins protruding from the bark provide evidence of infestation. Moths mimic some wasps in color and also in their actions, with intermittent rapid running and fluttering of the wings (Brown and Eads 1965b). There is one generation per year.

**Injury and damage.** First signs of infestation are wet spots on the trunk followed by copious sap flow on vigorous trees. Reddish granular frass in bark crevices, in the crotches of lower branches, and on the trunk also indicates infestation. Frass may accumulate in piles on the ground at the base of heavily infested trees. Light infestations may go unnoticed until bark begins to appear rough and scarred. When the roughened bark is scraped away, numerous meandering tunnels, often partially filled with reddish frass, can be observed (figure 27F). Tunnels are primarily in the bark, extending into the wood. Old, rough, slow-growing tissue around limb crotches and bark injuries from cultivation and mowing equipment, vandals, and storm damage are favored sites for attack. Several larvae may tunnel close together, but two larvae never occupy one burrow. Galleries of an active infestation are damp and moist; vacated galleries become dry. The mines of one larva may cover up to 100 $cm^2$. Mature trees are more apt to be infested than young ones. Infestation is most common on the lower trunk, particularly around the base, but attacks may be found on the trunk and lower branches up to about 9 m. Larvae mine extensively in the bark and cambium of the trunk (Brown and Eads 1965a, 1965b). Large, open-grown trees, such as those for shade and ornament around homes, along streets, in parks, and in other high-use areas, are likely to be infested. Heavy infestations can kill large areas of bark, which can slow or retard tree growth. The bark at infested sites becomes rough and ugly, detracting from the tree's esthetic value. Specimen trees may be girdled by repeated attacks and eventually die. The attacks slow healing and provide entry points for other insects and diseases. Infestations in orchards

have concerned avocado growers, but to date, damage has been light (Ryan 1928).

**Control.** Effective control is enhanced when trees are kept vigorous by good cultural practices. Larval populations may be reduced by removing the rough bark over infested areas and painting the wound with a protectant. Applying insecticides to the affected part of the trunk is justified for high-value shade, ornamental, and orchard trees (Brown and Eads 1965a, 1965b). Commercial synthetic attractants can be used to determine when moths are active to help better time chemical treatment (Duckworth and Eichlin 1978).

### *Synanthedon rhododendri* (Beutenmuller)

rhododendron borer (figure 28)

**Hosts.** Rhododendron, mountain-laurel, azalea. Rhododendron preferred. Mountain-laurel and deciduous azaleas attacked occasionally, especially when close to heavily infested rhododendron (Neal 1982, Schread 1971).

**Range.** A native first described from specimens collected in Pennsylvania (Beutenmuller 1909). Now best known in the Northeast but also distributed along the Atlantic Coast south to South Carolina (Neal 1982, Snow and others 1985). Recently reported in Mississippi (Solomon and others 1982).

**Description.** ***Adult.*** Black and yellow clearwing moth. Forewings and hindwings transparent with few scales on veins; wingspan of 10 to 15 mm (figure 28A) (Beutenmuller 1909, Engelhardt 1946). Black head with face lightly marked with white; thorax blue black with broad patch of pale yellow on each side beneath. Abdomen lustrous, steel blue or coppery black with segments 2, 4, and 5 narrowly banded with yellow in male and broadly banded in female. Anal tufts lustrous black touched with yellow at sides; fan shaped in male and rounded in female. ***Egg.*** White, oblong, flattened on two opposite sides, and about 0.5 by 0.3 mm. ***Larva.*** Yellowish white, semitransparent, with reddish brown head and legs (figure 28B) (Britton 1923). Mature larva about 10 mm long. ***Pupa.*** Brown, 5 to 9 mm in length, and enclosed in cocoon constructed of silken threads, frass, and debris (figure 28C and D).

**Biology.** Moths emerge during the morning from mid-May through late June (Neal 1984, Schread 1971). They are docile and easily observed resting on foliage of hosts. Females attract males between 10 a.m. and 2 p.m. and mate for about 1 hour. By midafternoon, males rest on foliage, but females have moved to the plant interior to oviposit. Sites for oviposition include old pruning scars, narrow V-crotches, and bark crevices (Neal 1982). Most desirable sites are old larval feeding galleries. Eggs are concentrated around protruding pupal skins, tucked deeply into cracks and bark crevices, and are barely visible even to the trained observer. Adults do not feed and live only a day or two. Females contain an average of about 40 eggs (Neal 1984). Eggs incubated indoors hatch in 10 to 15 days but require slightly longer periods at cooler temperatures outdoors. Newly hatched

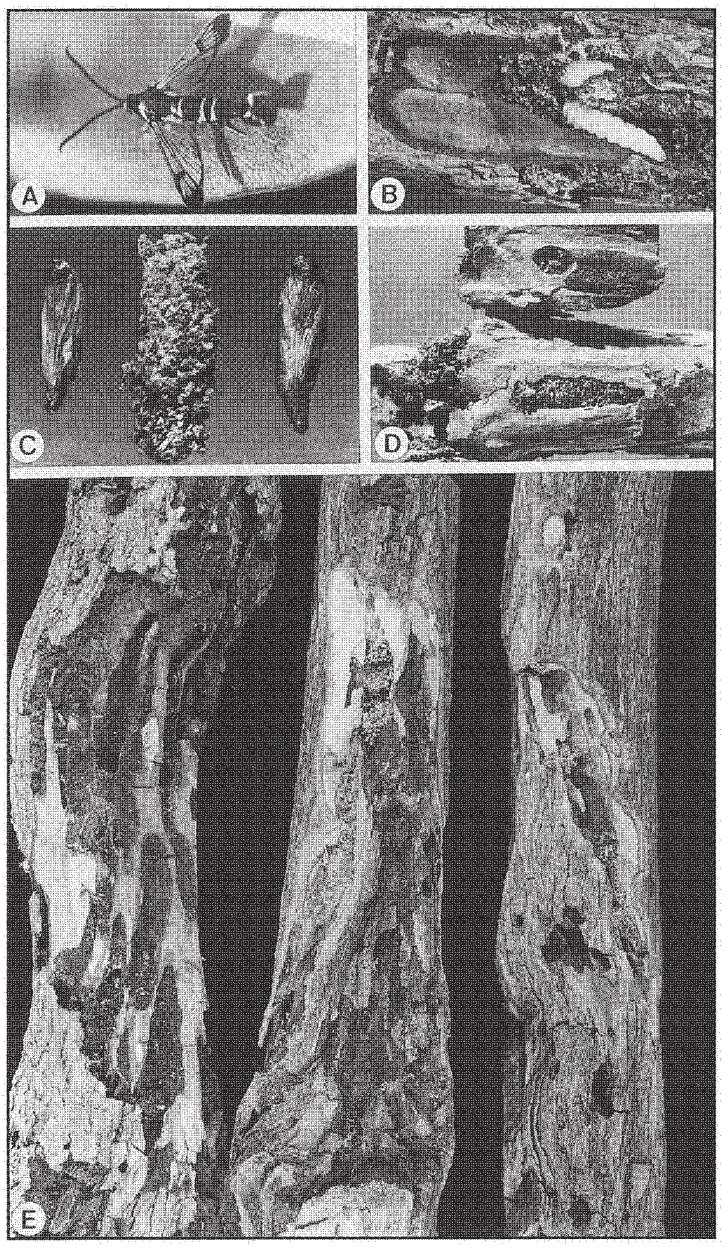


**Figure 28**—Synanthedon rhododendri, *rhododendron borer: A, adult; B, larva; C, pupae and frass-covered cocoon; D, bark removed exposing pupation chamber and cocoon; E, extensive larval burrows under bark of rhododendron stems (A, C, & D, courtesy J. Neal; B, courtesy D. Nielsen; E, courtesy C. Pless).*

larvae frequently make entrances in new callus tissue that is developing over old galleries or pruning wounds. At uninjured sites, young larvae burrow laterally in the cambium for about 1 cm, then turn and tunnel up or down the stem, gradually extending cambial galleries shallowly into the sapwood. By late November, larvae spin filamentous cocoons in the galleries for hibernation. They resume feeding by late March and undergo seven instars (Neal 1984). Mature larvae cut exit holes nearly through the bark, then plug the galleries tightly with frass, spin cocoons, and pupate. Pupation lasts about 15 days, possibly longer (Britton 1923). A generation is completed in 1 year, but some evidence suggests that part of a brood requires 2 years (Britton 1923, Neal 1984).

**Injury and damage.** Injury becomes noticeable as leaves lose their sheen and become pale green, then olive, chlorotic yellow green, and finally wilt and die (Leach 1982). Branches that have not made normal growth and that produce sparse, undersized foliage should also be suspected of being infested. Searching limb crotches and the ground beneath plants will usually turn up small accumulations of fine brown sawdust-like frass. Just above the piles of frass will be small buckshot-sized holes and sometimes larger dark brown irregular pits. Attacks may occur anywhere on the plant, but branches and trunks higher than 30 cm are preferred (Engelhardt 1946). Young plants 45 to 60 cm tall are readily attacked, as are larger plants. Cutting into infested stems reveals irregular galleries 25 to 50 mm long under bark and in the sapwood (figure 28E) (Britton and Zappe 1927). New attacks are often around old damage—the injury being cumulative (Britton 1923). Trunks that have been attacked repeatedly are heavily scarred. Larvae sometimes girdle or partially girdle branches and trunks (Johnson and Lyon 1988). Branches may die back, or the entire plant may succumb. Small plants are particularly susceptible and may be killed even by light infestations. Large plants tolerate more injury, but they too may succumb when an infestation is allowed to continue. Wild rhododendron seems to suffer little, but ornamental rhododendron may be seriously damaged. When an infestation is not suppressed on older plants, unsightly scars and wounds develop, annual growth may be slight, and the foliage may brown, depreciating the beauty of the plants. The widespread use of new rhododendron and azalea varieties has contributed greatly to the increase of borer injury in residential communities, parks, arboretums, gardens, and nurseries (Neal 1982, Schread 1971).

**Control.** Natural controls help to reduce infestation. Woodpeckers, particularly the downy woodpecker, and two hymenopterous parasites—*Bracon sanninodeae* (Gahan) and *Macrocentrus* sp.—are the major natural enemies (Britton 1923, Marsh 1979). Any twigs and branches under attack should be pruned and destroyed during fall, winter, and early spring; whole plants also should be destroyed if heavily infested. Succulent, fast-growing varieties are most susceptible (Leach

1982). Good cultural practices can minimize damage. There is some evidence of host resistance among new varieties, but further evaluations are needed (Neal 1982). Insecticides offer considerable promise when properly timed; pheromone traps can show when adult activity is greatest and pesticides are most effective (Neal 1981, 1982; Schread 1971).

### *Synanthedon pyri* (Harris)

apple bark borer (figure 29)

**Hosts.** Apple, pear, hawthorn. Appears most in the literature under the name "pear borer," a misnomer because the insect prefers and attacks apple far more than pear (Brooks 1920, Woodside 1952). Hawthorn most common wild host. Mountain-ash, serviceberry, cherry, and black cherry mentioned (Brooks 1920) as hosts, but seem questionable.

**Range.** A native of North America, distributed from southern Canada south to West Virginia and west to Illinois (Eichlin and Duckworth 1988).

**Description.** ***Adult.*** Black and yellow clearwing moth. Wings tipped with metallic purplish black or brownish black; dark areas partly covered on underside with yellow scales; wingspan 12 to 17 mm (figure 29A). Upper body parts purplish black with white and yellow markings on head, yellow markings on thorax, and three yellow bands around abdomen. Throughout, colors have metallic luster. ***Egg.*** Light brown, oval, somewhat flattened, 0.6 by 0.3 mm (Brooks 1920). Slightly truncated on one end and distinctly concave on one side. ***Larva.*** Creamy white with brown head, sparsely covered with short, stiff hairs and 15 mm long and 2 mm wide when fully grown (figure 29B). ***Pupa.*** Yellowish white to brown; 8 to 10 mm long (Brooks 1920).

**Biology.** Adults emerge from late April to late August. Eggs are deposited singly, but repeated deposits by the female and other females during the season result in groups of eggs in bark crevices and under bark scales (Brooks 1920). Eggs hatch in about 1 week (Woodside 1952). Larvae feed mostly in the bark and cambium of the trunk and larger branches; where bark is thin, larvae etch furrows into sapwood. In growths caused by disease, larvae feed in porous tissues, and, after feeding at the edge of dead areas, full-grown larvae may burrow into adjacent decaying wood and overwinter in silk-lined hibernacula. Pupation occurs in cocoons within burrows or adjacent dead tissue beneath the bark and lasts about 3 weeks (Brooks 1920). Depending on when the eggs hatch and on food supply, the life cycle is 1 or 2 years. In West Virginia, about 25% develop in 1 year and 75% in 2 years (Brooks 1920).

**Injury and damage.** Borers attack almost any aboveground part except small twigs, frequently on trees stressed from neglect, weather, and disease (Engelhardt 1946). They commonly attack borders of mechanical wounds in the bark, sunscald and winter injury areas, sapsucker injuries, grafting wounds, pruning wounds, and around the tunnels of other species of borers (Brooks 1920). Larvae feed in the

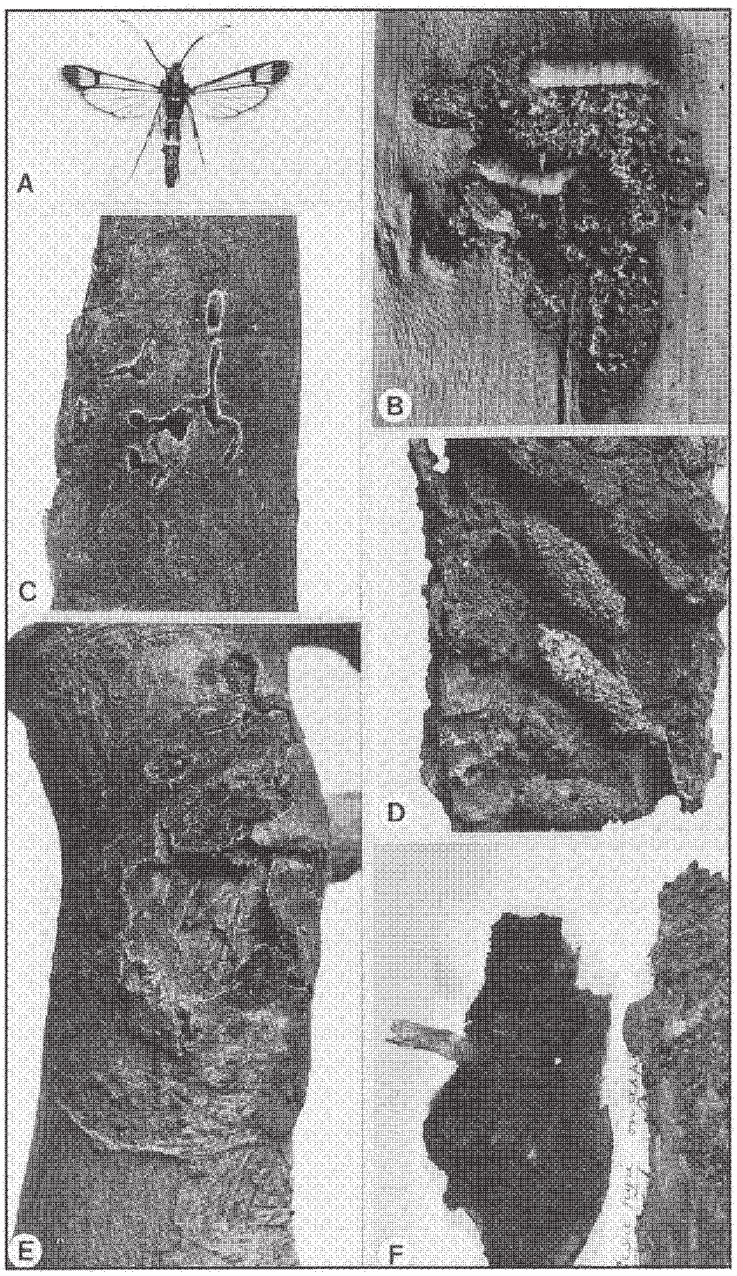


**Figure 29**—Synanthedon pyri, *apple bark borer: A, adult; B, larvae; C, active attack sites on trunk; D, cocoons under bark; E, bark scars over previous attacks; F, bark with pupal skin protruding (A & F, specimens courtesy R. Hodges).*

inner bark and cambium. Beginning in spring, they eject reddish frass through bark openings, usually mixed with sap ooze (figure 29C). Feeding occasionally extends slightly into the sapwood, grooving the surface but not penetrating deeply (Brooks 1920, Woodside 1952). Lifting a portion of the bark reveals larval burrows and frass-coated cocoons (figure 29D). Bark of heavily infested trees becomes rough (figure 29E), and they grow slowly, becoming scraggly and neglected in appearance (Brooks 1920). Empty pupal skins protrude from the roughened bark during the growing season (figure 29F). Because the insect is very small, the injury by one borer is slight, and infestation of a medium to large tree by a few borers seldom causes appreciable injury. Severe damage may result when a dozen or more larvae populate part of a tree. Damage tends to occur in the same parts of the tree year after year because the roughened bark of infestations attracts ovipositing moths. Large cankers usually develop on the lower surfaces of larger branches from repeated attacks. Infested branches eventually succumb to partial girdling, reducing the fruit-bearing area of the tree and affecting its health. Large trees may be killed after several years from the cumulative effects of the attacks (Woodside 1952).

**Control.** Woodpeckers are common natural enemies of the larvae. Several parasites attack both larvae and pupae; mortality rates caused by parasites sometimes reach 50%. Hymenopterous parasites include the following—*Ephialtes aequalis* (Prov.), *Itoplectis annulipes* (Brulle) (Brooks 1920), *Lissonota* n. sp., *Lissonota sesiavora* (Rohwer) (Carlson 1979), *Macrocentrus* n. sp., *Microbracon* sp. (Marsh 1979), *Phaeogenes ater* Cresson, and *Tetrastichus* sp. (Brooks 1920, Burks 1979). Healthy trees resist borer attacks (Engelhardt 1946). Cut surfaces should be painted afterwards with a wound protectant (Brooks 1920). Insecticides are most effective when sprayed during the season that adults fly (Woodside 1952). Applications can be made at other times if the sprays are applied at high pressures that dislodge loose bark and penetrate cracks and crevices (Kelsey and Stearns 1960).

### *Synanthedon kathyae* Duckworth and Eichlin

[holly clearwing borer] (figure 30)

**Hosts.** Holly. Larvae first collected from American holly; however, the horticultural hollies (English/Chinese crosses) preferred, with the Blue Angel variety being most susceptible (Ghidiu and others 1987).

**Range.** An eastern species reported only from South Carolina, North Carolina, Virginia, Maryland, New Jersey, New York, Massachusetts, and Nova Scotia (Duckworth and Eichlin 1977b; Ghidiu and others 1987; Neal and Eichlin 1983).

**Description.** ***Adult.*** Clearwing moth. Bluish black with yellow markings (figure 30A) (Duckworth and Eichlin 1977b). Wings mostly hyaline except for blue-black scales on veins and light powdering with yellow on margins; wingspan 18 to 25 mm. Head blue black with yellow fringe and yellow labial palpi; thorax blue black with subdorsal

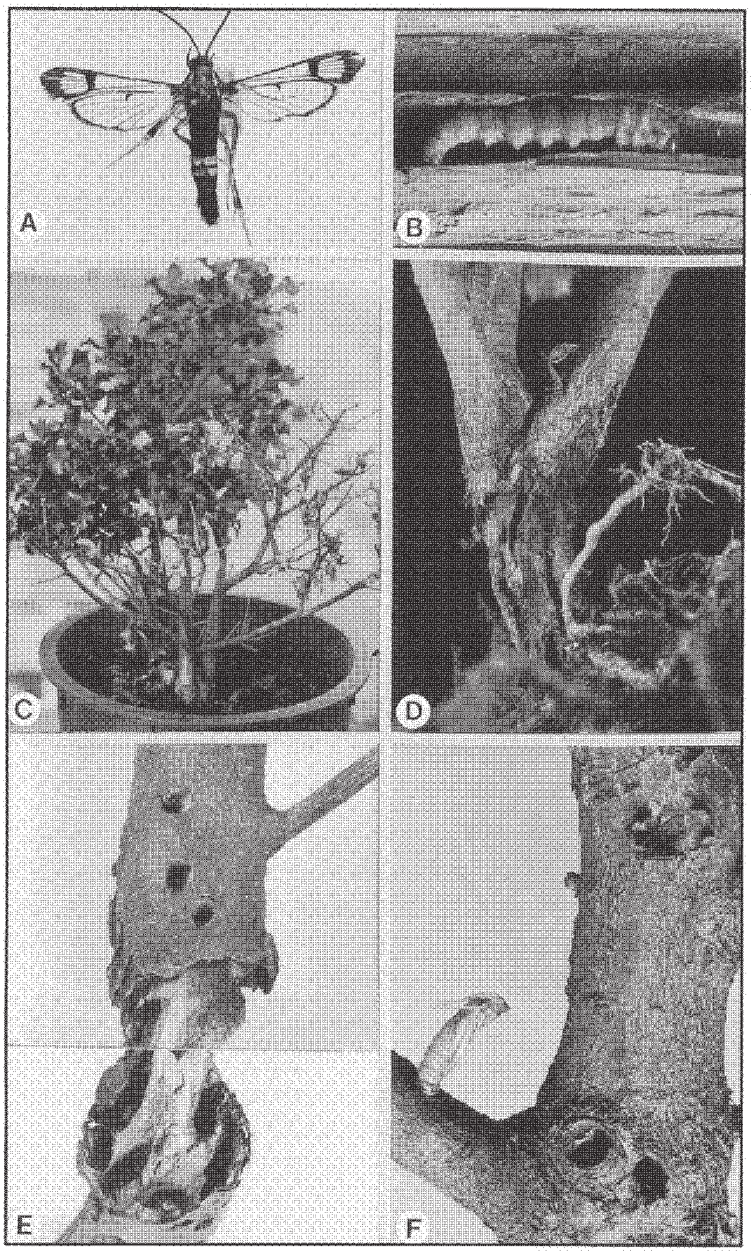


**Figure 30**—Synanthedon kathyae, *[holly clearwing borer]: A, adult; B, larva; C, potted holly with girdled stems dying; D, bark removed at root collar to expose galleries; E, multiple galleries and pupal exits; F, pupal skin protruding from stem. (specimens courtesy G. Ghidiu and L. Vasvary).*

yellow stripes. Abdomen blue black with segments 4 and 5 marked with yellow dorsally. Elongate anal tuft in male, brushlike in female. Legs yellow and blue. ***Egg.*** Very small, oval, brown. ***Larva.*** White with brown head and spiracles, and 15 to 21 mm long when mature (figure 30B).

**Biology.** Adults emerge from late May until late July (Duckworth and Eichlin 1977b, Ghidiu and others 1987). However, infestations in container-grown holly in heated greenhouses have produced adults in February. Larvae extend galleries in stems from 3 to 7 cm above the soil line down to 1 to 2 cm below the surface. Larvae inhabit separate galleries, but several may feed close together within the same stem. Galleries usually are kept open and clean except for small amounts of loose frass. Mature larvae prepare for adult emergence by cutting round exit holes 4 to 5 mm in diameter, leaving thin bark covers. Pupation occurs head-upward in galleries. Pupal skins protruding from exit holes are common around the root collar and lower branches during the emergence season. Galleries and larvae of uniform size and emergence within a year suggest one generation per year.

**Injury and damage.** The main stem and stems at the base of the plant 8 to 40 mm in diameter are the favored sites for attack. Initial signs of infestation are wilting and drooping of tender terminal and branch shoots (Ghidiu and others 1987). Foliage first becomes chlorotic to yellowish and finally brown and curled. Girdled branches sometimes drop leaves; the rest of the plant remains green (figure 30C). Heavily infested plants exhibit progressive dieback, sometimes limb by limb, until eventually the entire plant succumbs. Dieback and mortality are most noticeable in early to mid-November. Light brown frass is ejected from bark entrances just above the soil line. The frass gradually becomes coarsely granular and accumulates in piles around the root collar. Raking away frass reveals cracked, loose bark that is easily removed to expose larvae and their tunnels (figure 30D). Multiple galleries in wood are common; up to six with pupal skins and gallery exits have been observed on plants 3 to 4 cm in diameter at the root collar (figure 30E and F). Plants of this size infested by three or more larvae usually die. Galleries are irregularly shaped but oval in cross section and measure 4 to 8 mm wide and 5 to 8 cm long. Nursery plants have been heavily injured in New Jersey and sometimes require chemical control. One nursery manager reported that 30% of the Blue Angel variety was infested during 1981–1982, amounting to an estimated loss of $6,000 (Ghidiu and others 1987).

**Control.** Stressed, weakened plants are most vulnerable to attack; injury can be avoided or minimized by keeping the plants vigorous and healthy. The Blue Angel variety of holly (as previously noted) is most susceptible, followed by Nellie Stevens and Inkberry; Blue Prince and Blue Princess varieties are least susceptible (Ghidiu and others 1987). Therefore, where borer problems exist, plant the least-susceptible hollies. Chemical control may be needed to protect nursery stock.

### *Synanthedon decipiens* (Hy. Edwards)

[oakgall clearwing] (figure 31)

**Hosts.** Oak. Seems limited to the oaks. Reared from black oak, water oak, pin oak, live oak, and several scrub oaks (species unknown) (Engelhardt 1946). Adults have been swept from Gambel oak.

**Range.** Widely distributed from Ontario and New York south to Florida and west to Texas, Colorado, and New Mexico (Engelhardt 1946, MacKay 1968).

**Description.** ***Adult.*** Clearwing moth with black, yellow, orange, and red markings (figure 31A) (Beutenmuller 1901, Engelhardt 1946, Kellicott 1892). Forewings transparent but heavily scaled with black and orange with a discal mark of bright red or yellow; hindwings transparent. Wingspans 13 to 18 mm. Head black with yellow collar and palpi and black antennae; thorax black with partial yellow band and small yellow patch on each side. Males with coppery black abdomens with segments 2, 6, and 7 narrowly banded with yellow and segment 4 broadly banded. Females similar except segment 7 not banded. Anal tuft black, edged with white; fan shaped in males and edged with yellow and rounded in females. ***Larva.*** White and about 13 mm long (MacKay 1968). ***Pupa.*** Flattened clypeal spine and median ridge on mesothorax (Kellicott 1892).

**Biology.** Adults emerge from April to September (Eichlin 1975, Kellicott 1892, Engelhardt 1946, Snow and others 1985). Females deposit eggs on the bark and galls of hosts. Larvae tunnel into the host and produce extensive cavities. Galls caused by *Andricus* spp. are favorites for infestation; however, other woody (rather than soft or spongy) galls, and only those nearly or fully developed with living tissue, are infested. They pupate in silk-lined cells excavated in the pithy interior of the gall. The life cycle reportedly lasts 1 year (Engelhardt 1946), but peak catches in pheromone traps in Georgia during April-May and August-September suggest two generations per year (Snow and others 1985).

**Injury and damage.** This borer occasionally attacks the bark of host trees, but it is limited mostly to infesting the hard, woody cynipid galls on them (MacKay 1968). Small clumps of brown to reddish frass are usually found clinging to bark or galls of infested trees (figure 31B). Sometimes small openings or soft areas are found on the bark surface. Dissecting the bark or gall reveals mines and larvae. Vacated larval mines may be partially filled with reddish excrement pellets. Brown empty pupal skins protruding from infested galls can be seen during and after emergence (figure 31C). This clearwing is of little or no economic importance.

**Control.** Because this borer largely infests woody twig galls, controls have not been needed.

### *Synanthedon sapygaeformis* (Walker)

[Florida oakgall clearwing] (figure 32)

**Hosts.** Oak. Specimens reared from live, water, and scrub oaks (Engelhardt 1946).

**Range.** Known distribution limited to Florida and southern Georgia, but probably

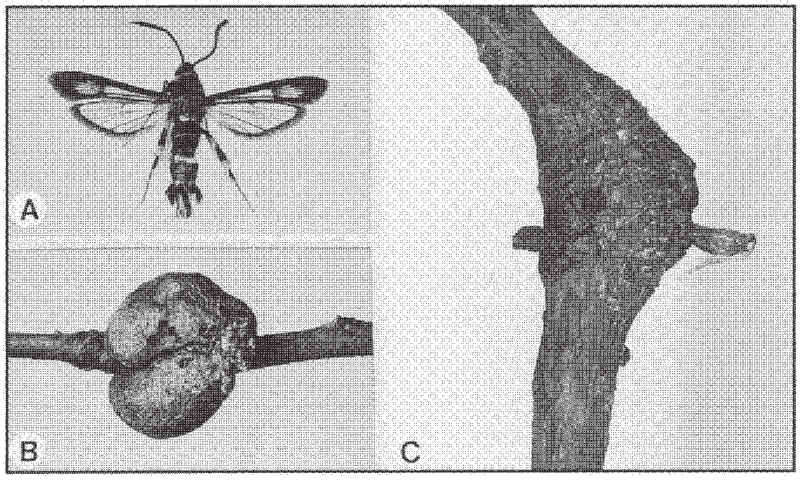


**Figure 31**—Synanthedon decipiens, *[oakgall clearwing]: A, adult; B, oak gall with entrance holes and frass; C, galled branch with pupal skin protruding (specimens courtesy R. Hodges).*

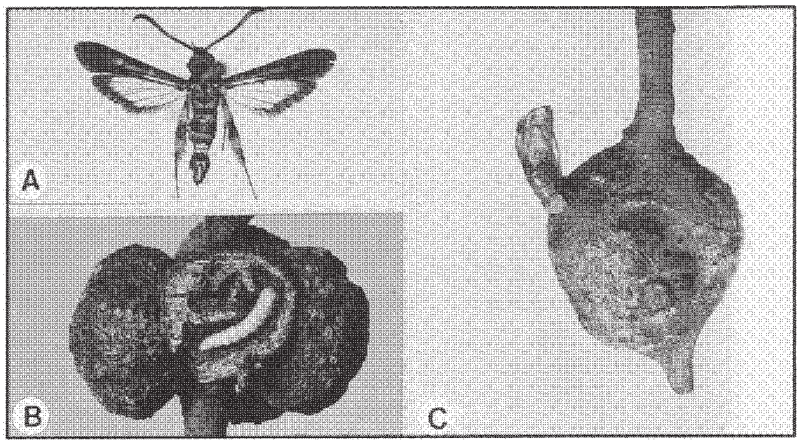


**Figure 32**—Synanthedon sapygaeformis, *[Florida oakgall clearwing]: A, adult; B, gall with burrows and larva; C, gall with pupal skin protruding (specimens courtesy R. Hodges).*

occurs elsewhere in the Southeast (Engelhardt 1946, Sharp and others 1978).

**Description.** ***Adult.*** Clearwing moth, variable in color but generally black and marked with orangish red (figure 32A) (Beutenmuller 1897, Engelhardt 1946). Forewings clear with black and orange borders. Wingspans 13 to 21 mm in males and from 18 to 22 mm in females. Head and thorax black with red collar and orangish red labial palpi. In one color form, abdomen black with segments 4, 5, 6, and 7 red in males and only segments 5, 6, and 7 red in females. In another color form, segment 5 black instead of red in both sexes. Anal tuft black and wedge shaped in male, short and blunt in female. ***Larva.*** White with brown head and spiracles and 12 mm long (figure 32B) (MacKay 1968).

**Biology.** Adults emerge from January through December, with peak emergence in April (Sharp and others 1978). Moths deposit eggs on woody twig galls; specimens reared from woody galls caused by *Callirhytis batatoides* (Ashmead) (Morse 1957). This species probably infests galls caused by other gall wasps as well. Larvae develop inside the galls that are well developed and have living tissue (Morse 1957). Pupation occurs within pupal cases in silk-lined galleries inside the galls. At least one generation occurs per year, possibly two (Engelhardt 1946, Morse 1957).

**Injury and damage.** Larvae infest twig and branch galls on host trees. Shallow sunken areas or openings may be present in infested galls. As larvae develop, brownish frass with reddish excrement pellets adheres to the sides of galls. Larval tunnels and white larvae can be exposed by opening the galls (figure 32B). Empty pupal skins can often be observed protruding from the surface of infested galls (figure 32C). The insect is of no economic importance and could be considered beneficial, since it may reduce survival of the cynipid wasps that cause the galls it attacks.

**Control.** Because infestations are limited mostly to insect-caused galls, controls have not been needed.

### *Synanthedon geliformis* (Walker)

[pecan clearwing borer] (figure 33)

**Hosts.** Pecan, hickory, dogwood, oak, elm. Pecan favored, but hickory, dogwood, oak, and elm readily attacked (Engelhardt 1946, MacKay 1968).* Has once been recorded infesting wounds on Australian pine (Engelhardt 1946).

**Range.** Primarily a tropical and subtropical species from Mexico through the West Indies into Florida, Georgia, and South Carolina (Eichlin and Duckworth 1988, Engelhardt 1946).

**Description.** ***Adult.*** Clearwing moth, bluish black, marked with red; wingspan 15 to 20 mm (figure 33A) (Engelhardt 1946). Forewings mostly opaque and blue black; hindwing transparent and broadly margined with dull black. First segment of the abdomen bluish black above and red beneath; all other segments reddish above and beneath. Anal tuft red and edged with black, fan shaped in male, and rounded in

*Mizell, R. F. August 23, 1984. (personal communication). University of Florida, Monticello, FL.

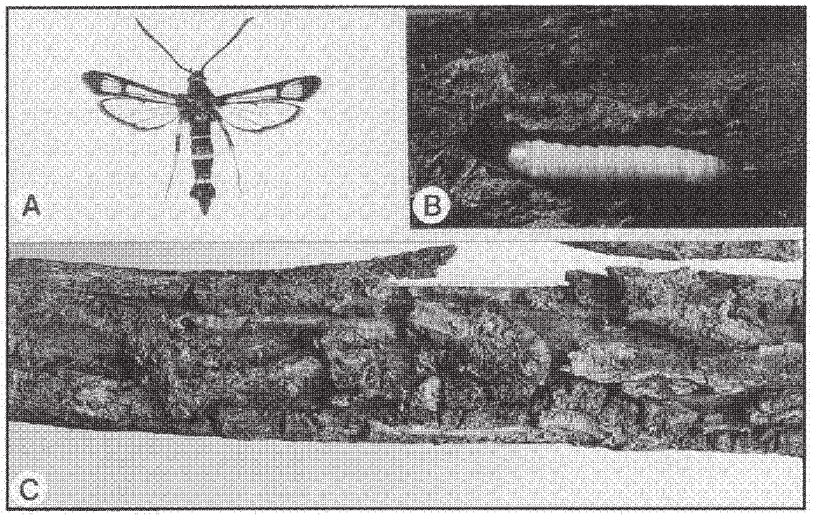


**Figure 33**—Synanthedon geliformis, *[pecan clearwing borer]: A, adult; B, larva; C, rough, loosened bark at attack site (A, specimen courtesy R. Hodges; B & C, specimens courtesy R. Mizell).*

female. ***Larva.*** White, 10 to 15 mm long when mature (figure 33B) (MacKay 1968). Head somewhat broader than long and prothoracic shield with line of darker pigment on each side.

**Biology.** Moths previously were recorded to emerge from March to July but mostly in March and April (Engelhardt 1946, Turner and others 1918). Recently, however, moths were captured in pheromone traps from February to November (Sharp and others 1978). Females deposit eggs in bark crevices, particularly around diseased or injured sites. The tiny larvae burrow into the inner bark to feed. Each excavates a small area, but several mining together can cause sizeable wounds. Larvae overwinter in burrows in the bark and cambium. They resume feeding in spring, then pupate in cocoons of frass and silk under the bark. Pupae exit partially through the bark where the adults emerge. One, possibly two generations develop each year.

**Injury and damage.** This bark and cambium borer prefers to attack trees with diseased, bruised, or injured areas. Fine frass in bark crevices on the trunk and branches may be the first evidence of infestation. Later, frass becomes coarse and reddish brown and may adhere in clumps to the bark. Lifting the bark often reveals numerous burrows and larvae (figure 33C). Brown pupal skins may protrude from bark during spring and summer. Seedlings to mature trees may be attacked at any point from the ground to 6 m or more. However, abused and heavily scarred trees are most apt to be infested (MacKay 1968). Nursery-grown trees seem especially prone to attack. This borer seldom causes serious injuries except when locally high populations partially or completely girdle small trees. In 1984, it seriously damaged container-grown Chinese elm in nurseries in Tampa,Florida.*

**Control.** Cultural practices that promote tree health and smooth bark help to minimize losses. Chemical control may be necessary to control these borers in valuable trees, especially in nurseries.

### *Synanthedon rubrofascia* (Hy. Edwards)

[tupelo clearwing borer] (figure 34)

**Host**. Tupelo. Most of the scattered reports on this borer give the host simply as sourgum (tupelo) (Engelhardt 1946, USDA FS 1985). It has been recorded specifically in blackgum, but probably attacks other *Nyssa* species as well (MacKay 1968). Moths have been collected from flowers of chinkapin (Engelhardt 1946).

**Range.** Primarily a southeastern species, occurring from Florida, Georgia, and Louisiana north to Massachusetts and west to Michigan and Indiana (Eichlin and Duckworth 1988, Engelhardt 1946, MacKay 1968, Reed and others 1981).

**Description.** ***Adult.*** Black and red clearwing moth with slight metallic luster (figure 34A) (Engelhardt 1946). Wings vary from mostly transparent in male to opaque in female; wing margins and veins purplish black above. Wingspans vary from 26 to 36 mm, with those of females slightly

*Mizell, R. F. August 23, 1984. (personal communication). University of Florida, Monticello, FL.

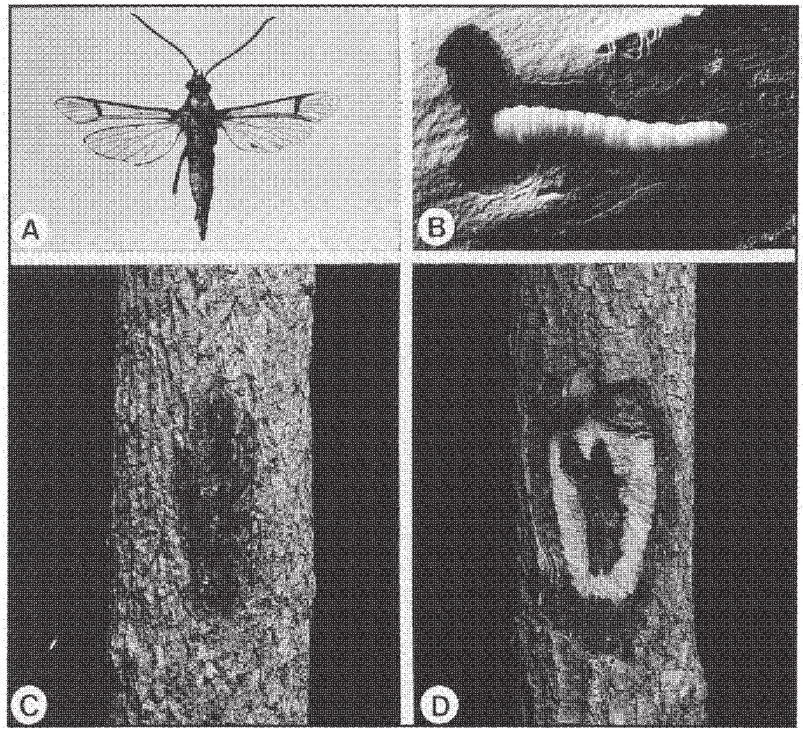


**Figure 34**—Synanthedon rubrofascia, *[tupelo clearwing borer]: A, adult; B, larva; C, sapspot at site of attack; D, bark removed to expose larval burrow (A, specimen courtesy W. Snow).*

longer than those of males. Abdominal segments 4 and 5 deep orange red above and beneath. Orange-red scales sometimes extend over part of segment 6. Wedge-shaped anal tuft in male black, edged with white toward tip. ***Larva.*** Little known, but setal arrangement, head, and crochets have been illustrated; 18 mm long (figure 34B) (MacKay 1968).

**Biology.** Adults emerge and fly during most of the growing season; captured in pheromone traps from March to November (Engelhardt 1946, Sharp and others 1978, Snow and others 1985). Moths deposit eggs on the bark, preferring to oviposit near fresh and callusing wounds. Larvae burrow into the bark and cambium, where they make long sinuous burrows. They sometimes scrape or etch the surface of the wood but do not bore into it. Mines and tunnels are kept moist by the sappy wound tissue. Pupation occurs within oblong cocoons of debris and silken thread with exits facing crevices or openings in the bark. In Georgia, two generations develop per year (Snow and others 1985).

**Injury and damage.** This borer typically invades injuries on trunks of large trees (Engelhardt 1946). Larvae produce mines and tunnels under the bark, usually in association with other bark injuries (Engelhardt 1946). Sap spots on the bark sometimes provide evidence of infestation (figure 34C). Dissecting infested bark reveals the mines and tunneling larvae (figure 34D). Large, mature trees are reportedly most susceptible to attack. This borer is fairly widespread, but populations are scattered and rarely large (Engelhardt 1946). Recently, however, moderate numbers were captured in pheromone traps in Georgia, indicating that populations are increasing (Snow and others 1985).

**Control.** Valuable trees should be protected from injuries to avoid infestation. Chemical controls are rarely needed.

### *Synanthedon sigmoidea* (Beutenmuller)

[willow clearwing] (figure 35)

**Hosts.** Willow. Black willow is a specific host, but other willows probably are attacked (Engelhardt 1946, Forbes 1923).

**Range.** Maine south to the Carolinas westward through the Midwest to the Rocky Mountains and New Mexico, and in southern Canada (Engelhardt 1946, MacKay 1968).

**Description.** ***Adult.*** Black and yellow clearwing moth. Wings transparent with black veins and margins; forewing with orange discal patch of scales. Wingspan 18 to 26 mm (figure 35A) (Beutenmuller 1901, Engelhardt 1946). Black head with black antennae, yellow labial palpi, and yellow collar. Black thorax with yellow mark on each side; abdomen coppery black and segments 2, 4, 6, and 7 narrowly banded with yellow. Anal tuft black and edged with yellow. ***Larva.*** White with brown head, light brown thoracic shield; about 12 mm long (figure 35B) (MacKay 1968).

**Biology.** Moths emerge during July to September and deposit eggs on the small stems of hosts (Engelhardt 1946, Forbes 1923). Larvae bore into the bark and tunnel small shoots and branches. The larvae

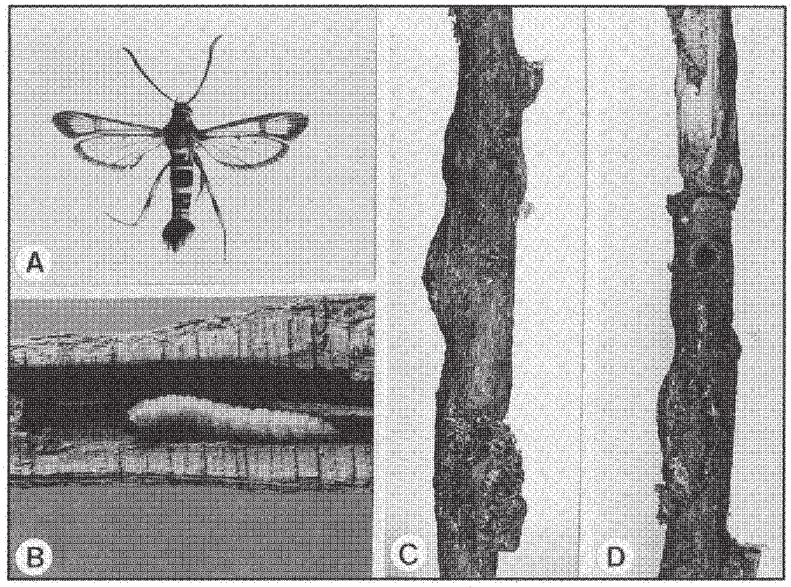


**Figure 35**—Synanthedon sigmoidea, *[willow clearwing]: A, adult; B, larva; C, openings, swellings, and frass on infested stem; D, round exit hole in bark (specimens courtesy R. Hodges).*

overwinter in their galleries, feed again in spring, and pupate in the burrows during summer. The life cycle has not been fully worked out, but there appears to be one generation per year.

**Injury and damage.** This borer infests canes and branches of low-growing shrub willows and, less frequently, willow trees (Engelhardt 1946, USDA FS 1985). Sap spots and frass on the bark of shoots and branches are evidence of infestation (figure 35C). The site of attack commonly swells (Engelhardt 1946). Infested shoots sometimes break where the insects have tunneled. Round exit holes and brown pupal skins protruding from swollen points on the stems are good evidence of infestation (figure 35D). Heavy infestations can cause considerable breakage, but only occasionally is this species of any economic importance.

**Control.** Woodpeckers prey on the larvae. Nothing else is known of natural controls, and direct controls have not been needed.

### *Synanthedon albicornis* (Hy. Edwards)

[western willow clearwing] (figure 36)

**Hosts.** Willow. Reared from Pacific willow and Bonpland willow but no doubt also occurs in other willows within its range (Duckworth and Eichlin 1978). Poplar casually mentioned, but not confirmed, as a host (Doane and others 1936).

**Range.** California and Washington east through the Rocky Mountains and north to British Columbia and the Northwest Territories (Duckworth and Eichlin 1978, MacKay 1968).

**Description.** ***Adult.*** Bluish to purplish black clearwing moth with yellowish and white markings (figure 36A) (Duckworth and Eichlin 1978, Engelhardt 1946). Wings transparent with black veins and margins; wingspan varies from 16 to 22 mm. Head and thorax black; labial palpi pale yellow and white ventrally. Abdomen bluish and iridescent with pale yellow laterally on segments 1 and 2, occasionally forming narrow band dorsally on segment 2. ***Larva.*** White with brown head, and light brown cervical shield with dark brown curved lines (figure 36B) (Beutenmuller 1901, MacKay 1968).

**Biology.** Adults emerge mostly from June through August (Duckworth and Eichlin 1978) but have been recorded from March to October (Engelhardt 1946). Females deposit eggs on the bark. Larvae bore into the bark and make sizeable burrows there and in solid wood (Doane and others 1936). Larvae overwinter in their burrows where they pupate the next spring and summer. This clearwing has one generation per year.

**Injury and damage.** Larvae bore into the bark of host trees and sometimes break small stems, but the insect does little economic damage. Bark wounds attract invasion. The bark of large trees and exposed roots, branches, and canes of smaller willows may be attacked (Engelhardt 1946). The upper branches of small willows are infested most frequently (Duckworth and Eichlin 1978). Wet, sap-stained spots on the bark, small cracks or openings in the bark, and fine frass mixed with sap or small clumps

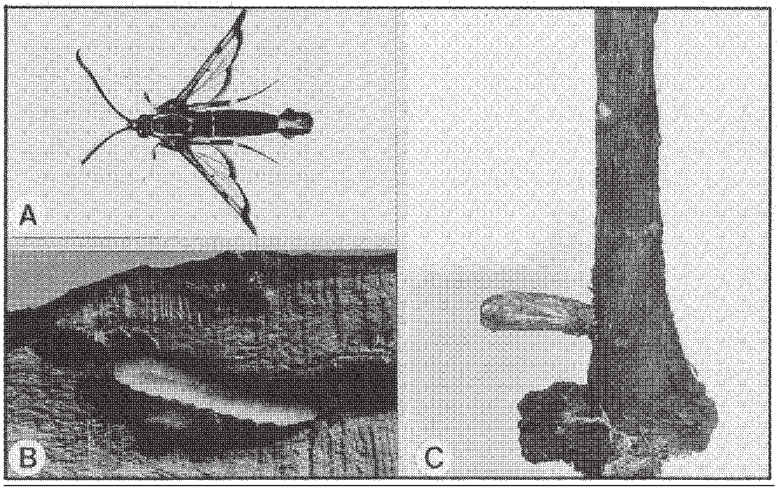


**Figure 36**—Synanthedon albicornis, *[western willow clearwing]: A, adult; B, larva; C, young willow with frass clump and protruding pupal skin.*

of granular frass extruded from the bark are good evidence of infestation. Masses of brown excrement pellets, frass, and numerous pupal skins protruding from larval burrows in bark suggest heavy infestation (figure 36C) (Engelhardt 1946). Moderate swelling occurs at infested sites on exposed roots, branches, and trunk.

**Control.** Direct controls have not been needed.

### *Synanthedon proxima* (Hy. Edwards)

[eastern willow clearwing]

**Hosts.** Willow. Small low-growing, shrub-type willows are the principal hosts (Tietz 1945, USDA FS 1985).

**Range.** Occurs in the Northeast, particularly from Maine to Pennsylvania, west to North Dakota, and in Canada from Ontario west to Alberta (Engelhardt 1946).

**Description.** ***Adult.*** Blue to bronzy black clearwing moth with lighter markings (Engelhardt 1946). Wings transparent with black veins and margins; forewing shaded with pale yellow beneath. Wingspan ranges from 16 to 24 mm. Head and thorax black with pale yellow collar; antennae white near tip, labial palpi white beneath, and thorax with pale yellow stripes. Anal tuft edged with white in male and black in female. **Larva.** White with brown head, but much lighter around the mouth and has black spots at base of antennae (Beutenmuller 1901). Cervical shield light brown with curved darker lines.

**Biology.** Adults emerge from May to August and deposit their eggs on the bark (Engelhardt 1946). Larvae bore into bark, making large burrows. Young larvae frequently invade the edges of burrows made by *Cryptorhynchus lapathi* (Linnaeus) and galls of *Saperda concolor* LeConte (Beutenmuller 1901, Tietz 1945). Larvae overwinter and then pupate in cocoons within burrows during spring and summer. There is one generation per year.

**Injury and damage.** Larvae bore into the bark and wood of host shrubs, causing breakage of many smaller stems. Sap spots and frass issuing from openings on stems of host plants are signs of infestation. Exposed roots, canes, and branches of low-growing willows on moist or swampy sites are most apt to be attacked (Engelhardt 1946). Because this species occurs mostly in wild shrub willows, the damage is of little economic consequence.

**Control.** Protecting the bark of host trees from other borers and from mechanical injuries helps to prevent attacks. Direct controls have not been needed.

### *Synanthedon bolteri* (Hy. Edwards)

[northern willow clearwing]

**Hosts.** Willows. Low-growing, shrub-type willows are favored (Engelhardt 1946, Tietz 1945).

**Range.** New York west to Washington and north through the Canadian Provinces, Yukon Territory, and Alaska (Engelhardt 1946).

**Description.** ***Adult.*** Clearwing moth with black, white, and yellow markings (Beutenmuller 1901, Engelhardt 1946). Wings transparent with black veins, sparsely intermixed with orange or coppery red

scales. Wingspans vary from 15 to 21 mm (Forbes 1923). Head black with white markings; antennae black, tipped with yellowish white; labial palpi lightly scaled beneath with orange. Abdomen coppery black; segments 4 and 5 encircled with deep orange or scarlet.

**Biology.** Moths emerge from May to August and deposit their eggs on the bark of host shrubs (Engelhardt 1946). Larvae bore into the bark, making galleries in both the bark and wood; they prefer wounds and injuries to gain entrance. The low-growing willows are most apt to be infested, but attack sites can occur well above the ground. Larvae overwinter in burrows and pupate in spring in oblong cocoons within burrows. The life cycle is apparently completed in 1 year, but 2 years may be required in its northernmost range.

**Injury and damage.** Larvae burrow into the stems of host shrubs and sometimes occur in large numbers. Heavily infested stems may be weakened and broken. Frass extruding from bark wounds and brown pupal skins protruding from the bark are good evidence of infestation. Attacks are associated mostly with attack sites of other borers, including *Cryptorhynchus lapathi*, *Saperda concolor*, and *Paranthrene tabaniformis* (Rottemburg). The host plants have little economic value.

**Control.** Controlling other more important borer species will also help to prevent attacks by this borer.

### *Synanthedon viburni* Engelhardt

[viburnum clearwing borer] (figure 37)

**Hosts.** Viburnum. Arrowwood and other unspecified viburnum species are the only known hosts (Engelhardt 1946, USDA FS 1985).

**Range.** Recorded generally from Nova Scotia, Ontario, and New York south to Virginia and west to Illinois and Wisconsin (Adler 1983, Engelhardt 1946, MacKay 1968). However, two specimens were recently collected at Fort Collins, Colorado (Eichlin and Duckworth 1988).

**Description.** ***Adult.*** Small, bluish black clearwing moth (figure 37A) closely resembling the lesser peachtree borer (Engelhardt 1946). Wings hyaline with black veins and lightly shaded with pale yellow beneath. Wingspan from 16 to 22 mm. Head black with pale yellow collar. Antennae black in both sexes, but banded with pale yellowish white near tip in female. Thorax blue black with pale yellow markings; abdomen steel blue except segment 2 narrowly banded with white above, and segment 4 broadly marked with white on sides. Anal tuft black and edged with white; wedge shaped in male, and straight and narrow in female. Legs steel blue marked with white. ***Larva.*** Varies from pinkish white to dark pink with reddish brown head and about 15 mm long (figure 37B) (MacKay 1968).

**Biology.** Moths emerge and fly from May to early August (Engelhardt 1946, Greenfield and Karandinos 1979b, Karandinos and others 1977). Females deposit eggs on the bark of hosts, and the larvae bore

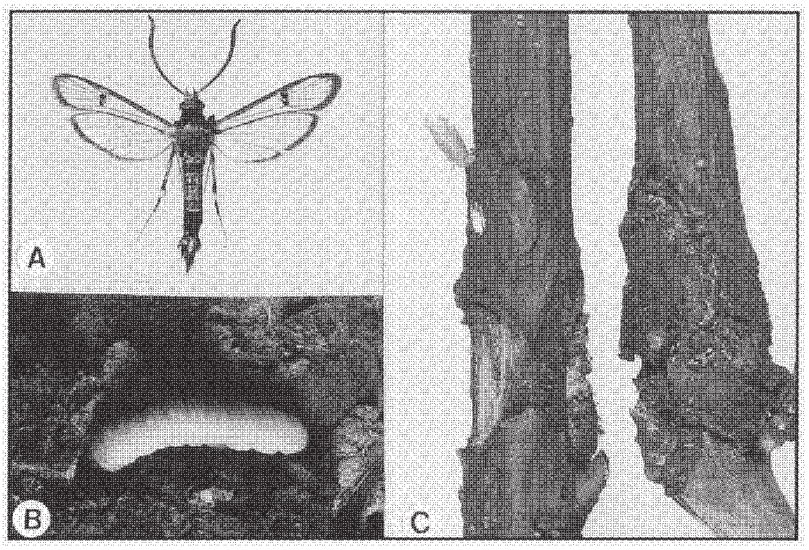


**Figure 37**—Synanthedon viburni, *[viburnum clearwing borer]: A, adult; B, larva; C, gnarled scarred stems with pupal skin protruding from bark (A & C, courtesy R. Hodges).*

into the bark, preferring to enter at injured or galled sites. Larvae overwinter in burrows, and pupation occurs the following spring in oblong cocoons constructed within the burrows. There is one generation per year.

**Injury and damage.** Larvae tunnel in the bark and cambium but do not enter the wood. Attacks are most often found with gall growths, abrasions, and other wounds that have caused distortions and swellings on main stems and branches (figure 37C) (Engelhardt 1946). Empty pupal skins may be found protruding from the bark during summer. Although found commonly in a few places, infestations are very widely scattered. Overall damage has been light.

**Control.** This borer is heavily parasitized by hymenopterous parasites, making it difficult to rear-out the adults (Engelhardt 1946). Good plant maintenance (including prevention of bark injuries) helps to minimize injury.

### *Synanthedon fatifera* Hodges
[lesser viburnum clearwing]

**Hosts.** Viburnum. American cranberrybush and other viburnum species are the only known hosts (Hodges 1962, MacKay 1968).

**Range.** A little-known species recorded from southern Ontario and Ohio, New York, Maryland, Wisconsin, Florida, and Idaho (Adler 1983, Eichlin and Duckworth 1988, Hodges 1962, Nielsen and others 1975, Sharp and others 1978).

**Description.** ***Adult.*** Bluish black and yellow clearwing moth. Wings transparent with blue-black veins dusted with yellow scales and dark fuscous fringes (Hodges 1962). Wingspan of 17 to 19 mm in males and 20 to 22 mm in females. Antennae blue black with few pale yellow scales, slightly depressed apically, and short apical tuft. Head blue black with pale yellow scales on face and below eyes. Thorax and legs bluish black with yellowish markings. Abdomen blue black with small lateral patch of yellow scales on segments 1 and 4, and anal tuft edged with pale yellow.

**Biology**. Adults emerge from April to early August (Neal and Eichlin 1983, Sharp and others 1978). Females deposit eggs on the bark, and larvae burrow in the bark and cambium, where they feed and develop. Male moths have been attracted to traps baited with synthetic sex attractant (Adler 1983, Karandinos and others 1977, Neal and Eichlin 1983, Sharp and others 1978).

**Injury and damage.** Tunnels in the stems of host plants, but it is of little importance because populations are widely scattered and sparse. Bark openings and distortions with mines and frass underneath are evidence of infestation.

**Control.** Direct controls have not been needed.

### *Synanthedon mellinipennis* (Boisduval)
[ceanothus clearwing borer]

**Hosts.** Ceanothus. Blueblossom appears to be the favored host, but other ceanothus species are also attacked (Engelhardt 1946, Williams 1909). Adults have been collected from the flowers of *Artemisiae* spp. and

*Senecioides* spp. (Englehardt 1946).

**Range.** A western species occurring primarily in the mountains of California north to British Columbia (Duckworth and Eichlin 1973). Scattered, isolated collections reported east to Nevada and Colorado (Beutenmuller 1901, Duckworth and Eichlin 1973).

**Description.** ***Adult.*** Yellow-black clearwing moth closely resembling yellowjacket. Wings mostly transparent with black margins; orange powdering between veins, and orange-red discal spot. Wingspans from 22 to 27 mm; female slightly larger than male (Beutenmuller 1901, Duckworth and Eichlin 1973, Engelhardt 1946). Head brown black fringed in yellow with black and yellow antennae and yellow labial palpi. Thorax blue black with yellow stripe on each side and yellow beneath. Abdomen broadly banded with yellow on segments 2, 4, 6, and 7 in male and segments 2, 4, 5, and 6 in female. Anal tuft black with yellow center. Legs mostly yellow with black markings.

**Biology.** Adults emerge from mid-June through August (Duckworth and Eichlin 1973). Females deposit eggs on the bark of host trees. Newly hatched larvae bore into the bark and cambium and later into the xylem. Larvae occasionally occur in very large numbers locally and may kill much of the cambium. Larvae pupate in cocoons constructed of silk and particles of wood under the bark (Williams 1909).

**Injury and damage.** Rough, borer-scarred bark of host trees is evidence of infestation. The trunk is sometimes riddled with borer tunnels over extensive areas. Galleries extend into the cambium and sometimes into solid wood (Williams 1909). Larvae may be found in some mines and galleries. Current and old silken cocoons may be found in cavities under the bark. Infestations are widely scattered and have occurred mostly in large decumbent trunks of old decadent shrubs (Engelhardt 1946). Overall damage is light.

**Control.** Maintaining high vigor in trees minimizes the extent of infestations. Damaging populations can be controlled by fumigating the burrows.

### *Synanthedon culiciformis* (Linnaeus)

[large redbelted clearwing]

**Hosts.** Alder, birch. Alder is the preferred host in North America (Duckworth and Eichlin 1978); white birch is favored in Europe (Beutenmuller 1901). Adult moths have been taken at flowers (Duckworth and Eichlin 1978).

**Range.** From Alaska south to California and Nevada and east to Montana and Colorado (Doane and others 1936, Engelhardt 1946). Ranges in Europe to Lapland, Finland, and along the northern borders into Siberia; thus, considered a circumpolar species (Engelhardt 1946).

**Description.** ***Adult.*** Black and orange clearwing moth. Wings mostly hyaline except for dark scales on margins, veins, and discal spot (Duckworth and Eichlin 1978, Thompson 1927). Forewings lightly powdered with orange near base. Wingspan of 21 to 28 mm. Head and antennae brownish black with white laterally and orange-red scales ventrally on labial palpi. Thorax

brown black with orange markings beneath wings. Abdomen black with slight blue-green iridescence. Segment 4 orange red dorsally and ventrally. Segment 2 often narrowly edged with orange red. Anal tuft wedge shaped and blue black in male; narrow and blunt in female. ***Larva.*** Generally light colored with dark brown head and light brown thoracic shield; 17 to 22 mm long.

**Biology.** Moths emerge as early as April in California and as late as August in Washington (Eichlin and Duckworth 1988). Females deposit eggs on the bark of host trees, preferring to oviposit on trees with bark injuries. Young larvae begin boring into the bark and cambium and later into the wood. Attacks usually are concentrated around bruised places, cuts, and other bark injuries. Tunnels are usually shallow and meandering. Larvae overwinter in galleries and pupate in early spring; adults emerge during spring and summer.

**Injury and damage.** Wet spots on the bark and frass in bark crevices provide evidence of active attack. Attacks occur on the trunk and larger limbs. Initially, burrows are found only in the bark and cambium, but later galleries penetrate the wood (Essig 1958, Thompson 1927). The outer bark of heavily damaged trees may appear roughened or blistered. Gallery openings in the bark up to 7.2 mm in diameter distinguish the species from *S. resplendens* (Hy. Edwards), which makes openings in the bark of only about 1.2 mm in diameter (Kaya 1984). Pupal skins protruding from openings in the bark are sure signs of infestation. Open-grown trees in parks, recreation areas, and urban settings suffer most from this borer (Engelhardt 1946).

**Control.** Good tree maintenance, especially prevention of bark injuries, helps to minimize infestations. The only insect parasite reported is *Macrocentrus marginator* (Nees) (Marsh 1979). Entomogenous nematodes—*Neoaplectana bibionis* Bovien and *N. carpocapsae* Weiser—have yielded 77 to 93% control of larvae when applied during fall (Kaya 1984, Kaya and Brown 1986). Chemical sprays properly timed can control infestations.

### *Synanthedon castaneae* (Busck)

[chestnut clearwing borer]

**Hosts.** Chestnut. American chestnut is the only recorded host, but chinkapin and other *Castanea* species are undoubtedly attacked (Engelhardt 1946, Snow and Eichlin 1986).

**Range.** The range corresponds closely with that of its host, American chestnut: Ontario and Maine southward to Florida and west to the Mississippi River (Engelhardt 1946, Snow and Eichlin 1986).

**Description.** ***Adult.*** Bluish black clearwing moth with yellow markings, and sometimes confused with *S. pictipes* (Grote and Robinson) (Engelhardt 1946). Wings clear with veins in forewings marked with black scales. Wingspans range from 17 to 20 mm for males and 12 to 28 mm for females. Antennae black; labial palpi yellow; two lateral stripes on thorax; abdominal segments 2 and 4 narrowly banded with yellow, with banding more pronounced in female.

Anal tuft wedge shaped in male and straight and narrow in female. ***Larva.*** White with brown head and light brown thoracic shield and spiracles, and reaches about 22 mm long (MacKay 1968).

**Biology.** Adults emerge April to July (Eichlin and Duckworth 1988, Engelhardt 1946, MacKay 1968). Females deposit eggs on the bark. Young larvae usually enter at wounds and produce burrows in the inner bark and cambium. Larvae overwinter in their mines and pupate in rough, oblong cocoons made of wood chips and silk under the bark the next spring. There is one generation per year (Engelhardt 1946).

**Injury and damage.** Larvae bore into the trunks of host trees, preferring bruised or diseased areas (USDA FS 1985). Frass and sap ooze may be present at infestation sites. Lifting the bark reveals burrows and larvae adjacent to the bruised or affected areas. In the early 1900's, before the demise of American chestnut, this borer was fairly common in the Atlantic Coast region and damaged many fine trees (Engelhardt 1946, MacKay 1968). Moreover, it has been implicated as a dispersal agent for the chestnut blight fungus that caused the demise of American chestnut (Snow and Eichlin 1986).

**Control.** Good tree maintenance that protects the bark from injuries and disease cankers helps to prevent infestation. Chemical control may be justified to protect research plantings and other high-value trees.

### *Synanthedon tipuliformis* (Clerck)

currant borer (figure 38)

**Hosts.** Currant, gooseberry, blackberry. Currants and gooseberries are the major hosts (Duckworth and Eichlin 1978). Blackberry and other *Rubus* species are minor hosts. In Australia and other countries, sumac, grape, persimmon, and some ornamentals have been mentioned as occasional hosts (Bedding and Miller 1981, Metcalf and others 1962).

**Range.** Native to Europe; introduced into the United States before 1826 (Harris 1851, Slingerland and Crosby 1919). Found throughout the world wherever its hosts grow, including North America, Europe, Asia, Australia, and New Zealand (Bedding and Miller 1981, Duckworth and Eichlin 1978).

**Description.** ***Adult.*** Black and yellow clearwing moth. Wings transparent with margins and veins yellow, black, and purplish blue; wingspan 16 to 23 mm. Head, antennae, and palpi black to brown black with yellow-white markings, and thorax black with two longitudinal yellow stripes (figure 38A) (Duckworth and Eichlin 1978, Harris 1851, Metcalf and others 1962, Thompson 1927). Abdomen purplish black with yellow bands on segments 2, 4, 6, and 7 in male; three yellow bands on segments 2, 4, and 7 in female. Anal tuft bluish black. ***Egg.*** Brown, almost oval or globular (figure 38B) (Gillette 1892). ***Larva.*** Yellowish to white with darker line along back, brown head and legs and reaches 12 to 19 mm long (figure 38C) (Metcalf and others 1962). ***Pupa.*** Light brown, oblong, and

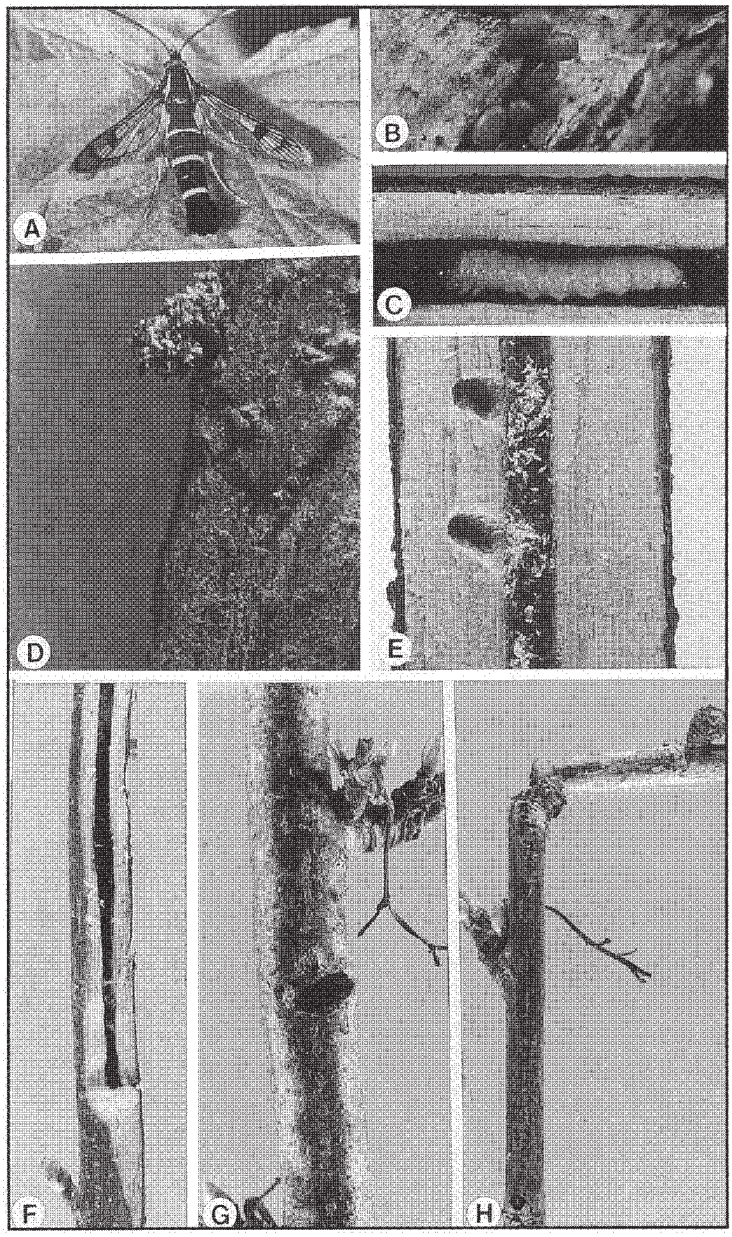


**Figure 38**—Synanthedon tipuliformis, *currant borer: A, adult; B, eggs; C, larva; D, frass clump on bark; E, larval burrows in wood; F, larval burrow in pith; G, entrance hole in cane; H, cane broken at entrance site (A-C, F-H, courtesy R. Bedding; D, courtesy A. Antonelli; E, courtesy R. Scott).*

abdomen with short spines and transverse rings of sharp teeth dorsally (Harris 1851).

**Biology.** Adults emerge mostly in June and July but may be present as early as late April (Duckworth and Eichlin 1978, Metcalf and others 1962). Females lay 20 to 60 eggs singly on bark near buds (Gillette 1892, Harris 1851). Larvae bore into the canes and feed on the pith and wood. They bore up and down the stem for several centimeters and enlarge burrows and entrance holes. Larvae overwinter in the canes a short distance above ground. In spring, larvae feed briefly, then bore exit holes through the stems. They cover the exit holes with silk webbing or leave the thin outer bark intact (Harris 1851). Some larvae use the entrances for exits instead of making new holes. Pupation occurs either in silken cocoons or silk-lined cavities close to the exits and lasts 2 to 3 weeks (Harris 1851, Metcalf and others 1962, Slingerland and Crosby 1919). New adults emerge, leaving empty pupal skins projecting from the cavities. This species has one generation per year (Slingerland and Crosby 1919).

**Injury and damage.** Infestations are most easily detected during spring. Clumps of frass may be present on the canes (figure 38D). Leaves of infested plants become yellowish and undersized and often die. Galleries in the pith and partly in wood (figure 38E) are several centimeters long and sometimes run nearly the length of the canes (figure 38F) (Metcalf and others 1962). One or more round or irregular exit holes are present along canes (figure 38G). Infested plants are usually weakened and stunted, and branches are often bent, crooked, or broken (figure 38H) (Harris 1851). Extensive tunneling in the stems results in considerable reduction in fruit yield and death of plants (Bedding and Miller 1981, Metcalf and others 1962). Yield losses of 56 to 90% have been reported (Bedding and Miller 1981).

**Control**. Six species of insect parasites—*Bracon sanninoideae* (Gahan), *Macrocentrus marginator* (Nees) (Marsh 1979), *Coccygomimus tenuicornis* (Cresson), *Dolichomitus irritator* (Fabricius), *Lissonota scutellaris* (Cresson), and *Phaeogenes ater* Cresson (Carlson 1979)—have been recorded but do not prevent economic losses. Water suspensions of entomogenous nematodes *Neoaplectana bibionis* Bovien and *N. carpocapsae* Weiser sprayed onto infested plantings have given 32 to 99% control of borers in experimental trials (Bedding and Miller 1981). Removing infested canes is the best control; they should be cut close to the ground and burned during fall, winter, or spring (Metcalf and others 1962, Slingerland and Crosby 1919, Thompson 1927). Chemical control with insecticides has given about 80% reduction in populations.

### *Pennisetia marginata* (Harris)

raspberry crown borer (figure 39)

**Hosts.** Raspberry, blackberry. The hosts are limited to the genus *Rubus*. Raspberries and blackberries are the principal hosts (Breakey 1963), but several other species have been mentioned (Raine 1962).

**Range.** Reported extensively throughout

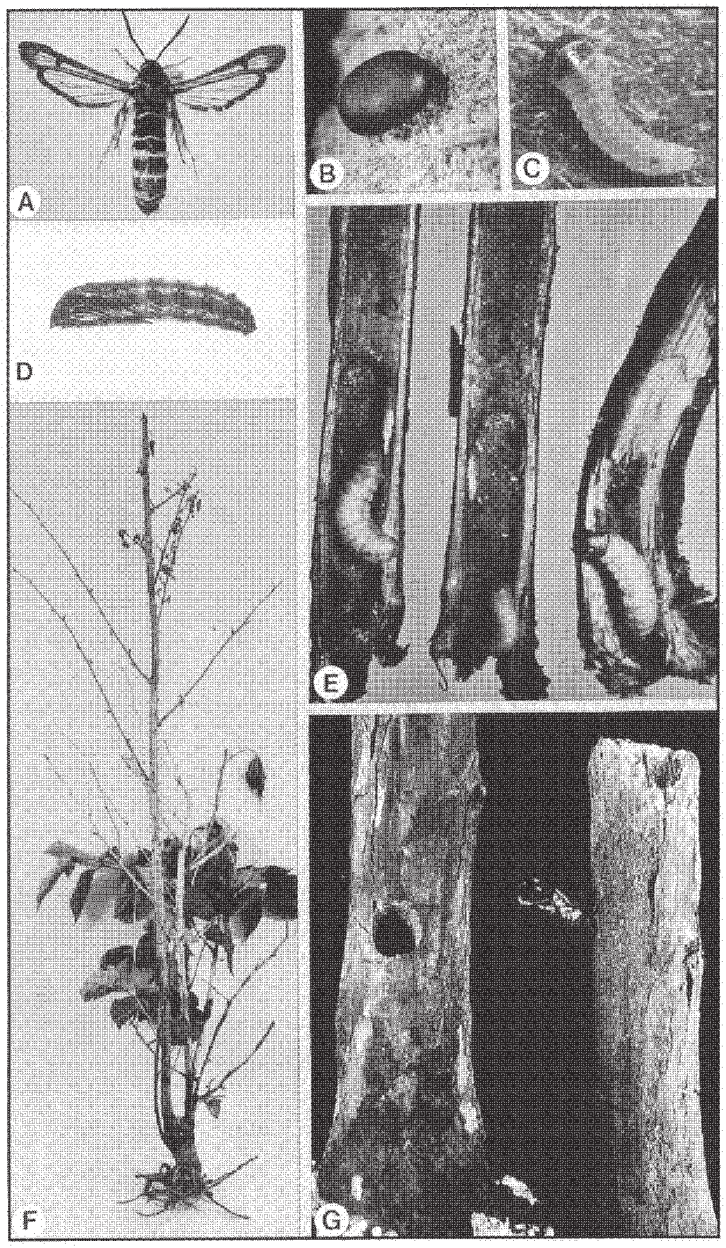


**Figure 39**—Pennisetia marginata, *raspberry crown borer: A, adult; B, egg; C, larva; D, pupa; E, tunneled canes; F, cane dieback with new shoots; G, exit hole and pupal skin protruding (A, specimen courtesy R. Hodges; B, C, courtesy R. Williams; D, E, G, courtesy A. Antonelli and E. Breakey).*

the northern United States and Canada, and less commonly through the South west to California (Duckworth and Eichlin 1978, Raine 1962, Slingerland and Crosby 1919).

**Description.** ***Adult.*** Black and yellow clearwing moth similar to yellowjacket, except darker with much less yellow, and body covered with scales (figure 39A) (Breakey 1963, Raine 1962). Wings clear with russet shade and brown margins (Breakey 1963, Slingerland and Crosby 1919). Wingspan 18 to 25 mm in males and 25 to 37 mm in females. Head black with yellow ring around each eye. Thorax brownish black with three yellow spots on each side. Each segment of abdomen, except last, encircled by black and yellow bands. ***Egg.*** Oval, reddish brown, smooth, and about 1.5 mm long (figure 39B) (Breakey 1963, Raine 1962). ***Larva.*** Nearly white with dark brown head; however, feeding larva has greenish or pinkish cast (figure 39C) (Breakey 1963, Raine 1962). When mature, reaches 29 to 38 mm in length. ***Pupa.*** Reddish brown, becoming darker, and has two bands of spines on each abdominal segment (figure 39D).

**Biology.** Moths emerge from July to October and are present until early November (Breakey 1963, Duckworth and Eichlin 1978). Females usually deposit eggs singly on the underside of leaves. Young larvae crawl down the canes or may drop from silk threads. They form overwintering hibernacula of silk and frass in root crowns. Hibernacula are usually 25 to 76 mm below ground, but a few may be found above ground (Breakey 1963, Headlee and Ilg 1926). In spring, larvae leave the hibernacula and enter the root crowns of canes (Slingerland and Crosby 1919). Larvae burrow just beneath the bark and around shoots, often completely girdling canes (Breakey 1963, Slingerland and Crosby 1919). Older larvae tunnel into woody parts to the center of the canes. Larvae feed from late March to the end of October and spend a second winter in their burrows. In spring, they burrow upward and prepare pupal chambers, usually in the canes, but sometimes in crowns. Before pupating, they cut exit holes nearly to the bark surface, leaving only the thin epidermis intact over the openings. Pupation occurs from July to mid-September, and the pupal stage lasts 25 to 30 days (Headlee and Ilg 1926, Slingerland and Crosby 1919). Two years are required for development (Wylie 1970).

**Injury and damage.** Larvae cause injury by burrowing in the root crowns and lower parts of canes (figure 39E). Boring weakens the canes, reducing crop yields (Breakey 1963, Headlee and Ilg 1926). Damaged canes seldom are as strong and large as uninjured ones. Injured canes often break. Larvae sometimes girdle canes, causing them to wilt and die. New shoots arise from the rootstock (figure 39F). But in many cases, callus develops to form large gall-like swellings near the base. Heavy infestation reduces the summer crop and may eliminate the late summer and early fall crops (Headlee and Ilg 1926). Round exit holes in the canes and pupal skins protruding from bark provide good evidence of infestation (figure 39G).

**Control.** Larvae are sometimes killed by

fungi (Breakey 1963), and two species of hymenopterous parasites—*Barichneumon* sp. (Carlson 1979, Raine 1962) and *Bracon bembeciae* (Walley) (Marsh 1979)—have been recorded. Cultural control through destruction of infested canes effectively reduces infestation (Smith 1891). Insecticides can control infestations (Breakey 1963, Wylie 1970).

### *Vitacea polistiformis* (Harris)

grape root borer (figure 40)

**Hosts.** Grape. Both cultivated and wild varieties of grape are hosts, but cultivated varieties are preferred (Brooks 1907, Slingerland and Crosby 1919).

**Range.** Throughout the eastern United States north into southeastern Canada and west to Minnesota and Arkansas (Brooks 1907, Slingerland and Crosby 1919). Economic importance is greatest in the South, where it has been a serious pest in commercial vineyards for over 100 years (Dutcher and All 1979).

**Description.** ***Adult.*** Dark brown clearwing moth. Forewings opaque and brown black; hindwings transparent with dark brown veins and margins. Wingspans range from 26 to 42 mm, with those of females markedly larger than males (figure 40A) (Brooks 1907). Head and antennae brownish, face whitish; black collar fringed with yellow orange. Thorax brown black with yellow-orange markings on sides. Abdomen blackish brown with segments 2 and 4 narrowly banded with pale yellow. Anal tuft short, black brown with four orange-brown pencils. ***Egg.*** Chocolate brown, oval, slightly flattened at sides, with one face evenly convex and other marked with deep longitudinal furrow or groove (figure 40B) (Bambara and Neunzig 1977, Brooks 1907). Surface finely and densely punctured and marked with network of delicate lines. About 1.0 by 0.7 mm. ***Larva.*** White, with brown head and pale brown thoracic shield, short thoracic legs, and very small prolegs (figure 40C). Mature larvae 25 to 35 mm long. ***Pupa.*** Pale to dark brown with yellowish bands encircling abdomen (figure 40D).

**Biology.** Moths emerge from May in the South to October in the North (Eichlin and Duckworth 1988, Snow and others 1989). Adults live 10 to 14 days, and females deposit an average of 354 eggs (a range of 122 to 797) over 8 days (Dutcher and All 1979, Slingerland and Crosby 1919). Eggs are deposited singly on leaves or stems of grapevines and other low-growing plants under or near vines. Eggs hatch in 13 to 23 days. Newly hatched larvae work their way into the soil and bore through the outer bark of the crown or roots, whichever is encountered first (Brooks 1907). Young larvae excavate irregular furrows in bark, sometimes encircling the root. Later, larvae produce large gougelike wounds in the periderm, mostly of large roots. Galleries may be irregular, long, straight and narrow, or spiral. Most larvae are found in roots at depths of 5 to 20 cm, but some may be as deep as 80 cm (All and Dutcher 1977). Larvae overwinter in their root burrows. When mature, most larvae move to pupation sites within 5 cm of the soil surface

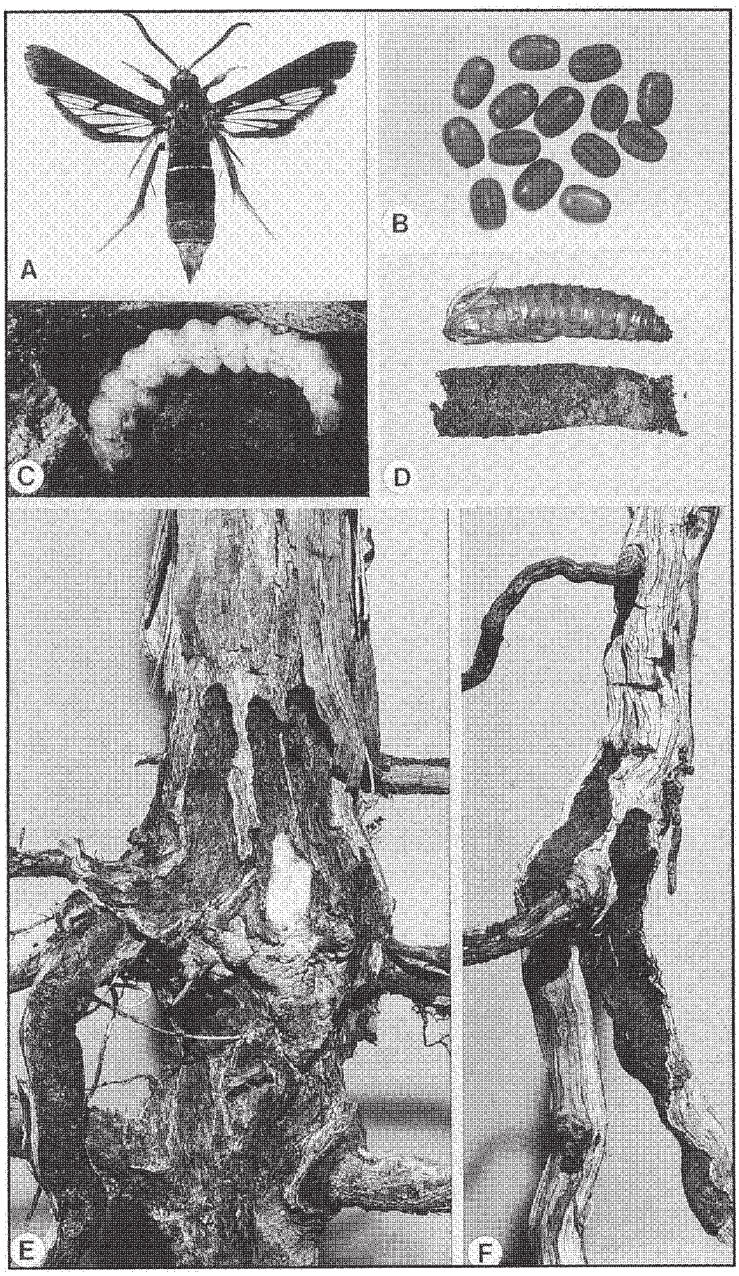


**Figure 40**—Vitacea polistiformis, *grape root borer: A, adult; B, eggs; C, larva; D, pupal skin and earthen cocoon; E, multiple galleries at root collar; F, burrows extending along main roots (B-D, courtesy D. Pollet).*

where they spin cocoons of silk, soil, frass, and other debris. A few larvae pupate in root galleries. The pupal stage lasts 29 to 44 days. Just before emergence, the pupae work their way upward out of the cocoons, so that they protrude through the soil surface. Here, the adults emerge and crawl onto grapevines or other plants. The life cycle usually requires 2 years (Brooks 1907, Dutcher and All 1979), but sometimes only 1 year (Pollet 1975).

**Injury and damage.** Because the larvae are underground in the roots and the adults often not seen, an infestation may be present without the vineyardist knowing it (Attwood and Wiley 1963). Serious damage may occur before infestations are detected (Dutcher and All 1979). Wilting and dying vines may indicate injury (Clark and Enns 1964). Although vines may survive attack for several years, they are often so weakened that annual growth is meager and yield of fruit is small (Brooks 1907). Larvae bore in the crown and roots and may girdle the trunk (figure 40E). Roots smaller than about 15 mm in diameter may be destroyed (Dutcher and All 1979). On larger roots, larvae may tunnel to the center, but usually they tunnel along the underside of the root (figure 40F). When infested vines are pulled, they often break where larvae have partly or completely severed the roots. Brown pupal skins can often be found protruding from the soil near the base of grapevines. One larva feeding in the trunk base generally reduces the yield of fruit 47%. Entire vineyards have become so heavily infested that they have been abandoned (Attwood and Wylie 1963) or uprooted and destroyed, then replanted.

**Control.** Birds, including the crested flycatcher, mockingbird, and barn swallow, are important predators in some localities (Brooks 1907, Clark and Enns 1964). Two fungi—*Beauveria bassiana* (Balsamo) Vuillemin and *Metarrhizium anisopliae* (Metchniknoff) Sorokin—are occasionally found infecting larvae (Clark and Enns 1964). A nematode, *Neoaplectana* sp., and a wasp, *Bracon caulicola* (Gahan), parasitize the larvae, but incidence is low (Pollet 1975). Cultural controls including cultivation at pupation or mounding of soil over the pupae just before emergence have shown promise (Brooks 1907, Dutcher and All 1979). A strip of black polyethylene 60 to 120 cm wide under a row of vines as a mechanical barrier has given 90 to 100% control in experimental trials (Attwood and Wylie 1963). Insecticides give incomplete and erratic results but show some promise (Dutcher and All 1979). Use of the synthetic sex pheromone to disrupt communication is promising for control.

### *Vitacea scepsiformis* (Hy. Edwards)

[Virginia creeper clearwing] (figure 41)

**Hosts.** Virginia creeper, Boston ivy. Virginia creeper and Boston ivy are the only known hosts, but other species in the genus *Parthenocissus* probably are attacked (Engelhardt 1946, MacKay 1968).

**Range.** From New York south to Florida and west to Texas, Arkansas, and Missouri (Engelhardt 1946, MacKay 1968).

**Description.** ***Adult.*** Blackish brown

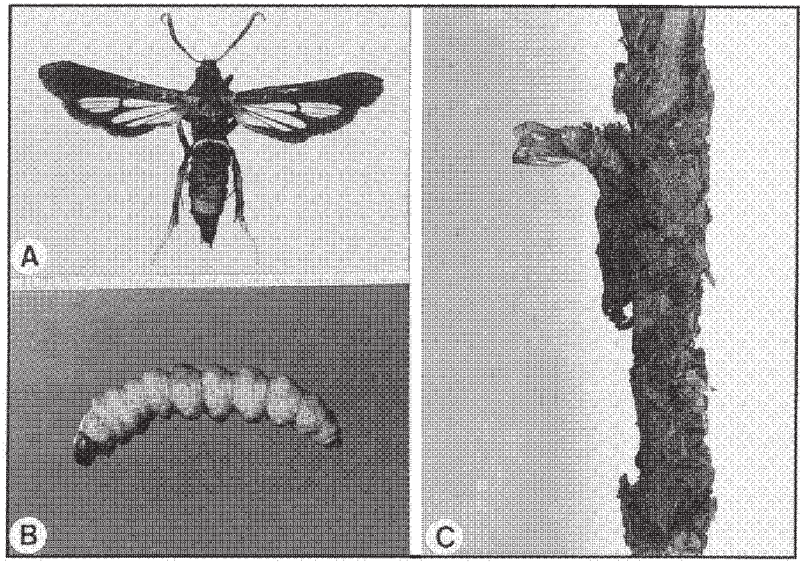


**Figure 41**—Vitacea scepsiformis, *[Virginia creeper clearwing]: A, adult; B, larva; C, damaged stem with pupal skin protruding from bark (specimens, courtesy R. Hodges).*

clearwing moth. Closely resembles the *Polistes* wasps (figure 41A). Forewings opaque and purplish black; hindwings transparent (less so in specimens from Florida) with brownish black veins and margins. Wingspans from 20 to 36 mm (Beutenmuller 1901, Engelhardt 1946, Forbes 1923). Head purplish brown and fringed with chestnut red; antennae broadly bipectinate, and black with orange tips; labial palpi red and black. Thorax purplish brown marked with yellow on sides. Abdomen shiny black to reddish black with segment 2 partially banded with yellow. Anal tuft rusty black with four pencils. Legs marked with red, brown, black, and yellow. ***Larva.*** White with brown head and pale brown prothoracic shield and indistinguishable from larva of grape root borer (figure 41B) (MacKay 1968).

**Biology.** Moths emerge from June to October (Engelhardt 1946). Larvae feed under bark on soft succulent tissue, rather than on hard central core. Mature larvae pupate in June and July in elongated cocoons constructed from debris, frass, silken threads, and soil. Pupation occurs most often under bark at the upper end of galleries but sometimes in adjoining soil. Moths emerge 3 to 4 weeks later. The life cycle requires 2 years.

**Injury and damage.** Infestations are difficult to detect, but weakened plants should be examined for borer attacks (Engelhardt 1946). Galleries and larvae in the root collar and roots provide evidence of infestations. Attack sites are most apt to be in the upper main and shallow branching horizontal roots near the soil surface. Brown pupal skins protruding from galleries provide positive evidence of infestation (figure 41C). Weakened plants may need to be removed and others replanted in landscape plantings. Populations are apparently scarce and widely scattered, so that overall damage has been negligible.

**Control.** Nothing is known of natural controls, and direct controls have not been needed.

### *Carmenta phoradendri* (Engelhardt)

[mistletoe borer] (figure 42)

**Hosts.** Mistletoe. Found only in mistletoe growing on mesquite (Engelhardt 1946). Moths have been collected from the flowers of *Baccharis* spp.

**Range.** Known only from Bexar and Victoria Counties in Texas, southeastern Arizona, and Mexico (Eichlin and Duckworth 1988, Engelhardt 1946).

**Description.** ***Adult.*** Small, black and yellow clearwing moth resembling dogwood and apple bark borers (figure 42A) (Engelhardt 1946). Wings transparent with margins and veins covered with black scales with dull yellow suffusions between veins; wingspans vary from 18 to 20 mm. Head, antennae, and labial palpi black with coppery blue reflections and pale yellow collar. Thorax black, but marked lightly with yellow. Abdomen black with segments 2 through 6 narrowly banded with yellow in male; segments 2, 4, and 6 banded in female.

**Biology.** Adults emerge in April, May, and June, and again in August and September, possibly signifying a double-brooded

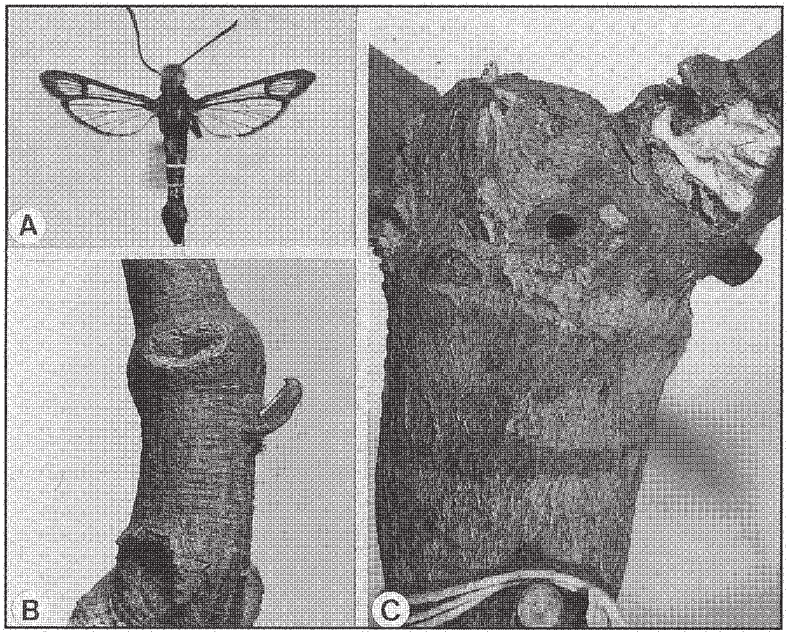


**Figure 42**—Carmenta phoradendri, *[mistletoe borer]: A, adult; B, pupal skin protruding from stem; C, feeding injury and exit hole (specimens courtesy R. Hodges).*

species (Engelhardt 1946). Larvae tunnel in the basal stems and larger branches of mistletoe, making either long galleries or irregular cavities. Larvae overwinter in galleries, and pupation occurs in smooth silk-lined cocoons firmly attached near burrow exits.

**Injury and damage.** Infestations are easily detected by the wilted, discolored appearance of the mistletoe (Engelhardt 1946). Burrows and tunneling larvae can be found in the larger, lower swellings on the basal stems of mistletoe. Brown pupal skins protrude from gallery exits for a short time after adult emergence (figure 42B). Round exit holes and feeding wounds become evident on infested plants (figure 42C). Because mistletoe is a parasite on many economically important hardwoods, this borer might be potentially useful as a biocontrol of mistletoe.

**Control.** Direct controls are not likely to be needed.

### *Carmenta prosopis* (Hy. Edwards)

[mesquite clearwing borer]

**Hosts.** Mesquite, mimosa. Honey mesquite and mimosa are the only hosts recorded, but other *Prosopis* species probably serve as hosts as well (Eichlin and Duckworth 1988, Engelhardt 1946).

**Range.** A southwestern species recorded from Arizona, New Mexico, and Texas south into Mexico (Beutenmuller 1901, Eichlin and Duckworth 1988, Engelhardt 1946).

**Description.** ***Adult.*** Small black clearwing moth with white markings (Beutenmuller 1901, Engelhardt 1946). Wings transparent with black veins and margins; hindwings fringed in white. Wingspans from 13 to 16 mm. Head, thorax, and abdomen black; second joint of labial palpi white; second and last segments of abdomen narrowly banded with white. Anal tuft fan shaped and black, edged with white.

**Biology.** This borer is only known to infest small woody galls caused by encyrtid gallmaking wasps on stems of host plants (Engelhardt 1946, Essig 1958).

**Injury and damage.** Holes and frass may be found on the surface of galls on the plant parts. Dissection will reveal the larvae burrowing in the gall. Borer injuries in these host plants are of little or no importance.

**Control.** Natural enemies have not been studied, and direct controls have not been needed.

### *Carmenta querci* (Hy. Edwards)

[western oakgall clearwing]

**Hosts.** Oak. Mexican blue oak and Arizona white oak have been recorded as specific hosts (Engelhardt 1946).

**Range.** Collected only from Arizona (Engelhardt 1946).

**Description.** ***Adult.*** Small, blue and yellow clearwing moth resembling *S. decipiens* (Beutenmuller 1901, Engelhardt 1946). Wings transparent with black veins and some shading of yellow; mostly yellow beneath; wingspans from 12 to 20 mm. Female markedly larger than male. Head black with white face, yellowish white collar, and short antennae covered with yellowish orange scales. Thorax steel blue, marked with pale yellow. Abdomen blackish blue

with yellow banding on segments 2, 3, and 4 in male and segments 2, 3, and 6 in female.

**Biology.** The larvae burrow and feed in spongy galls on host trees (Beutenmuller 1901, Engelhardt 1946). Adult moths reared from galls have emerged from March to mid-August.

**Injury and damage.** Frass and openings on the surface of galls indicate infestations. Dissection reveals burrows and larvae. Populations are sparse and of no economic importance.

**Control**. Nothing is known of natural enemies, and direct controls have not been needed.

## Family Cossidae—Goat Moths or Carpenterworm Moths

Adults are medium to large moths with heavy, spindle-shaped bodies (Barnes and McDunnough 1911, USDA FS 1985). In most species, the wings are mottled, moderately narrow, pointed, and strong. Males are usually smaller than females and are strong fliers; females are sometimes so heavy with eggs that they can fly only short distances. Some members are diurnal and others are nocturnal. Mouthparts are rudimentary; adults do not feed. Antennae are simple to bipectinate. The larvae are hairless except for scattered tubercles bearing setae; vary in color from reddish pink to white, to greenish white except for dark brown head and light brown thoracic shield; and have disagreeable odors. They excavate large galleries in the branches, trunks, and roots. Some species do great economic damage.

### Genus and Species

### *Prionoxystus robiniae* (Peck)

carpenterworm (figures 43 and 44)

**Hosts.** Oak, elm, willow, poplar, ash, boxelder, black locust, sugarberry, sycamore. First recorded as "riddling black locust" in Massachusetts (Peck 1818). Wide range of hosts, but certain species are preferred, depending on location and availability (Hay and Morris 1970). In the East and South, oaks are preferred (particularly those in red oak group); in southern bottomlands, overcup oak (white oak group). In the prairie region, chief hosts are green ash and elm; in the Rocky Mountains, poplars; and in California, coast live oak and introduced elms. Occasionally attacks fruit trees, ornamental shrubs, and other hosts.

**Range.** A native of North America, widely distributed throughout the United States and southern Canada (Solomon and Hay 1974).

**Description.** ***Adult.*** Large, grayish, stout-bodied moth (figure 43A), with uniform mottling of gray and black scales over body and wings. Moth protected by its coloration; at rest on bark of oak, its gray and black mottling harmonizes closely with bark color, making it almost invisible. Female twice size of male; average wingspread of females 75 mm. Posterior half of each of male's hindwings covered by yellowish orange spot. ***Egg.*** Dark olive brown, oval, 2.3 mm long by 1.5 mm wide (figure 43B). ***Larva.*** Newly hatched 6 mm long and reddish pink with dark head. As larva matures, gradually becomes greenish white. Mature larvae 50 to 75 mm long; shiny dark brown heads with powerful black mandibles (figure 43C). ***Pupa.*** Dark, shiny brown, 37 to 50 mm long, broad at head end, tapering to blunt point at hind end, with pair of toothed bands on dorsal surface of abdominal segments.

**Biology.** Moths emerge in late April to early July, varying by region from south to north. Females produce sex attractant that lures males from long distances. Mating occurs in the afternoon and ceases by nightfall. During the night, females deposit 200 to 1,000 eggs singly or in small groups in bark crevices and under vines and lichens. Eggs hatch in 10 to 13 days. Newly hatched larvae construct loose silken webs and bark coverings and either begin their boring or move elsewhere to make their entry. Young larvae feed initially in the phloem and cambium but soon initiate crooked galleries into the sapwood. As larvae approach maturity, they chew away the sides of the crooked galleries to facilitate exit of pupae. Larvae keep galleries open or only loosely plugged with frass. During spring of the last year of development, full-grown larvae partially line the tunnel with yellowish brown silken threads before pupating in the innermost part of the galleries. Three to six weeks later, pupae wriggle to the exits where the moths emerge. Empty pupal cases remain in place unless dislodged. Many female moths are so heavily laden with eggs that they cannot fly until they have deposited many of their eggs on the same tree from which they emerged. The life cycle is 1 to 2 years in the South and 2 to 4 years in the North.

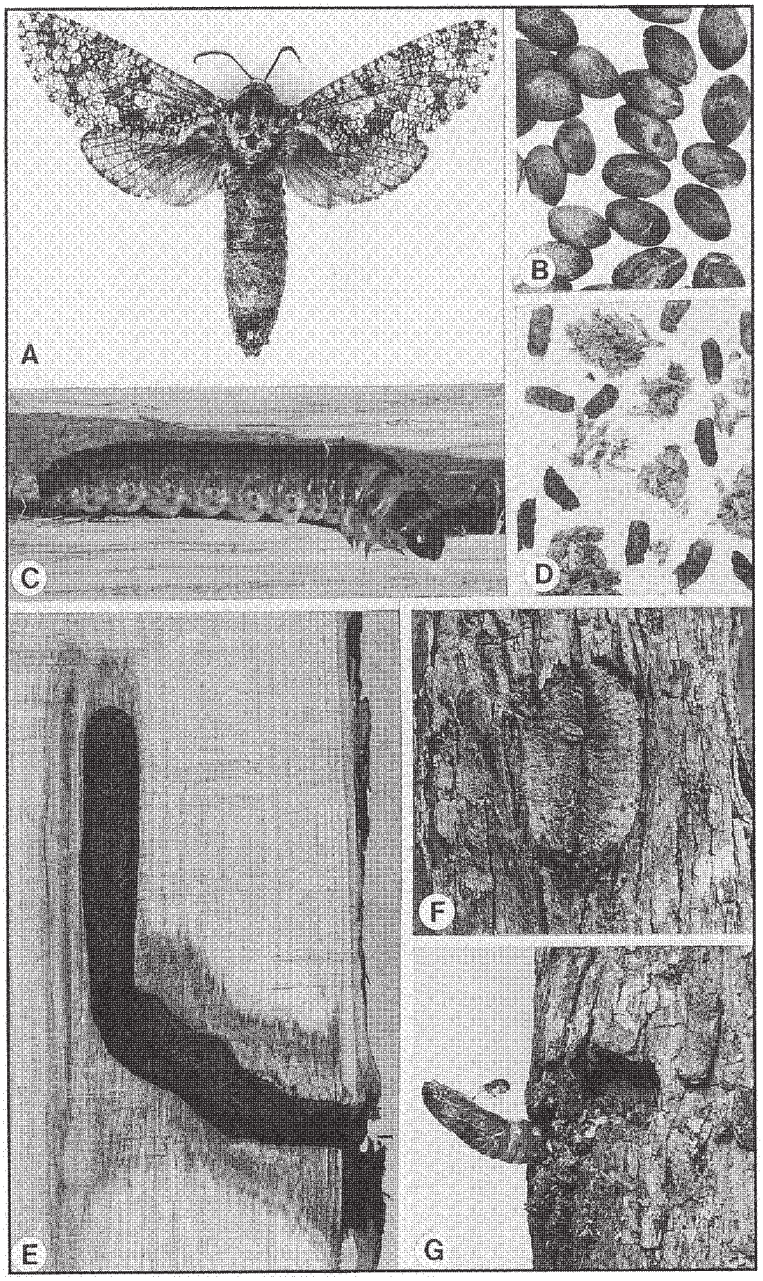


**Figure 43**—Prionoxystus robiniae, *carpenterworm: A, adult female; B, eggs; C, larva in gallery; D, frass of wood chips and excrement pellets; E, typical gallery; F, oval bark scar; G, pupal case protruding from exit hole.*

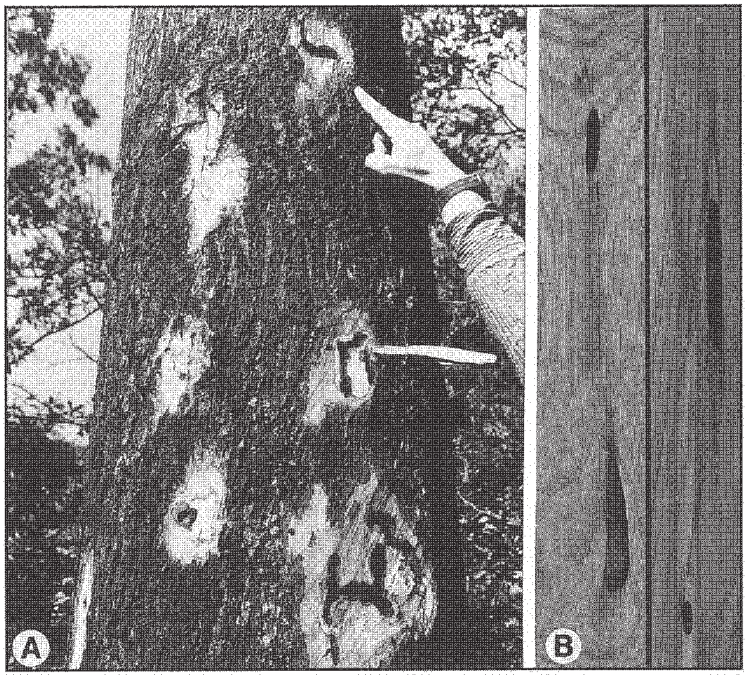


**Figure 44**—*Damage caused by* Prionoxystus robiniae, *carpenterworm: A, numerous attacks on bole of large red oak; B, wormhole defects in oak lumber.*

**Injury and damage.** Earliest signs of attack are sap spots with fine frass mixed with sap ooze. Later, stained bark spots become larger, and frass (wood chips and excrement pellets) is ejected from entrance holes (figure 43D). Frass often becomes profuse at the entrances, in bark crevices, and around the bases of infested trees. Usually, larvae hollow out irregular, cavelike burrows 50 mm in diameter under the bark. Galleries 12 to 16 mm in diameter and 12 to 22 cm long extend obliquely upward, then straight upward in the sapwood and heartwood (figure 43E). Wounds usually heal in 1 to 2 years, leaving oval to irregular bark scars that remain as evidence of attack for 10 to 20 years (figure 43F). Empty pupal cases protrude from the bark until dislodged (figure 43G). Damage in sawn lumber appears as pockets of ingrown bark and oval or irregular holes 12 mm or larger in diameter surrounded by stained wood. Stain may extend from a few centimeters to 60 cm up and down the trunk from the gallery. The inner surface of the hole is dark stained. Until recent years, this borer mainly attracted attention as a pest of shade and ornamental trees (Doten 1900, Felt 1905) and windbreak trees (Munro and Fox 1934). Foresters are now taking notice of its effect on hardwood timber in forest stands (figure 44A). Degrade from its damage has been estimated at 15% of the value of roughsawn oak lumber (figure 44B) (Hay and Morris 1970). It is a major contributor to the $20.65 per thousand board foot average loss in oaks attributed to insect borers in the South (Morris 1977). Infested trees are seldom killed, but young trees honeycombed by several generations of borers may be broken off by wind.

**Control.** Natural enemies suppress the carpenterworm but often do not keep damage to acceptable levels. Two hymenopterous parasites—*Lissonota prionoxysti* (Rohwer) and *Pterocormus devinctor* (Say)—have been found (Carlson 1979); the first reportedly reduced moth emergence by 12% in an eastern Kentucky population (Hay and Morris 1970). The entomogenous nematode *Steinernema feltiae* Filipjev has shown some promise for control (Lindegren and Barnett 1982). Disease organisms—especially *Beauveria bassiana* (Bals.) Vuill.—have been found, but natural infection is low. Predators, including spiders, insects, and birds, are the most important natural enemies. Spiders are particularly important predators of newly hatched larvae. A small carabid, *Coptodera aerata* Dej., consumes many first- and second-instar larvae. Birds, especially woodpeckers, are also important predators. Woodpeckers have been credited with capturing upwards of 75% of young carpenterworm larvae in North Dakota (Munro and Fox 1934). The hairy woodpecker effectively excavates carpenterworm larvae from galleries in small trees under 15 cm in diameter. Other birds observed capturing moths include the Arkansas kingbird, common kingbird, red-bellied woodpecker, redheaded woodpecker, Carolina wren, summer tanager, and blue jay. Cultural practices that promote tree vigor, prevent bark injuries, and remove

brood trees help to minimize damage. Treating galleries with commercially available fumigants and insecticides is effective for individual high-value trees (Solomon 1985a). Trunk-applied insecticides timed with the use of sex attractants to correspond with egg hatch are effective in preventing infestation.

### *Prionoxystus macmurtrei* (Guerin)

little carpenterworm (figure 45)

**Hosts.** Red oaks, chestnut. Northern red oak principal oak host (Hutchings 1924a, 1924b); also reported from black oak (Tietz 1945). Probably attacks other species in red oak and white oak groups.

**Range.** Mainly eastern Canada and the northeastern United States, as far south as Texas and as far west as Minnesota (Hutchings 1924a).

**Description.** ***Adult.*** Gray-black moth; female with spindle-shaped body covered with dark gray scales; forewings mottled with gray and black, hindwings mostly clear (figure 45A) (Hutchings 1924b). Males with dark gray bodies with wings mostly clear and shining except for scattered gray-black scales (figure 45B). Wingspan about 60 mm in female and 35 mm in male. Males bear little resemblance to females in color and size and are easily mistaken for another species. ***Egg.*** Oval shaped, measuring about 3 mm by 1.5 mm. When first laid, dull greenish yellow, turning dull brown (Hutchings 1924a). ***Larva.*** Newly hatched about 5 mm long. When fully grown, female larvae are about 63 mm long and 15 mm wide; males about 38 mm long and less robust than females. Head and thorax of larvae dark brown. Body changes during development from pinkish white to bright pink by end of first season, to dull greenish white in full-grown larvae. Dark tubercles that appear on body during first season less distinct in fully grown larvae (Hutchings 1924b). ***Pupa.*** Rounded, shiny, and reddish brown to mahogany (figure 45C). Female pupae about 46 by 11 mm; males about 25 by 6 mm (Hutchings 1924b).

**Biology.** Moths emerge mostly from late May through early July. Males are strong fliers and strongly attracted to females. Mating occurs shortly after emergence, and oviposition soon begins. Eggs are laid singly or in small groups, usually in bark crevices or other rough areas of bark. Females can lay 50 to more than 275 eggs in about a week. Female moths die soon after oviposition. Eggs hatch in 10 to 13 days (Hutchings 1924a). Young larvae usually excavate burrows in and under bark near egg sites. Cavities are expanded during summer and measure about 25 mm in diameter and 9 to 13 mm deep at first season's end. Larvae spend their first winter in the excavated burrows and resume feeding in spring, extending their tunnels deeper and wider in the inner bark and outer layers of wood. When two or more larvae feed close to one another, an area several centimeters across may be skeletonized. During the second summer, larvae move inward, tunneling the outer layers of sapwood initially and then heartwood. After overwintering in heartwood, the larvae feed inward and usually upward. By the end of the third summer, tunnels are uniform in diame-

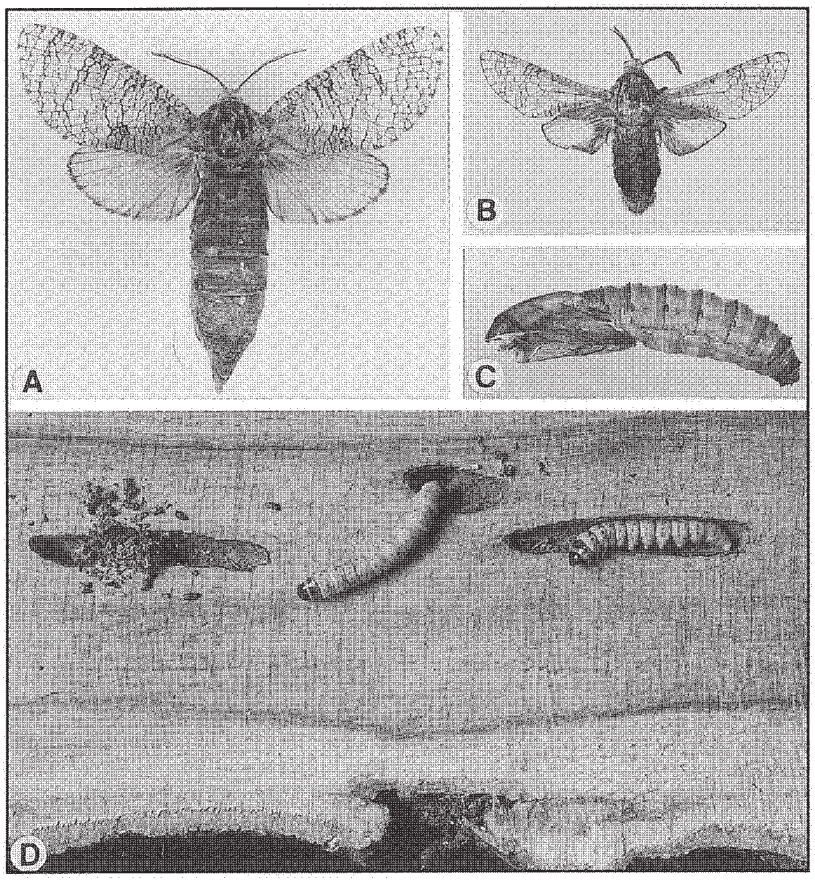


**Figure 45**—Prionoxystus macmurtrei, *little carpenterworm: A, adult female; B, adult male; C, pupal case; D, larvae with tunnels in red oak (specimens A & B, courtesy R. Hodges).*

ter with enlarged bark exits. During the last fall, mature larvae lay down soft, silklike coverings on the gallery walls. Pupation occurs behind silken, feltlike curtains within the galleries the next spring. Just before moth emergence, pupae move down the galleries and partially through the exit openings. Moths emerge and crawl upward onto the bark.

**Injury and damage.** New larval activity can be detected by small quantities of fine, brown, sandlike borings held loosely together by invisible silken threads in crevices of the bark and around the crevices of scars. Bark discolored by oozing sap may also indicate new attacks. Older larvae eject frass of wood chips and excrement pellets from large openings in trunks and branches (Solomon 1977b). Galleries extend for a short distance under bark and then generally extend inward and upward. There may be considerable crossing and intersecting of galleries (figure 45D). Gallery size varies greatly but ranges from 8 to 12 mm in diameter and 15 to 30 cm long. Unsightly bulging scar tissue usually forms around exterior openings. All parts of a tree over 3 cm in diameter are susceptible to attack, and branches that have been girdled or small branches that have been tunneled may break or die. A tree that is repeatedly attacked becomes badly honeycombed, and its interior may be converted into a labyrinth of dark tunnels that cross and intersect from many directions (Hutchings 1924a). Such damage markedly reduces its value for lumber (Donley 1974). Trunk wounds healing from the outside form thick, horny, bulging scars that reduce the beauty of ornamentals. Branches may be tunneled, resulting in breakage, or girdled, causing dieback. Trees with such top damage may become asymmetrical. Damage is similar to that caused by *P. robiniae* (Peck), but total impact is much less because of localized, scattered populations and limited distribution.

**Control.** Woodpeckers and other birds are the most important natural enemies. Young larvae burrowing in the bark are especially vulnerable (Hutchings 1924a). Nuthatches, brown creepers, chickadees, warblers, and other birds feed on the eggs and newly hatched larvae. An unidentified dipterous parasite has been reared from a 2-year-old caterpillar (Hutchings 1924a). Brood-tree removal will help to reduce damage. Insecticides or fumigants can effectively prevent and control small carpenterworms in high-value trees.

### *Prionoxystus piger* (Grote)

[baccharis carpenterworm] (figure 46)

**Hosts.** Baccharis. The hosts are limited to species of baccharis (small trees and shrubs) that grow mainly on the eastern and southern coastal plain and Cuba (Clarke 1952). Eastern baccharis appears to be the major host, based on unpublished observations and on other findings (Landolt and others 1985).

**Range.** Limited to south Florida and Cuba (Clarke 1952, Grote 1865).

**Description.** ***Adult.*** Moderately robust black-gray moth; wingspan of females 43 to

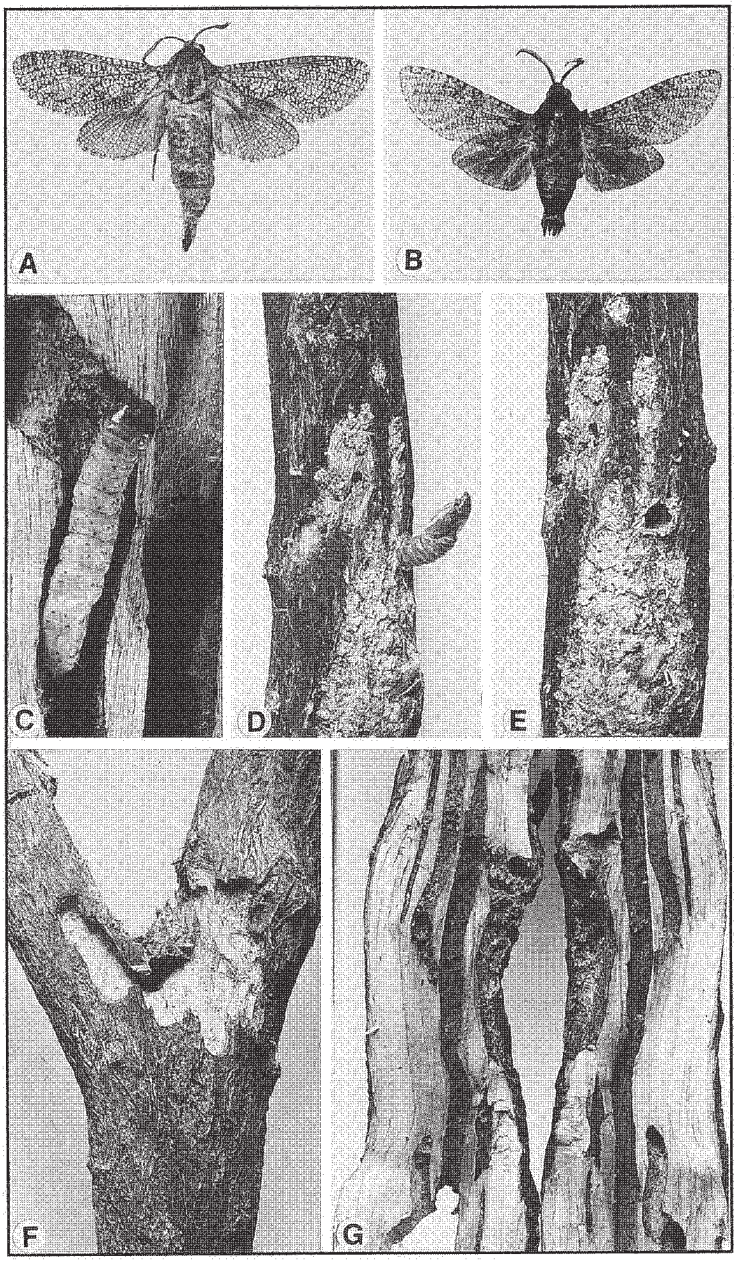


**Figure 46**—Prionoxystus piger, *[baccharis carpenterworm]: A, adult female; B, adult male; C, larva in gallery; D, pupal case in exit hole; E, entrance hole and frass; F, cambial burrow; G, larval galleries (specimens A & B, courtesy R. Hodges; specimens C-G, courtesy W. Palmer).*

45 mm (figure 46A) and that of males 34 to 40 mm (figure 46B) (Clarke 1952). Gray forewings covered with fine netlike pattern of black with metallic blue iridescence. Hindwings blackish brown in males and pale gray in females. Moths resemble *P. robiniae*, but smaller with black hindwings, whereas *P. robiniae* males have bright orange spot on hindwings. However, an orange spot occurs occasionally on *P. piger* males, making dissection and examination of genitalia necessary for identification. Head, thorax, and abdomen ashy gray with dusting of black scales. ***Larva.*** Black head and pink initially but creamy white when mature (figure 46C). ***Pupa.*** Dark brown with toothed bands on dorsal surface of abdominal segments (figure 46D).

**Biology.** Moths emerge in south Florida from February to July (Clarke 1952, Landolt and others 1985). After mating, females deposit eggs in bark crevices on stems of host plants. Newly hatched larvae bore through the bark and make extensive burrows 25 to 50 mm in diameter in the cambium. These burrows are irregularly shaped and typically have fingerlike projections. As the larvae grow, they chew galleries that extend into the wood and then upward (figure 46G). Wood galleries are 8 to 11 mm in diameter and 8 to 15 cm long. Some frass may be packed in bark burrows, but wood galleries are generally kept open and free of frass. Mature larvae line their galleries with silken threads and pupate in the innermost parts. Pupation begins during winter and continues until summer. Duration of the life cycle has not been established, but observations suggest 1 year.

**Injury and damage.** Wet sap spots on the bark are earliest evidence of attack. Granular frass mixed with dark excrement pellets is ejected from gallery entrance holes (figure 46E) and is usually present in large amounts in bark crevices and on the ground around infested plants. Removing bark reveals an extensive mine or burrow beneath and an entrance hole into the wood (figure 46F). Brown pupal skins protruding from exit holes in bark may be observed during spring and summer (figure 46D). Trunks and branches from 25 to 76 mm in diameter may be infested, but 50-mm-diameter stems seem to be preferred (Clarke 1952). Broken branches or dying plants may indicate attack. Elongate scars and exposed wood are often present on plants suffering from repeated attacks (Clarke 1952). Larvae mine the bark and tunnel the stems. Small stems are often girdled and killed. Because baccharis plants are of little or no economic value, the pest is of minor importance in North America but is being studied by scientists in Australia as a candidate for introduction as a biological control of baccharis plants, problematic weeds in pasturelands.

**Control.** Woodpeckers are the only known natural enemies. Sex pheromones have been used to determine the time of moth emergence (Landolt and others 1985), but direct controls have not been needed.

### *Cossula magnifica* (Strecker)

pecan carpenterworm (figures 47 and 48)

**Hosts.** Pecan, hickory, oak. Pecan and hickory are the major hosts (Matz 1918, Moznette and others 1931, USDA FS 1985). Does not attack oaks to the same extent as pecan and hickory, but among oaks, favors white oak. Post oak, scarlet oak, and black oak also recorded as hosts.

**Range.** Distributed from North Carolina and Florida west to Texas and Mexico and Guatemala (Matz 1918, Moznette and others 1931, USDA FS 1985).

**Description.** ***Adult.*** Grayish moth mottled with brown and black blotches (figure 47A) (Gill 1924, Moznette and others 1931, USDA FS 1985). Forewings mottled with small brown patches, and each has large brownish area at distal end; hindwings uniformly darker without distinct markings. Wingspan ranges from 37 to 44 mm. ***Larva.*** Pinkish and naked or only sparsely covered with short, fine setae that arise from numerous tubercles (figure 47B). Head, cervical shield, and anal plate shiny dark brown. Mature larvae may reach 37 mm in length. ***Pupa.*** Brown and has sharp projections on head, used to help force its way through pupal cell and along larval burrow to exit hole.

**Biology.** Adult moths emerge late April through June and deposit eggs on the bark of small branches in the tops of trees (Gill 1924, Moznette and others 1931, USDA FS 1985). Newly hatched larvae first attack small twigs and branches, tunneling out the pithy centers. When too large for the small twig, larvae crawl out and enter a large branch. Entrances in twigs and small branches usually adjacent to buds, leaf petioles, or small secondary branches. Larvae may tunnel up to 10 cm in both directions from the entrance holes, leaving only shells of small branches 9 to 13 mm in diameter (Solomon and Payne 1986). By early fall, larvae vacate branch galleries, move downward, and bore into the trunk and large branches. Larvae attacking the trunk usually initiate galleries in bark crevices and tunnel horizontally or obliquely upward 13 to 32 mm, then vertically for another 6 to 13 cm. Many larvae also tunnel downward from the points of entrance another 5 to 10 cm. Cross sections of the vertical portions of the galleries are usually round and 6.5 mm in diameter. Larvae overwinter in their galleries. In April or May, mature larvae enlarge the entrance holes, then enclose themselves in the upper ends of the galleries behind networks of thread-like material. Just before emergence, the pupae, using sharp projections on the heads, move through the barriers and down the tunnels to the entrance holes. The life history is little known, but the species appears to have one generation per year.

**Injury and damage.** Entrance holes may be obvious on the trunk (figure 47C), but the earliest signs of attack are sapstained bark and small quantities of moist frass at entrance holes on small branches (figure 47D) (Solomon and Payne 1986). Splitting an infested branch reveals the gallery (figure 47E). Signs are often overlooked because infested branches may be high above ground and the frass scatters as it falls. Attack sites

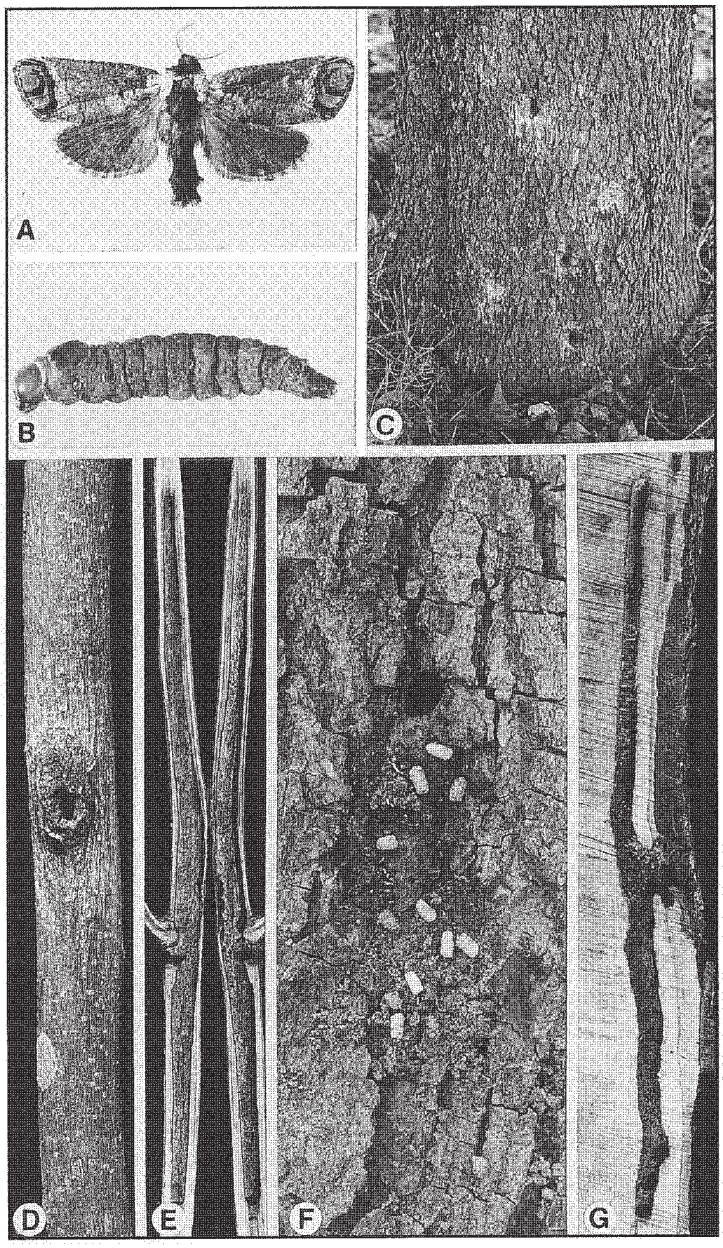


**Figure 47**—Cossula magnifica, *pecan carpenterworm: A, adult male; B, larva; C, holes and bark scars on trunk; D, entrance hole in branch; E, branch gallery; F, entrance hole, frass, and stained bark on trunk; G, completed gallery in trunk (specimens A & B, courtesy D. Habeck).*

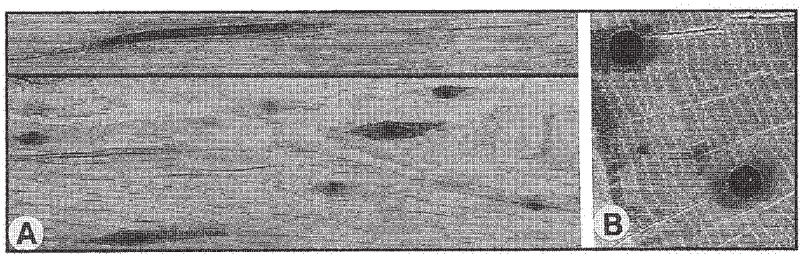


**Figure 48**—*Damage caused by* Cossula magnifica, *pecan carpenterworm: A, wormhole defects in lumber; B, round holes in log end.*

become easier to recognize when larvae later bore into the trunk during fall (Moznette and others 1931, Turner and others 1918). Most attack sites are concentrated around the base of the trunk from groundline up to about 1.2 m. Attack sites in the trunk are characterized by small circular entrance holes about 6.5 mm in diameter, with sapstained bark below the entrances and a few excrement pellets and fine frass in bark crevices (figure 47F). Galleries may extend both upward and downward from the points of entrance (figure 47G). Pelletlike frass often accumulates in piles on the ground around the bases of infested trees. Entrance holes are enlarged to about 9.5 mm just before pupation. Brown pupal skins may be found protruding from entrance holes after moths emerge during May and June. Vacated galleries heal over, leaving uniformly round or oval bark scars for several years as evidence of attack (figure 47C). Branches and trunks of trees of all sizes are attacked, but those 8 to 31 cm in diameter are preferred. Small branches may break or die back at tunneled sites. Although very few trees break or die, heavy repeated attacks may structurally weaken a tree, reduce its vigor, and provide entry for decay fungi and other pathogens. Wormholes degrade and markedly reduce the value of sawlogs and lumber (figure 48A and B). Populations may be heavy locally, but widely scattered infestations and sporadic appearances minimize overall economic impact.

**Control.** Although largest populations occur in the South, damaging infestations are widely scattered and quite localized (Boethel and others 1980). Trees planted in orchards, groves, as ornamentals, or otherwise open grown are generally more heavily infested than those in well-stocked forest stands. New plantings should not be established adjacent to heavily infested old orchards. Infestations can be minimized by keeping trees vigorous and free of disease cankers and mechanical injuries. Two tachinid parasites—*Phorocera comstocki* Williston (Leiby 1925) and *P. signata* Aldrich and Webber—have been reared, but little is known of their effect on populations. Insecticides used regularly in managed groves to control nut and foliar insects provide some, but not complete, control. Chemical control specifically for pecan carpenterworm is seldom used (Boethel and others 1980).

### *Acossus centerensis* (Lintner)

[poplar carpenterworm] (figure 49)

**Hosts.** Poplar. Quaking aspen is preferred (Bailey 1883). Balsam poplar also has been casually mentioned as a host (Packard 1890).

**Range.** A northern species occurring from New York and New Jersey west to Illinois and North Dakota and in Canada from Quebec and Ontario west to British Columbia (Barnes and McDunnough 1911, Doane and others 1936, Doolittle and others 1976, Felt 1906, Forbes 1923).

**Description.** ***Adult.*** Moderately large, black and gray-mottled moth (figure 49) (Bailey 1883, Felt 1906, Forbes 1923). Forewings covered with black reticulations over black-gray scaling, shading darker toward base. Hindwings rounded and trans-

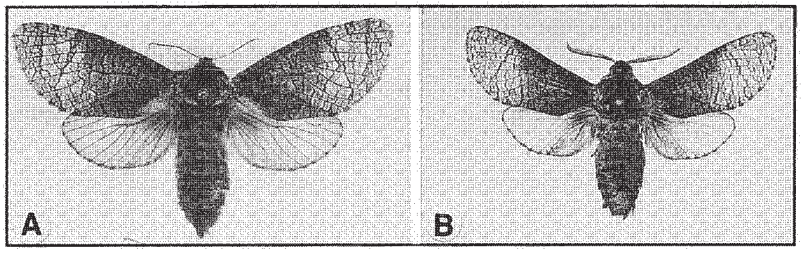


**Figure 49**—Acossus centerensis, *[poplar carpenterworm]: A, adult female; B, adult male (specimens courtesy R. Hodges).*

lucent with faint reticulation (more conspicuous beneath) in both sexes and blackish hairs at base. Wingspan of males 40 to 50 mm; females 50 to 64 mm. Head, thorax, and abdomen blackish and edged and shaded with gray. Sexes more alike than other cossid moths. Females (figure 49A) distinguished from males (figure 49B) by their threadlike antennae (feathery antennae in male) and slightly more robust bodies. ***Larva.*** Creamy white with dark brown head and strong black mandibles (Bailey 1883, Felt 1906). Thoracic shield pale yellowish to blackish brown. Thoracic legs well developed with black claws. Spiracles dark brown and anal shield yellowish. Mature larvae range from 32 to 45 mm long. ***Pupa.*** Narrow, shiny, wrinkled, brownish black, and about 30 mm long.

**Biology.** Adults emerge during the day in June and July (Bailey 1883, Doolittle and others 1976); prefer to rest on roughened areas of the bark, bark scars, or broken limbs. Moths are sluggish and easy to capture but resemble the bark so closely that finding them requires close scrutiny. Males are attracted readily to traps baited with synthetic sex pheromone (Dix and Doolittle 1985). Females deposit eggs singly or in small groups on the bark, in tunnels, and in other bark openings. Females have been observed to deposit 50 to 60 eggs in captivity, but probably deposit more in nature. Larvae bore in the bark and heartwood, often feeding in groups; 17 larvae have been found in a 90-cm-long branch. Larvae of three sizes have been found, indicating a 3-year life cycle. Mature larvae pupate in the innermost part of the galleries with their heads toward the openings. After slightly less than 1 month, pupae work their way to the gallery entrances and through the frass plugs, and the moths emerge.

**Injury and damage**. Attacks occur mostly on trunks and branches smaller than 31 cm in diameter and occasionally in trunks up to 41 cm diameter (Bailey 1883, Felt 1906). Heavily infested trunks may have many open entrances and numerous distorted bark scars from healing wounds. Dissection reveals many large galleries up to 15 mm in diameter running in diverse directions deep in the wood. The galleries end in smooth pupal cells about 40 mm long and often about the same distance from the bark. Exit openings are typically kept partly closed with wads of debris and frass. Fine chips and thin slivers are loosely pressed together against the wads. Empty brown pupal cases often can be seen protruding from bark perforations. Trees containing wounds, previous marks of borer attack, and pockets of decay are most apt to be infested. Infested trees sometimes break at weakened places. Heavily infested trees often succumb to this borer.

**Control.** Natural control agents include an unidentified ichneumonid parasite, woodpeckers, and ants (Bailey 1883, Packard 1890). Up to 15 ichneumonids have been recovered from 1 host pupa. Ants and birds destroy many eggs, whereas woodpeckers destroy large numbers of the larvae. Infestation can be prevented or controlled in high-value trees with chemical trunk sprays or gallery treatments.

### *Acossus populi* (Walker)

[aspen carpenterworm] (figure 50)

**Hosts.** Poplar. Cottonwoods and poplars listed as general hosts; quaking aspen mentioned as a specific host (Doane and others 1936, Furniss and Carolin 1977).

**Range.** Known to occur in Nevada, Colorado, California, and the northern Rocky Mountains, but reportedly found from coast to coast and in Ontario and British Columbia in southern Canada (Doane and others 1936, Dyar 1937, Essig 1929, Forbes 1923, Furniss and Carolin 1977, Neumoegen and Dyar 1894).

**Description.** ***Adult.*** Rather stout-bodied, whitish ash gray moth with yellowish gray and black markings (figure 50) (Barnes and McDunnough 1911, Neumoegen and Dyar 1894). Forewing very light gray with an irregular network of black reticulations heavier and more distinct in wing center. Wingspan 60 to 80 mm. Antennae and labial palpi black, and head gray with yellowish gray collar. Thorax gray with incomplete dark collar anteriorly and two transverse black marks posteriorly. Gray abdomen. Females (figure 50A) distinguishable from males (figure 50B) by their slightly heavier bodies, lighter gray color, less distinct reticulation on hindwings, and threadlike antennae. Male antennae feathery. ***Larva.*** Cream colored, shiny, and hairless with dark brown head and thoracic shield, and 35 to 40 mm long (figure 50C) (Furniss and Carolin 1977).

**Biology.** Adults emerge in July and deposit their eggs in bark crevices of host trees. Young larvae tunnel under the bark initially, then produce extensive galleries in the wood. Little is known of the life history; hosts and geographical range are similar to those of *A. centerensis*, and habits and development are probably similar also.

**Injury and damage.** Frass can be found in bark crevices of actively infested trees. Entrance holes and bark scars on the trunk provide evidence of infestation. Galleries with blackened walls up to 13 mm in diameter may extend deep into the wood. Heavily infested boles may be so riddled with tunnels that they break (Furniss and Carolin 1977). Populations are localized and widely scattered, which minimizes the overall importance.

**Control.** Nothing is known of the natural enemies or other controls.

### *Zeuzera pyrina* (Linnaeus)

leopard moth (figure 51)

**Hosts.** Elm, maple, ash, beech, walnut, oak, chestnut, poplar, willow, apple, pear, plum. Some host preferences depend on region; in New York, elms and maples preferred (Pike 1892, Seaver 1912). But attacks over 100 species of trees and shrubs (Britton and Crombie 1911). Except for evergreens, most woody plants of suitable size appear susceptible (Howard and Chittenden 1916).

**Range.** An introduced pest, probably from Europe, where it is a major problem in fruit trees (Britton and Crombie 1911). First reported from Hoboken, New Jersey, in 1882. Because female moths are extremely poor fliers, the spread has been slow. Now it is distributed mostly along the Atlantic

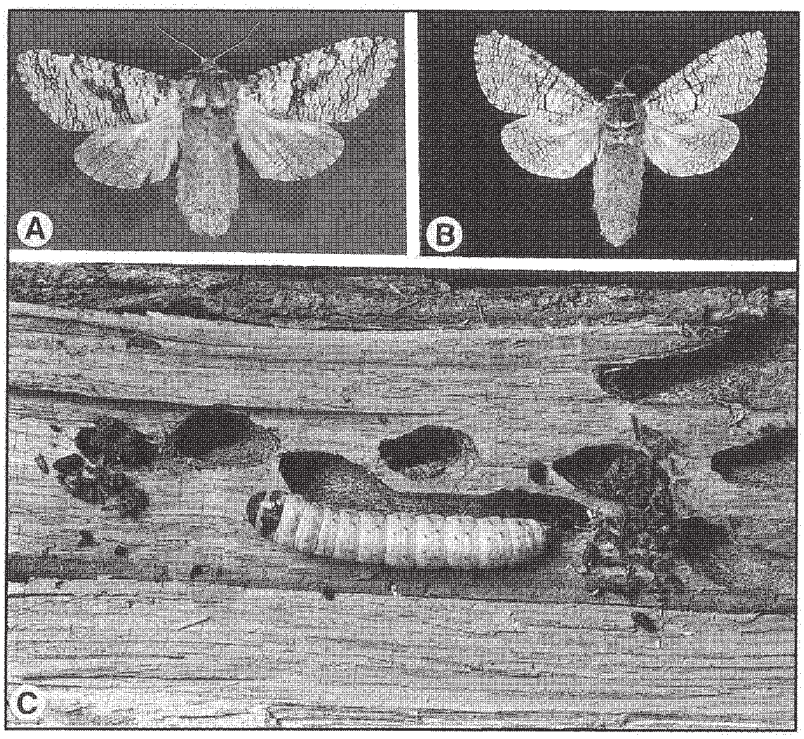


**Figure 50**—Acossus populi *[aspen carpenterworm]: A, adult female; B, adult male; C, larva and galleries in aspen (specimens courtesy R. Hodges).*

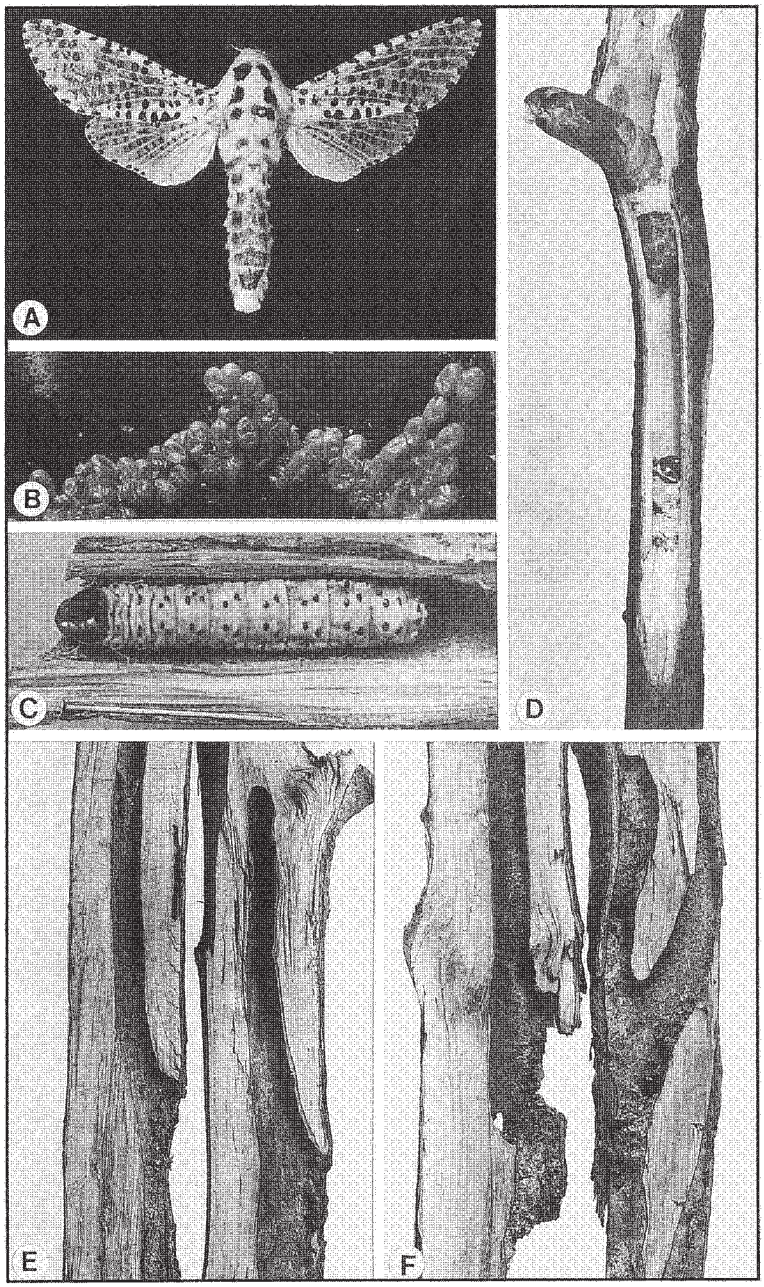


**Figure 51**—Zeuzera pyrina, *leopard moth: A, adult male; B, eggs; C, mature larva; D, tunneled twig with pupal skin protruding; E, single galleries in branches; F, multiple galleries in stem (B & C, courtesy of W. Johnson).*

seaboard from Philadelphia northward to Massachusetts (Commonwealth Institute of Entomology 1973, USDA FS 1985). Reportedly captured in Carson County, South Dakota (CIE 1973), but this occurrence is unconfirmed.

**Description.** ***Adult.*** Black and white spotted moth; derives name from its spots (figure 51A). Wings semitransparent, white, and thickly dotted with distinctly tinged black spots of dark blue cast (Howard and Chittenden 1916). Wingspan of females ranges from 62 to 75 mm (USDA FS 1985). Females heavy bodied and much larger than slender-bodied males. Thorax white with six large black spots and, near center, one small spot. White abdomen with dark crossbands (Howard and Chittenden 1916). ***Egg***. Oval, salmon, or orange yellowish, and about 1.5 mm long (figure 51B) (Britton and Crombie 1911). ***Larva.*** About 50 mm long, pale yellow, and often with a pinkish tinge when fully grown (figure 51C). Head, very prominent thoracic shield, and anal plate brownish black. Sparsely hairy body dotted with large, prominent dark tubercles on each segment (Howard and Chittenden 1916). ***Pupa.*** About 30 to 40 mm long, dark brown, and characterized by sharp protuberance on head (figure 51D) (Britton and Crombie 1911).

**Biology.** Adults emerge from May to September (Howard and Chittenden 1916). The heavy-bodied females seldom fly and often lay eggs near the sites where they emerged from the pupae. Moths eat nothing, live only a few days, and die soon after mating and oviposition. Females deposit 400 to 800 eggs singly or in small clusters in bark crevices or beneath plates of bark (Britton and Crombie 1911). Larvae hatch in about 10 days and begin boring into the wood, often entering the nearest bud, twig, or branch crotch. They bore into the pith of small stems and the heartwood of larger branches or trunks. Larvae move to larger branches when they grow too large for those in which they are feeding (Howard and Chittenden 1916, Seaver 1912). They grow to about 25 mm by the end of the first season. In fall, larvae bore tunnels that slant upward, 50 mm or more below the bark surface, where they remain dormant over winter. Larvae resume feeding the following summer, pass a second winter in dormancy, and begin pupation the second spring after the eggs hatch (Britton and Crombie 1911). Pupation occurs in small chambers near the bark. In 4 to 6 weeks, the pupae exit through the bark and move partially out of the tunnels. After the moths emerge, the pupal cases remain in the openings (Britton and Crombie 1911). A life cycle requires 2 years.

**Injury and damage.** The earliest symptoms may be girdled or broken twigs and branches with yellow, wilted foliage. Larval tunnels in the wood (figure 51E) and girdling burrows under the bark are visible at the ends of broken stems. Numerous partly broken branches with dead brown foliage hanging in tree crowns are characteristic of heavy infestations. Attacks on large branches and trunks are characterized first by fine, whitish frass in bark crevices and often by sapstained bark. Later, large quantities of frass—consisting mostly of small, cylindrical, yellowish to brown excrement pellets—are

expelled and can be observed in bark crevices and on the ground underneath an infested tree. Gallery entrances are usually kept covered with woven silklike webs. Large branches and trunks 10 to 15 cm may be girdled. Besides burrows under the bark, these insects construct galleries up to 12 mm in diameter and 5 to 15 cm long that slant upward into the wood (figure 51F). The shape and size of these galleries vary widely because larvae repeatedly vacate galleries and establish new ones. Boring and tunneling seriously damage infested trees. Large branches or even trunks of small trees are sometimes girdled and occasionally break in the wind. Ugly scars appear on the trunks of large trees where the bark dies, splits, curls, and eventually breaks away. Injuries in timber trees result in defects and degrade in sawn lumber. Seedlings and small trees are sometimes girdled and killed (USDA FS 1985).

**Control.** Birds, especially woodpeckers, are the most important natural control. Although four wasplike parasites have been found in Europe, only one species—*Copidosoma truncatellum* (Dalman)—has been reported in this country (Gordh 1979). Squirrels have been observed feeding on larvae (Howard and Chittenden 1916). Removal and destruction of infested branches are recommended, and heavily infested damaged trees should be destroyed. Planting species that are least susceptible to attack (species other than elms and maples) and spacing plantings so that the crowns do not touch discourage movement of the insect from tree to tree (Britton and Crombie 1911). The impact of injury may be reduced by maintaining trees in a vigorous condition. Chemical insecticides can be introduced into tunnels (Britton 1928).

### *Comadia suaedivora* Brown and Allen

[alkali blite borer] (figure 52).

**Host.** Alkali blite. Limited to one host, alkali blite, a woody holophytic shrub (Brown and Allen 1973).

**Range.** Distribution restricted to counties of Madera, Kern, Fresno, King, and Tulare in California (Brown and Allen 1973).

**Description.** ***Adult.*** Dark brown moth with black and white marks. Forewings dark brown with white marks and brown-tinged yellow patches above and light gray with dark brown and white below. Hindwings white toward base and light gray toward apex. Veins darkened and fringe white above. Female with darker wings than male, but amount of dark shading in both sexes varies. Wingspan about 34 mm for males and 38 mm for females. Collar and posterior edge of thorax dark brown. Abdomen creamy white anteriorly, becoming darker toward terminal segments. ***Egg.*** Two millimeters long and 1 mm in diameter. ***Larva.*** Whitish with rose-lavender highlights and heavy sclerotized horn on dorsal surface of anal flap (figure 52A). Head partly covered by first thoracic segment. Mature larvae reach about 30 mm long. ***Pupa.*** Dark brown, heavily spined, and about 15 mm long (Brown and Allen 1973).

**Biology.** Adult moths fly from early May to mid-June (Brown and Allen 1973). Male moths are more frequently attracted to light

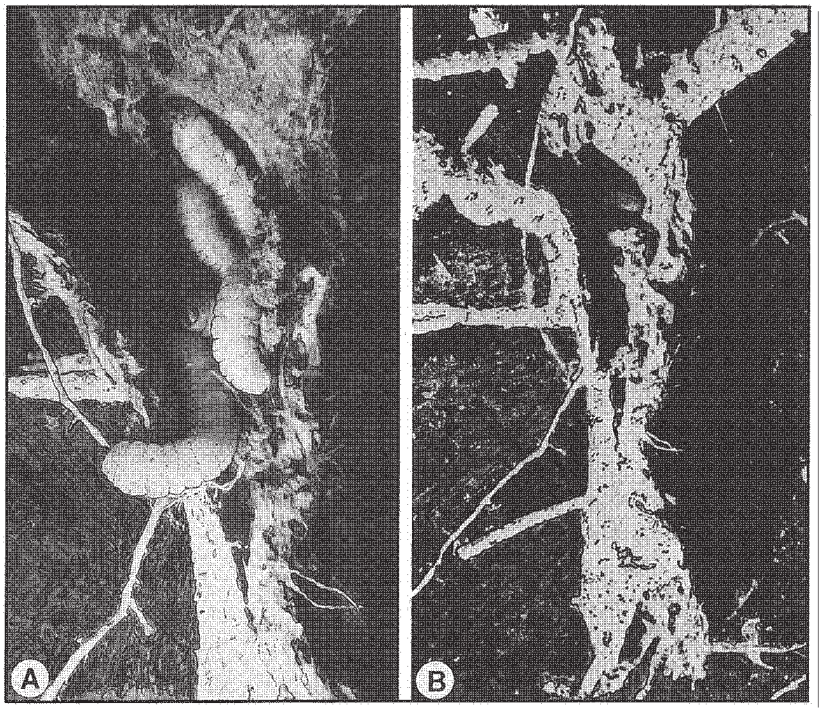


**Figure 52**—Comadia suaedivora, *[alkali blite borer]: A, cluster of larvae feeding in alkali blite; B, crown and root broken open to expose feeding cavity (courtesy R. M. Brown).*

than females; the most extensive flights have been observed on warm overcast nights during late May. Females deposit eggs in tight clusters glued to the host near the crown. Larvae bore into bark and burrow, feed, and develop in the crown and roots. The larvae are gregarious and, feeding together, sometimes completely hollow infested parts (figure 52A). When mature, larvae leave the host and enter the soil, where they construct subterranean cells before pupation. Just before emergence, pupae make their way back to the soil surface, where adults emerge. The life cycle appears to require 2 years.

**Injury and damage.** Weakened, dead, and dying plants usually indicate attack (Brown and Allen 1973). Larvae often completely hollow out the woody portion of crowns and roots of host plants, frequently killing them (figure 52B). The larvae can be found by excavating plants and breaking open infested parts. Brown pupal skins protruding from the ground around the base of host plants are excellent evidence of infestation.

**Control.** Natural controls have not been reported, and direct controls have not been needed.

### *Comadia bertholdi* Grote

[lupine borer]

**Hosts.** Lupine. The only recorded host is lupine (Rivers 1897).

**Range.** A western species reported from Colorado, New Mexico, Utah, California, and Arizona (Barnes and McDunnough 1911).

**Description.** ***Adult.*** Pale grayish moth with wing expanse of 27 to 35 mm (Neumoegen and Dyar 1894). Head and thorax fuscous gray, and wings silvery gray with blackish streak at base of forewing (Barnes and McDunnough 1911). Initially, larvae yellowish white, but becoming reddish as they grow, finally assuming shiny carnelian red (Rivers 1897). ***Larva.*** Dark brown head; light brown thoracic shield and spiracles; scattered fine setae; and black, curved, thick, hornlike spine on last abdominal segment. Full-grown larvae reach about 35 mm.

**Biology.** Moths are collected from May to July (Barnes and McDunnough 1911). Although little is known about the species' biology, larvae of several sizes have been found feeding in the same plant, indicating a life cycle of more than 1 year (Rivers 1897). Full-grown larvae leave their galleries in the host plant and wander in various directions over the soil. After burrowing to 30 cm or more, the larvae form cocoons of silk and soil and pupate. Five to six weeks later, the pupae move to the soil surface and adults emerge.

**Injury and damage.** Larvae tunnel the woody tissue of host plants, but their impact is negligible (Rivers 1897). Sapstained bark, bark openings, and frass mark the entrances to galleries. Evidence of attack may be found in the main trunk and larger roots. During summer, brown pupal skins may protrude from the soil around infested plants.

**Control.** Natural controls are not known, and direct controls have not been needed.

## Family Tortricidae—Twig Borers, Leaf Rollers, or Bell Moths

The adults of this family are small to medium-sized moths; few have wingspans that exceed 25 mm (Miller 1987, USDA FS 1985). Resting moths with their wings folded are often bell shaped. Most are of variegated colors but usually of dull, drab shades, with stout bodies, rough-scaled heads, and wide, oblong, fringed wings. They are active at night and are attracted to lights. The larvae are elongate with pale bodies and dark heads, shields, and tubercles. They are never conspicuously marked and are naked to sparsely clothed with scattered setae. When disturbed, the larvae of many species wiggle vigorously. Larvae feed in buds, twigs, stems, roots, fruits, nuts, and folded leaves. Several species are economically damaging.

### Genus and Species



### *Gypsonoma haimbachiana* (Kearfott)

cottonwood twig borer (figure 53)

**Hosts.** Poplars. Many poplars are attacked, but the deltoid species, especially eastern cottonwood, are particularly susceptible (Morris 1967).

**Range.** One of the most common and damaging insects of young cottonwood trees throughout the host species' range from Ontario to the Gulf of Mexico and west to the Great Plains (Morris 1967).

**Description. Adult**. Small ash gray moth, about 6 to 7 mm long, with wingspan of 13 to 17 mm (figure 53A) (Miller 1987). Base of forewing with dark gray patch that is outwardly angled. Alternate black and white dashes increase in size from base of costa to dark spot at apex. ***Egg.*** Oval, flattened, and about 0.4 by 0.6 mm (figure 53B). Eggs, nearly colorless when first laid, become clouded to reddish as embryos develop. ***Larva.*** Young larva cream colored with

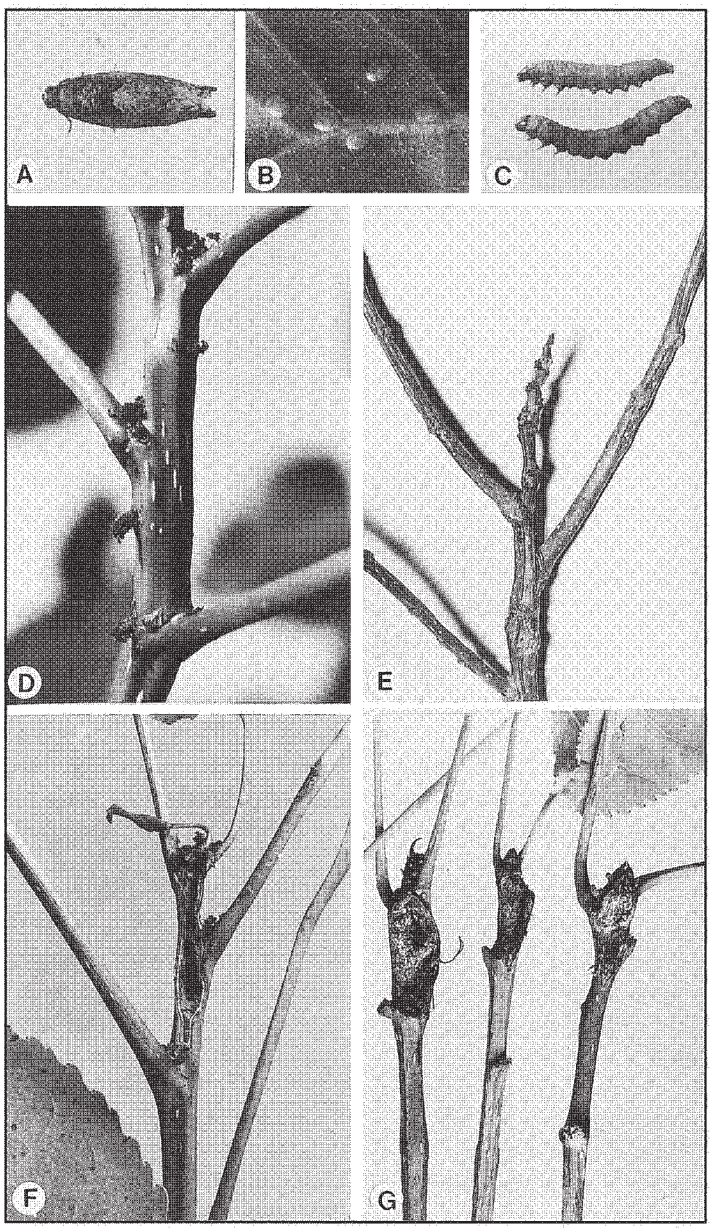


**Figure 53**—Gypsonoma haimbachiana, *cottonwood twig borer: A, adult; B, eggs; C, larvae; D, frass tubes at entrance holes; E, killed terminal; F, larval tunnel in terminal; G, Terminals flared open by potter wasp predation.*

brown head; full-grown larva, about 10 to 13 mm long, has pale body with brownish yellow head and thoracic shield (figure 53C). ***Pupa.*** Light brown, shiny, and about 7 mm long by 2 mm at widest point (Morris 1967).

**Biology.** This borer is nocturnal; adults rest on the bark or in undergrowth during the day and are most active on leaf surfaces and twigs at sunset. Adults live 5 to 10 days. Eggs are laid singly or in groups of two to six almost entirely on succulent leaves, normally on the upper surface along the midribs or along large leaf veins, and hatch in about 5 days. Newly hatched larvae initially cover themselves with silken trash and soon begin tunneling into the nearest midrib or large leaf vein. The silken sheaths are enlarged and serve as surface shelters. The first molt occurs in about 3 days. Then, young larvae move to tender twig tips where they build another silk and trash shelter and bore into the shoot, usually beneath the base of the first leaf below the bud. Larval growth is usually completed at this site, but a few move elsewhere on the twig. Three more molts occur during the next 21 to 23 days. After the first molt, late-season larvae move to sheltered locations near branch ends. These locations include healed borer entrance holes and ridges below leaf scars. There, the second-stage larvae excavate shallow pits and cover themselves with silk and trash to make well-camouflaged hibernacula for protection during winter. In spring, surviving larvae move to new shoots, tunnel in, and complete growth (Morris 1976). Fully grown larvae emerge from twigs and move down the tree to spin cocoons in bark crevices or in litter under trees (Morris 1976). Larval population varies during the season but generally increases in late summer, resulting in considerable terminal damage and mortality (Stewart and Payne 1975). The pupal stage lasts 8 to 9 days; then pupae move partly out of cocoons, and adults emerge. As many as five generations may occur during a season. The resulting large population leads to great larval activity, so that by late summer, one terminal may host several larvae of varying ages.

**Injury and damage.** Signs of feeding by newly hatched larvae are small, red, swollen areas along leaf veins and midribs. After the first molt, larvae bore into tender branches and terminals. Continued larval activity results in stunted or crooked terminals with short internodes and short dark brown tubes of silk and frass near leaf bases (figure 53D). Affected terminals soon are overtopped by undamaged laterals, often resulting in multiforked treetops (figure 53E). A crook frequently develops at the origin of the fork if one of the branches becomes dominant and functions as a new terminal (Morris and others 1975). They sometimes completely hollow out terminal shoots, leaving only thin shells (figure 53F). Injuries are less damaging to older trees than to young ones. Heavily damaged trees may be so distorted as to be of little value (Morris and others 1975). The twig borer can affect or eliminate economic production of eastern cottonwood in some areas (Payne and others 1972). Cottonwoods

growing on good sites and given recommended cultural treatment usually can tolerate high infestations without losing their terminals. But on cottonwoods growing on poor and marginal sites, even moderate infestations can cause loss of a high proportion of the terminals and result in poor tree form.

**Control.** Selection and hybridization of cottonwood resistant to the insect have been suggested (Payne and others 1972). Natural control agents include a number of parasitic and predacious insects. Insect parasites include *Agathis* sp., *Apanteles* sp., *A. clavatus* (Provancher), *Bracon* sp., *B. mellitor* Say, *Coccygomimus* spp., *Eubadizon pleurale* Cresson, *Itoplectis conquisitor* (Say), *Perilampus similis* Crawford, *Phanerotoma* sp., *Pristomerus austrinus* Townes and Townes, *P. euryptychiae* Ashmead, and *Trichogramma* spp. (Burks 1979, Carlson 1979, Marsh 1979, Morris 1976, Stewart and Payne 1972). *Trichogramma* sp., the most prevalent egg parasite found in studies in Mississippi and Texas, is an effective control agent in some areas. One of the most effective natural control agents is the potter wasp—*Eumenes frateanus* (Say)—which tears open young, infested cottonwood terminals and removes larvae from their tunnels (figure 53G). Other predators are plant bugs, lacewings, checkered beetles, and jumping spiders (Morris 1976). Sometimes, chemical control may be needed to protect nurseries and young plantations from economic loss (Morris and others 1975).

### *Proteoteras willingana* (Kearfott)

boxelder twig borer (figure 54)

**Hosts.** Boxelder, maple. Boxelder is the major, possibly only, host (Peterson 1958). However, other maples have been mentioned as hosts (MacAloney and Ewan 1964).

**Range.** Throughout the eastern United States west through the Great Plains. Also found in southern Canada. Most troublesome in the Great Plains of the United States and the Prairie Provinces of Canada, where boxelder is grown extensively for shade and farm shelterbelts (Peterson 1958).

**Description.** ***Adult.*** Small, gray-mottled moth with wingspan of 15 to 25 mm; female slightly larger than male (figure 54A) (Anonymous 1971, Peterson 1958). Wings with white to pale brown fuscous ground color overlaid with streaks, rings, and clusters of yellowish tan to black scales. Males with black subcostal streak on each forewing and black costal streaks on hindwing. Both sexes with four clusters of raised scales on each forewing. ***Egg.*** Round to elliptical, depending on closeness to leaf vein or midrib, with flangelike margins. Translucent, pearly white, and from 0.46 to 0.58 mm long and 0.33 to 0.50 mm wide (Peterson 1958). ***Larva.*** Yellowish white with light brown head and eye spots, later changing to greenish yellow with dark brown head (Peterson 1958). Older larvae whitish yellow with brown to black heads with oval, grayish black, raised cuticular areas bearing setae above and below abdominal spiracles (figure 54B). Mature larvae measure 6 to 13 mm long (Anony-

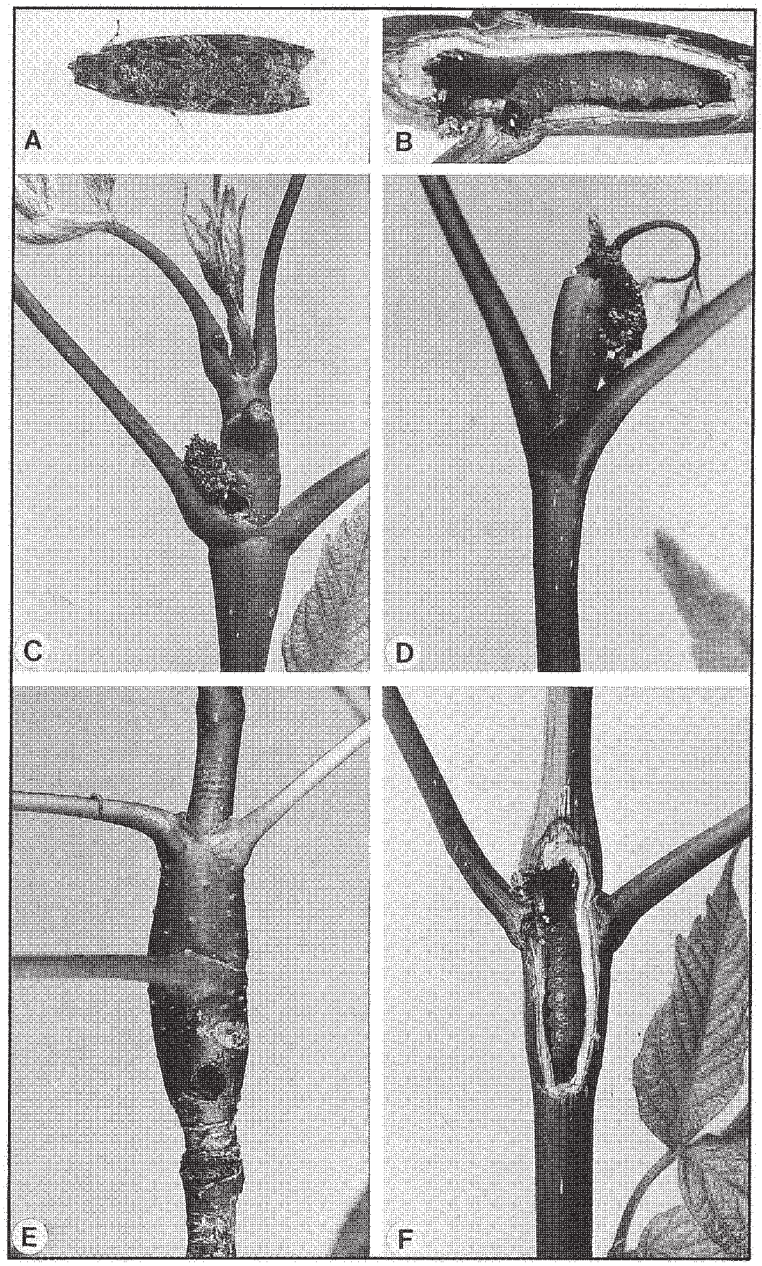


**Figure 54**—Proteoteras willingana, *boxelder twig borer: A, adult; B, larva; C, frass protruding from entrance at petiole juncture; D, dead terminal with frass at apex; E, gall-like swelling with entrance hole; F, gallery exposed.*

mous 1971, MacKay 1959). ***Pupa.*** Reddish brown and from 7 to 11 mm long (Peterson 1958).

**Biology.** In Canada, adults are present from late June to late July, flying with a darting motion. They are most active in evening, frequently resting on trunks or ground but seldom on leaves. Moths live 15 to 20 days at most. Females begin laying eggs soon after becoming adults and may deposit 100 or more eggs, mostly during the evening. Eggs are deposited singly on the undersides of leaves, usually close to the midribs or large veins. The egg stage lasts 9 to 14 days, with a mean of 11 days (Peterson 1958). Eggs hatch from early July to early August (Anonymous 1971). Newly hatched larvae begin feeding along the veins or midribs, usually on the lower leaf surfaces. They construct rooflike shelters of webbing and frass over themselves and feed on the protected leaf surfaces. The first two instars, about 11 to 23 days, are spent in shelters on the leaves. Third-instar larvae move to the base of petioles and bore into dormant leaf buds. Most larvae terminate this period in about 22 days by molting to the fourth instar, usually in late September, October, or November. The winter is passed in the fourth instar in silken cocoons within the dormant leaf buds. In Canada, during late April to late May, larvae vacate their winter quarters and burrow into other buds, where they feed actively. Each larva may destroy two or three buds during this stage. In May or June, larvae molt to the fifth instar, abandon the buds, and bore into the new stem growth of twigs and terminals. Larvae feed within the swollen or galled shoots until fully grown in May or June. Then, they drop to the ground and prepare pupation cells of silk and leaf-duff in the humus layer of the soil. The pupal period ranges from 13 to 18 days and averages 16 days (Anonymous 1971). The earliest recorded emergence of adults is June 19; the latest is July 23 (Miller 1987, Peterson 1958). The life cycle is 1 year.

**Injury and damage.** Two kinds of injury are important. The first, observed mostly in Canada, is the destruction of dormant buds from mid-August to early fall and from late April to early May (Anonymous 1971). The second, larval burrowing in succulent growing shoots, causes stem breakage, stunting, and mortality. Fine, dark brown or black frass often protrudes from entrances a few centimeters below the apex (figure 54C) or from the shoot tip (figure 54D). Feeding activity stimulates infested twigs to enlarge abnormally, forming spindle-shaped, gall-like swellings (figure 54E). Larval entrance holes can be found usually toward the lower ends of the galls. Burrows become quite extensive, resulting in tunnels 25 mm or longer (figure 54F). Splitting the swollen shoots reveals tunneling larvae. It attacks trees of any age, from first-year seedlings in nurseries to mature trees in urban and rural plantings. This borer occurs in almost all boxelder plantations in Manitoba, Saskatchewan, and Alberta. Up to 50% of the new growth may become infested with up to 30 twigs infested on a stem. New shoots are often killed or break, and terminal growth is prevented. Heavy outbreaks stunt established trees by killing much of the current tip growth on twigs and branches. Secondary branching

results, and when this growth is also destroyed, the affected trees may fork repeatedly, becoming bushy and undesirable as shade trees (MacAloney and Ewan 1964).

**Control.** Parasites and diseases are beneficial in controlling the borer. Sometimes up to 30% of the larvae are parasitized (Anonymous 1971, Peterson 1958). Insect parasites recorded include *Ascogaster* sp., *Atrometus clavipes* (Davis), *Bassus* sp., *Campoplex crassatus* (Viereck), *Cremastus similis* (Cushman), *Elachertus* (*hyssopus*) sp., *Erynnia tortricus* (Coquillett), *Euderus cushmani* (Crawford), *Lissonota* sp., *Macrocentrus delicatus* Cresson, and *Pristomerus euryptychiae* Ashmead (Arnaud 1978, Burks 1979, Carlson 1979, Marsh 1979, Peterson 1958). *Campoplex crassatus* is by far the most important parasite. Direct control practices can help to minimize injuries in shade and ornamental trees. Removing and burning secondary sucker growth and galled twigs in late fall or early spring are recommended. Treating foliage during mid-July to early August with recommended insecticides provides effective control (Drouin and Kusch 1979).

### *Proteoteras arizonae* Kearfott

[California boxelder twig borer] (figure 55)

**Hosts.** Boxelder. Moths reared only from California boxelder (Powell 1962).

**Range.** Reported from Arizona, New Mexico, Colorado, and California (Heinrich 1923, Powell 1962); likely occurs in Utah and Nevada.

**Description.** ***Adult.*** Small grayish moth with wingspan of 17 to 20 mm (figure 55A) (Heinrich 1923). Forewings with dull or muddy white ground color with blackish gray markings. Males differ from those of other *Proteoteras* species in having black sex scaling on outer half of forewing's underside and on outer two-thirds of hindwing's underside.

***Larva.*** Preserved, mature larva measures about 14 mm in length, and width of mature larval head capsule 1.2 mm (figure 55B). Head dark yellow brown, darker at posterior margin, and eye region black. Thoracic shield, pale yellow brown in preserved specimens. Setal pinacula large and somewhat raised, unpigmented, and not differentiated from body color. Spinules on integument minute, colorless, and barely discernible. Absence of anal fork separates it from *P. aesculana* Riley. Crochets on abdominal prolegs primarily biordinal, numbering about 38, and 23 to 27 on anal prolegs (Powell 1962).

**Biology.** Moth flight records suggest two generations a year in the San Francisco Bay area (Powell 1962). Adults collected in California from late June to early August. Larvae enter twigs at the base of current growth, ultimately killing them and foliage beyond the entrances. Working downward, larvae hollow out almost the entire woody content of the twig for 25 to 35 mm. Before pupation, larvae construct several fine silken partitions at varying intervals along the length of their tunnels. Pupation normally occurs within tunnels near the apical ends. Pupae develop in fine silklined chambers with heads situated close to exit holes. Thus, the pupation habits are markedly

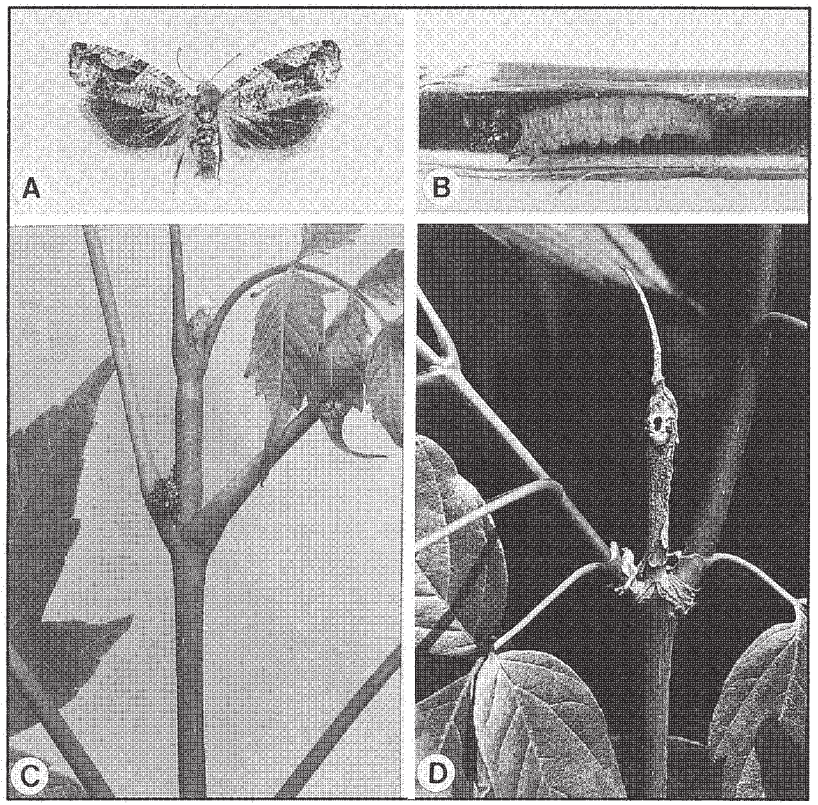


**Figure 55**—Proteoteras arizonae, *[California boxelder twig borer]: A, adult; B, larva; C, frass clump at larval entrance; D, dead terminal with entrance hole (A, specimen courtesy R. Hodges).*

different from the closely related *P. willingana* in Canada, which pupates in leaf litter on the ground (Peterson 1958).

**Injury and damage.** Close inspection reveals small larval entrance holes near the base of current growth. Small amounts of frass may adhere to webbing at entrance holes (figure 55C). Splitting twigs lengthwise reveals larval galleries 25 to 35 mm long and virtually free of frass, except near the lower ends of the tunnels. Wilted, dying, and dead twigs (figure 55D) may be found scattered throughout the tree crown. This borer does not cause spindle-shaped or gall-like swellings of the infested twigs as does *P. willingana* (Powell 1962). Reports of serious damage have not been recorded; however, it has the potential to deform and ruin young trees, particularly ornamentals.

**Control.** Little is known about natural enemies; however, in California, about 50% of one lot of larvae was parasitized by the ichneumonid wasp *Liotryphon nucicola* (Cushman) (Carlson 1979, Powell 1962). Pruning out the infested twigs can help to reduce infestations of ornamental trees.

### *Proteoteras crescentana* Kearfott

[northern boxelder twig borer]

**Hosts.** Boxelder, maple. Boxelder is the major host (Wong and others 1983). Maples have been listed as hosts, but nothing is known of injuries in them (Craighead 1950, Heinrich 1923).

**Range.** Maryland and Ohio west to South Dakota and south to Kansas (Heinrich 1923). Common in Alberta, Manitoba, and Saskatchewan (Forbes 1923, Heinrich 1923, Wong and others 1983).

**Description.** ***Adult***. Dull light gray moth with heavy black crescent-shaped band on forewings and wingspan of 16 to 19 mm (Forbes 1923, Heinrich 1923). Black band extends from middle of costa to apex. Costal patch enclosed by crescent distinctly yellow with slight brown tinge (Heinrich 1923, Miller 1987). Males differ from those of other *Proteoteras* species in lacking black sex scaling on wings (Heinrich 1923). ***Larva.*** Pale white with reddish brown head, darkest around eyes and mouth. Thoracic shield yellowish brown often darkening laterally and posteriorly. Mature larvae stout and about 13 mm long. ***Pupa.*** Reddish brown and about 9 to 11 mm long with spines on abdomen (Wong and others 1983).

**Biology.** Larvae tunneling in the new succulent shoots mature in May and June (Forbes 1923, Wong and others 1983). Pupation and adult emergence occur in June. Little else is known of the life and seasonal histories of this species, but it occurs in mixed populations with *P. willingana*, and their biologies appear similar.

**Injury and damage.** Larvae bore into new shoots and twigs, which may be stunted or killed, causing loss in terminal growth and deformed or misshapen trees and causing galls to form (Wong and others 1983). The galls are actually abnormal swellings that become elongate to spindle shaped, similar to those caused by *P. willingana*. Dark frass is often present around the entrance holes. Recent studies in the Canadian prairies strongly suggest that

previous damage attributed to *P. willingana* was actually due in part to *P. crescentana* (Wong and others 1983).

**Control.** Infested twigs should be collected and burned in May and June to destroy the larvae (Craighead 1950).

### *Proteoteras aesculana* Riley

[maple twig borer] (figure 56)

**Hosts.** Maple, boxelder. Silver maple, boxelder, sugar maple, and bigleaf maple have been listed specifically. Other maple species are probably hosts (Craighead 1950, Powell 1962).

**Range.** Transcontinental in distribution across the northern United States and south to Mississippi (Furniss and Carolin 1977, Powell 1962). Discontinuously distributed across Canada, from Nova Scotia to southern Alberta (Prentice 1965).

**Description.** ***Adult.*** Small grayish moth with wingspan of 11 to 18 mm (figure 56A) (Heinrich 1923). Forewings dark olive green mottled with yellow and gray and sometimes small indistinct black markings (Forbes 1923, Miller 1987). ***Larva.*** Pale white to gray, stout, and about 10 mm long when mature (figure 56B). Yellow-brown head somewhat wider than long, averaging 1.1 mm wide, with mouthparts directed forward. Thoracic shield yellow brown, often darker laterally and posteriorly. Spinules on integument moderately dense and dark (MacKay 1959). Poorly developed anal fork with 4 to 6 teeth. (MacKay 1959, Powell 1962).

**Biology.** Moths fly from April to October in the northern United States (Miller 1987). Moths have been collected in California as early as February and as late as September, suggesting that this species is multivoltine in the San Francisco Bay area (Powell 1962). Behavior is similar to that of *P. arizonae* in California, except that larval tunnels are somewhat longer (40 to 46 mm) and that they normally pupate outside of the tunnels, presumably in leaf litter.

**Injury and damage.** Larvae hollow out dormant buds and seeds in fall and continue to feed on dormant buds in spring (MacAloney and Ewan 1964). During the growing season, larvae bore in the current year's shoots, often killing them and preventing terminal growth (figure 56C). Frass, which is ejected from the galleries, is mixed with webbing to form shelters around the entrances (figure 56D). When terminals are killed, opposite lateral shoots begin elongating and often produce forks or other deformities (figure 56E). Larval entrance holes are typically present near the base of current season's growth (figure 56F). When an infestation is sufficiently severe, trees become bushy and disfigured (MacAloney and Ewan 1964). Large trees have been so heavily injured in early summer in West Virginia that they appeared to have been damaged by heavy frost. In the Pacific Northwest, 7 to 50% of bigleaf maple seeds have been destroyed by this borer. Boxelders planted in nurseries and shelterbelts and as ornamentals are often heavily infested in the northern Great Plains, as is sugar maple in the northern Great Lakes area (MacAloney and Ewan 1964).

**Control.** Two species of hymenopterous

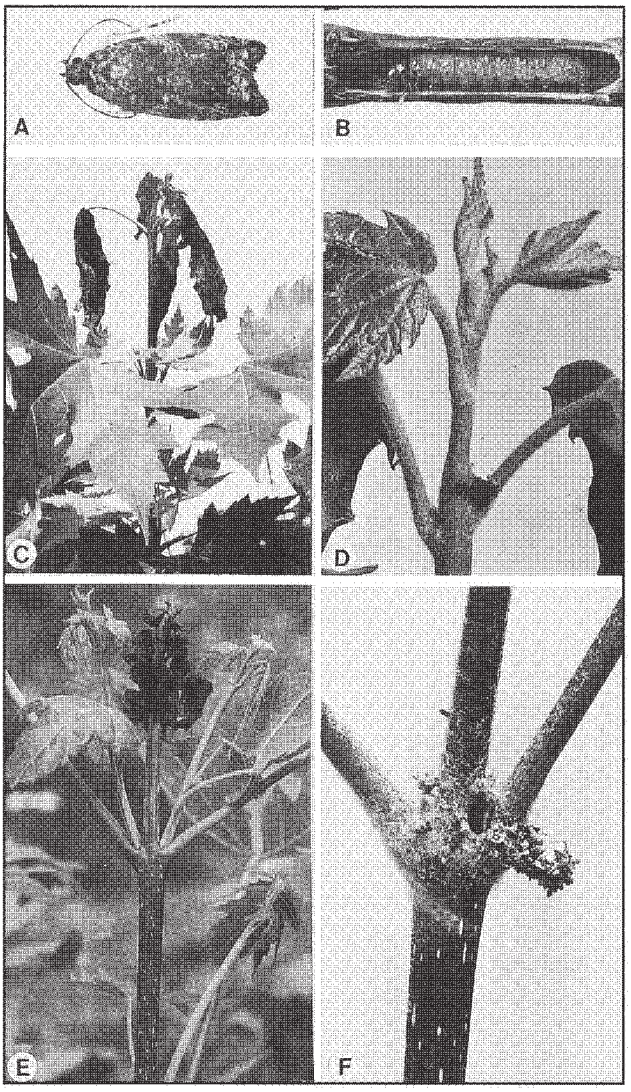


**Figure 56**—Proteoteras aesculana, *[maple twig borer]: A, adult; B, larva; C, dead terminal; D, frass at juncture of petiole; E, laterals elongating after terminal being killed; F, larval entrance hole.*

parasites—*Elachertus proteoteralis* Howard and *Scambus pterophori* (Ashmead)—have been recorded (Burks 1979, Carlson 1979). Removing and destroying infested twigs in fall or spring, combined with foliar applications of residual-type insecticides when moths are active, should help to prevent and reduce infestation of high-value trees.

### *Proteoteras moffatiana* Fernald

[maple bud borer] (figure 57)

**Hosts.** Maple. Sugar maple appears to be the favored host, but silver maple and red maple are also commonly attacked (Forbes 1923, Prentice 1965, Simmons and Knight 1973). The other maple species probably serve as occasional hosts.

**Range.** Recorded from New York south to New Jersey and west to Minnesota (Heinrich 1923, Miller 1987, Prentice 1965).

**Description.** ***Adult.*** Bright green and black moth with heavily mottled forewings that have black on basal third in form of curved band from middle of costa to apex (figure 57A) (Forbes 1923, Heinrich 1923, Miller 1987). Males differ from other *Proteoteras* species in having line of black sex scales only on underside of hindwing. Wingspan ranges from 14 to 20 mm. ***Larva.*** Dull orange with black head and about 10 mm long when mature (figure 57B) (Simmons and Knight 1973).

**Biology.** Adults are present from June to August (Forbes 1923, Miller 1987, Prentice 1965). Larvae often enter terminal buds at the junctions of leaf petioles. They mine the buds, usually completely excavating them, and overwinter inside the buds. The following spring, larvae vacate their overwintering sites and move to new buds, which they mine while shoot elongation is being completed (Simmons and Knight 1973).

**Injury and damage.** Larvae bore in the shoots, buds, and petioles (Forbes 1923, Prentice 1965, Simmons and Knight 1973). They typically enter terminal buds where leaf petioles are attached and eject black frass (figure 57C). Entrance holes are about 1 mm in diameter. When buds are completely excavated, they mine other buds before shoot elongation is completed. In most trees, terminal bud clusters die then the stem dies back to its lateral buds. Damage to either lateral bud is comparatively rare, but when it occurs, one shoot elongates rather than both (figure 57D). Leaves with tunneled petioles drop prematurely, and injured buds are aborted. Tunneled shoots frequently die back. Injury results in growth loss, stem deformities, and branchiness. Up to 91% of the forks in sugar maple have been attributed to attacks by this species and another shootborer, *Obrussa ochrefasciella* (Nepticulidae) (Miller and others 1978, Simmons and Knight 1973). In a study in northern Michigan, 22% of the terminal buds were killed by insects in a season, and only 1,037 of 2,000 young maples had an obvious leading stem (Tigner 1966).

**Control.** One braconid parasite—*Agathis annulipes* (Cresson) —has been recorded (Marsh 1979). Clipping and destroying infested buds and shoots should help to reduce infestations on

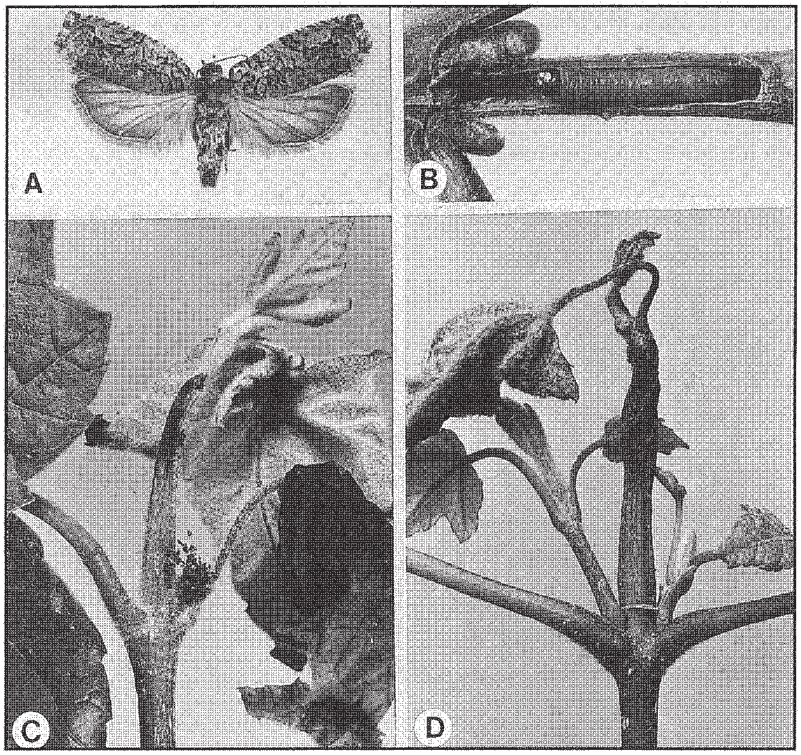


**Figure 57**—Proteoteras moffatiana, *[maple bud borer]: A, adult; B, larva; C, frass clump at base of dead petiole; D, terminal and one lateral dead allowing opposite lateral to elongate (A, specimen courtesy R. Hodges).*

high-value trees.

### *Zeiraphera claypoleana* (Riley)

[buckeye petiole borer]

**Hosts.** Buckeye. Ohio buckeye has been mentioned specifically, but other *Aesculus* species probably serve as hosts (Heinrich 1923).

**Range.** Recorded from Ohio, Missouri, Texas, and the Mississippi Valley (Forbes 1923, Heinrich 1923).

**Description.** ***Adult.*** Small, pale brownish gray moth heavily shaded with sage green; wingspan 12 to 15 mm (Forbes 1923, Heinrich 1923). Gray forewings greenish toward the base and crossed with black dashes and bars. Hindwings mouse gray with pale fringes.

**Biology.** Young larvae bore into the petioles of new expanding leaves (Forbes 1923, Heinrich 1923). Later, larvae vacate petioles and feed on withered leaves and sometimes the flowers.

**Injury and damage.** It bores in leaf petioles and flowers, but its damage is negligible. Larvae cause the leaves to wither and drop prematurely (Forbes 1923). Dissection of infested petioles reveals the larval burrows and sometimes the larvae.

**Control.** Controls have not been needed.

### *Spilonota ocellana* (Denis & Schiffermuller)

eyespotted bud moth (figure 58)

**Hosts.** Apple, cherry, hornbeam, hawthorn, quince, beech, oak, peach, pear, plum, laurel, blackberry, raspberry. Apple and cherry seem to be the favored hosts (Heinrich 1923, Oatman and others 1962, Porter 1924).

**Range.** Introduced into North America from Europe on apple and other nursery stock about 1840 (Porter 1924). Occurs from southern Canada south, throughout the apple-growing areas of the United States (Chapman and Lienk 1971).

**Description.** ***Adult.*** Small gray moth with wingspan of 12 to 16 mm (figure 58A) (Chapman and Lienk 1971, Heinrich 1923, Miller 1987, Porter 1924). Basal third of forewing and its outer edge with fringe hairs dark gray; middle creamy white and anterior margin with gray streak. Head and thorax dark or ash gray. ***Egg.*** Oval, quite flattened, bluntly pointed at one end, and 0.8 by 0.6 mm. Egg shell transparent and milky colored and faintly sculptured with polygonal markings (Frost 1927). ***Larva.*** Mature specimens about 9 to 14 mm long and dull brown except for shiny dark brown head, cervical shield, and anal plate (figure 58B). ***Pupa.*** Brown, about 7 mm long, and upper abdominal segments 2 to 7 each with two transverse rows of short spines.

**Biology.** Moths emerge June to September across the northern United States (Chapman and Lienk 1971, Miller 1987). Eggs are usually deposited singly on leaves; occasionally several eggs overlap. One female may deposit as many as 150 eggs. Eggs hatch in 8 to 10 days, and young larvae move to buds or the undersides of leaves, where they construct weblike shelters to feed. Some larvae burrow into the shoots for a few centimeters. In fall, larvae vacate their shelters and move to bark crevices or

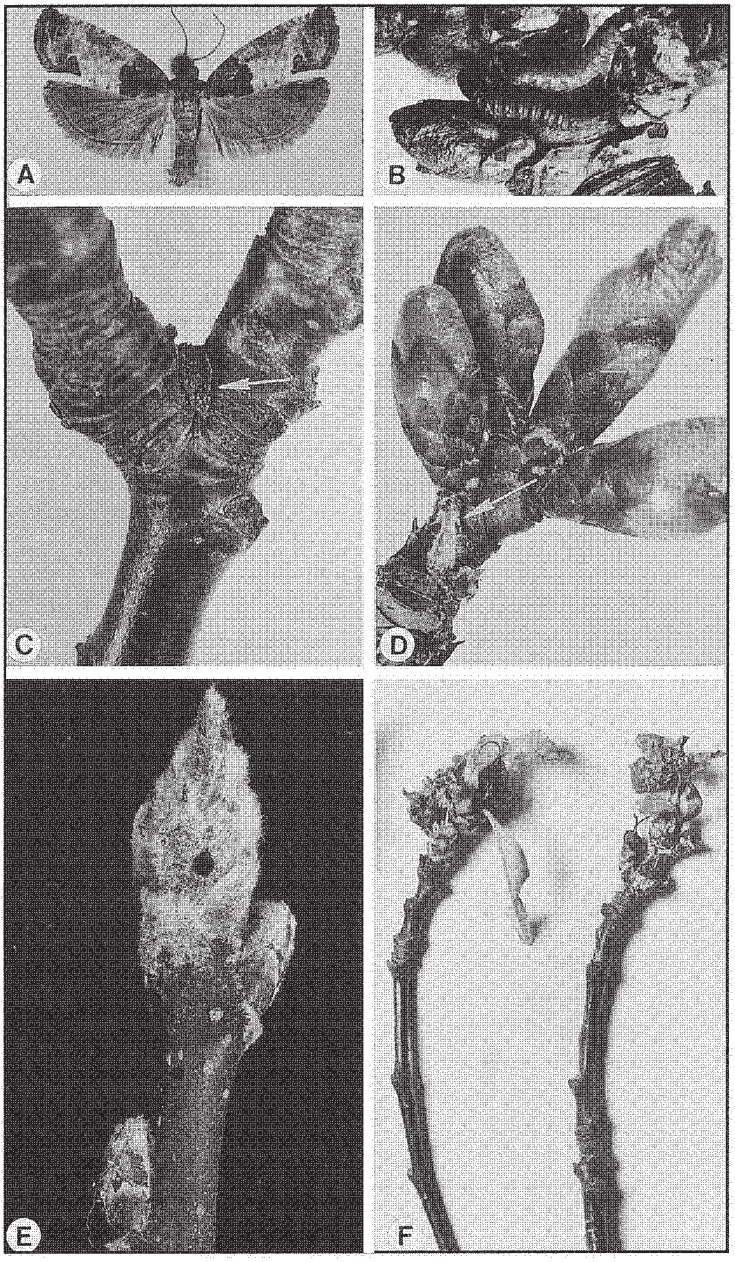


**Figure 58**—Spilonota ocellana, *eyespotted bud moth: A, adult; B, larvae; C, hibernaculum in twig crotch; D, hibernaculum opened to expose silken interior; E, larval entrance in bud; F, crumpled leaves at twig tip (B–F, courtesy E. Oatman).*

twig crotches, where they construct hibernacula 3 to 5 mm long for overwintering. Larvae leave the hibernacula in early spring and seek tender succulent buds and young foliage. Soon after, the larvae construct silken, tubular, crumpled leaf nests at twig tips as shelter while they feed. When fully grown, larvae pupate in silken chambers in feeding tubes or in curled leaves. Pupation is about 2 weeks. This moth undergoes one generation per year (Porter 1924).

**Injury and damage.** Close inspection before growth reveals small hibernacula in twig crotches and at the bases of buds (figure 58C and D). At bud swell in early spring, larvae burrow into buds and shoot tips, causing bud mortality and sometimes shoot-tip dieback (figure 58E) (Porter 1924). The most noticeable evidence of infestation is small, curled, dead, or partly dead leaves while the leaves are unfolding (figure 58F). Inspection at this time will reveal silken, tubular feeding nests among the folded, curled leaves, usually at twig tips. Newly set fruits occasionally are attacked by nearly-full-grown larvae, causing the fruit to drop prematurely or become disfigured (Porter 1924). Fruit set on apple trees has been reduced up to 80% in Nova Scotia (Frost 1927), and 92% of the fruit buds in cherry orchards in Wisconsin have been destroyed (Oatman and others 1962). Current spray schedules have reduced these losses markedly.

**Control.** There are at least 26 known insect parasites of this species (Arnaud 1978, Frost 1927, Krombein and others 1979). Birds, mites, mud wasps, and ground beetles have been listed as predators (Porter 1924). Insecticides applied during early spring when growth begins provide up to 92% control.

### *Epinotia solicitana* (Walker)

[birch shoot borer] (figure 59)

**Hosts.** Birch. Some evidence suggests white birch is preferred over gray birch, but both species are freely infested. Not found in other birch species (Smith 1946).

**Range.** Reported from Maine and New Jersey west to Minnesota and from Newfoundland west to British Columbia in Canada (Brown 1980, Heinrich 1923, Miller 1987, Smith 1946).

**Description.** ***Adult.*** Small grayish moth with wingspan of 12 to 16 mm (figure 59A) (Brown 1980, Miller 1987). Forewings grayish brown to light brown, darker on outer margins; post-basal area with white and brown scales mixed. Some specimens have scattered orange and dark brown scales on forewings with indistinct white or silvery lines. Hindwings and abdomen light gray without contrasting colors. ***Egg.*** About 0.56 mm long, slightly oval, shiny, and compressed. When first laid, eggs creamy white but contain orange internal spot 2 days before hatching and dark head of embryo visible through shell a few hours before hatching (Smith 1946). ***Larva.*** Five larval instars with mean head widths of 0.24 mm, 0.37 mm, 0.55 mm, 0.70 mm, and 0.92 mm for each instar (Smith 1946). Head tan to light brown with a narrow black band at top blending into larger black areas along sides

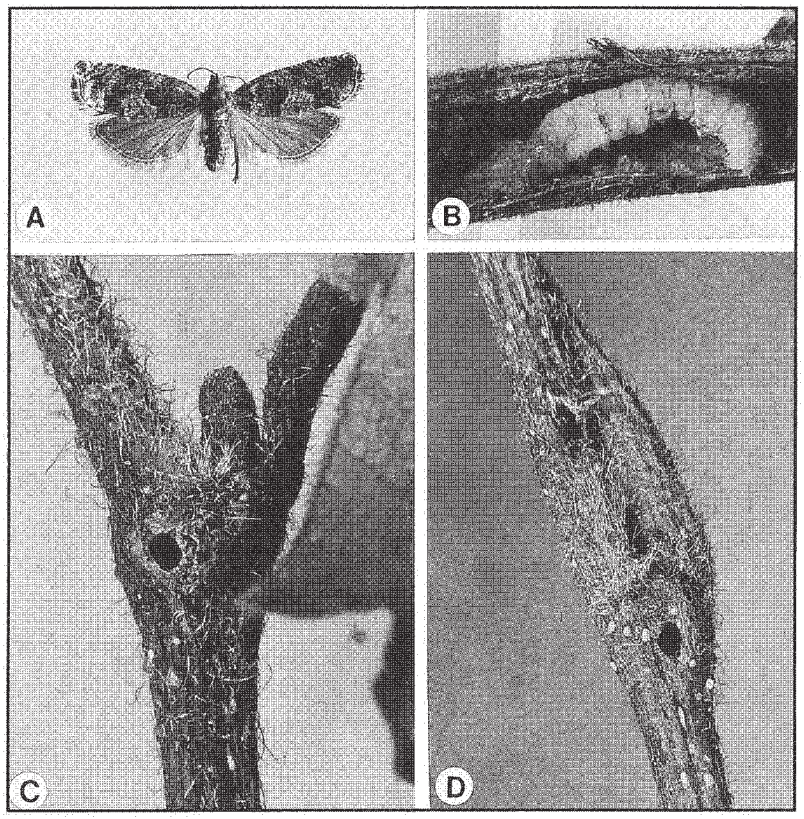


**Figure 59**—Epinotia solicitana, *[birch shoot borer]: A, adult; B, larva; C, infested swollen shoot; D, entrance hole near juncture of petiole and bud (A, specimen courtesy R. L. Brown).*

(figure 59B). Thorax and abdomen yellow green with faint brown markings on thorax.

**Biology.** Moths are in flight from May to July (Brown 1980). Eggs are deposited singly on the undersides of leaves. Numerous first-stage larvae in shoots have been observed by mid-July in New Brunswick (Smith 1946). Young larvae bore into current shoots from 2 to 5 mm above, and usually opposite, leaf petioles. After entry, larvae bore downward in the shoots toward new buds or slightly beyond. After becoming established in shoots, larvae construct brownish tubes 1 to 3 mm long, consisting of frass and silken threads, over the entrance holes. The openings of tubes are usually directed downward. Larvae vacate shoot galleries during the last instar and migrate to leaves that they fold over themselves. In September, most larvae can be found within leaf shelters, but some enter the soil to pupate. In New Brunswick, there is one generation per year.

**Injury and damage.** The first evidence of attack is dieback of small twigs, which is usually heaviest in the upper third of the crown. Young trees, in particular, may appear unthrifty, and injured shoots have noticeably smaller leaves. Close examination will reveal small tubes of frass, held together by silken threads, protruding from infested shoots, usually above new buds. Often, distinct swellings occur on shoots, particularly around the bases of infested buds (figure 59C). Injuries are most evident after leaves drop in autumn. Dead shrunken buds may remain on twigs, but most drop with falling leaves, exposing shallow feeding cavities or conspicuous holes (figure 59D). In some cases, frass tubes may remain after dead buds drop off, covering the larval feeding cavities (Smith 1946). Although not a tree killer, this pest causes significant shoot dieback and bud mortality. Damage surveys in New Brunswick revealed that from 2 to 20% of the current year's shoot growth and 5 to 28% of the new buds were killed in white birch stands; on gray birch, only 2 to 6% of the shoots suffered dieback, and 4 to 15% of the buds were killed (Smith 1946). Although damage from this insect is widespread, it usually is not serious.

**Control.** Several insect parasites—including *Angitia* sp., *Eulasiona comstocki* Townsend, *Microgaster canadensis* Muesebeck, *Phylodictus burgessi* (Cresson), and *Psalidopteryx psilocorsiphaga* Brooks—have been reared, but little is known of their effectiveness in natural control (Arnaud 1978, Smith 1946). Direct controls have not been investigated but may be needed occasionally to protect valuable trees.

### *Epinotia nisella* (Clerck)

[poplar branchlet borer]

**Hosts.** Alder, birch, maple, poplar, willow. Quaking aspen, black cottonwood, and balsam poplar have been mentioned as hosts (bud and leaf feeding), but larvae tunneling in branchlets have been found only in balsam poplar (Forbes 1923; Miller 1986, 1987; Wong and Melvin 1974).

**Range.** Generally distributed across the northern United States and southern Canada and in Europe (Forbes 1923, Miller 1986).

**Description.** ***Adult.*** Grayish brown

moth with wingspan of 13 to 16 mm (Forbes 1923, Miller 1987). The color pattern of forewings varies; most have dark markings of grayish brown or brownish black, often appearing as groups of black dots or bars at middle. Dorsal area sometimes orange. ***Larva.*** Yellowish white body with slightly darker pinacula, yellow head, and yellowish brown thoracic shield (MacKay 1959, Rose and Lindquist 1982). Mature larvae, with robust body and moderately developed anal fork, measure 10 to 12 mm long.

**Biology.** Adults are present from June to August and deposit eggs singly on host buds and twigs (Forbes 1923, Miller 1987, Wong and Melvin 1974). This insect overwinters either as eggs or as young larvae, possibly in hibernacula on twigs of host trees (MacKay 1959, Rose and Lindquist 1982). Eggs hatch and larvae become active during spring as flower buds are open. Initially, young larvae are bud miners and catkin feeders (Rose and Lindquist 1982, Wong and Melvin 1974). Later, larvae feed in leaf shelters or burrow into branchlets (Miller 1986). Larvae are present until early July. Tunneling larvae are solitary. Galleries measure up to 1.2 cm in length. For tunneling larvae, pupation reportedly occurs within the burrows (Miller 1986); for leaf-feeding larvae, pupation occurs on the ground (Wong and Melvin 1974).

**Injury and damage.** In Minnesota, gall-like swellings become noticeable on 2- to 4-cm-long branchlets of current growth by June 10 (Miller 1986). Tunnels usually extend basally in the branchlets but not into the previous year's growth. Exit holes are shrouded by silken sleeves 1 to 2 mm long containing incorporated frass pellets. Brown pupal skins may protrude from the silken sleeves at tunnel openings. This insect is best known as a feeder in catkins, buds, and leaves (Miller 1986, Rose and Lindquist 1982); only recently has it been reported as boring into branchlets (Miller 1986, 1987). Currently, injuries are of minor importance.

**Control.** Nothing is known of natural controls, and direct controls have not been needed.

### *Hendecaneura shawiana* (Kearfott)

[blueberry tip borer] (figure 60)

**Hosts.** Blueberry. Highbush varieties of blueberry seem to be the main and possibly only hosts of this little-known insect (Forbes 1923, Schaefers 1962, Still 1967).

**Range.** Known from New Hampshire, New York, and New Jersey west to Ohio and south to North Carolina (Heinrich 1923, Schaefers 1962, Still 1964).

**Description.** ***Adult.*** Mostly brown and white moth with wingspan of 9.5 to 14.5 mm (figure 60A) (Heinrich 1923, Schaefers 1962). Forewings predominantly brown but suffused with yellowish brown to orange on apical half. Silver-white spot extending half width of wing midway along posterior margin. Hindwings uniformly brown except for some fading along anterior margins. ***Egg.*** Oval, flattened, and somewhat paler than leaf surface when deposited (figure 60B). ***Larva.*** Slender and 1.5 to 2.0 mm long in first instar to slightly over 10 mm in

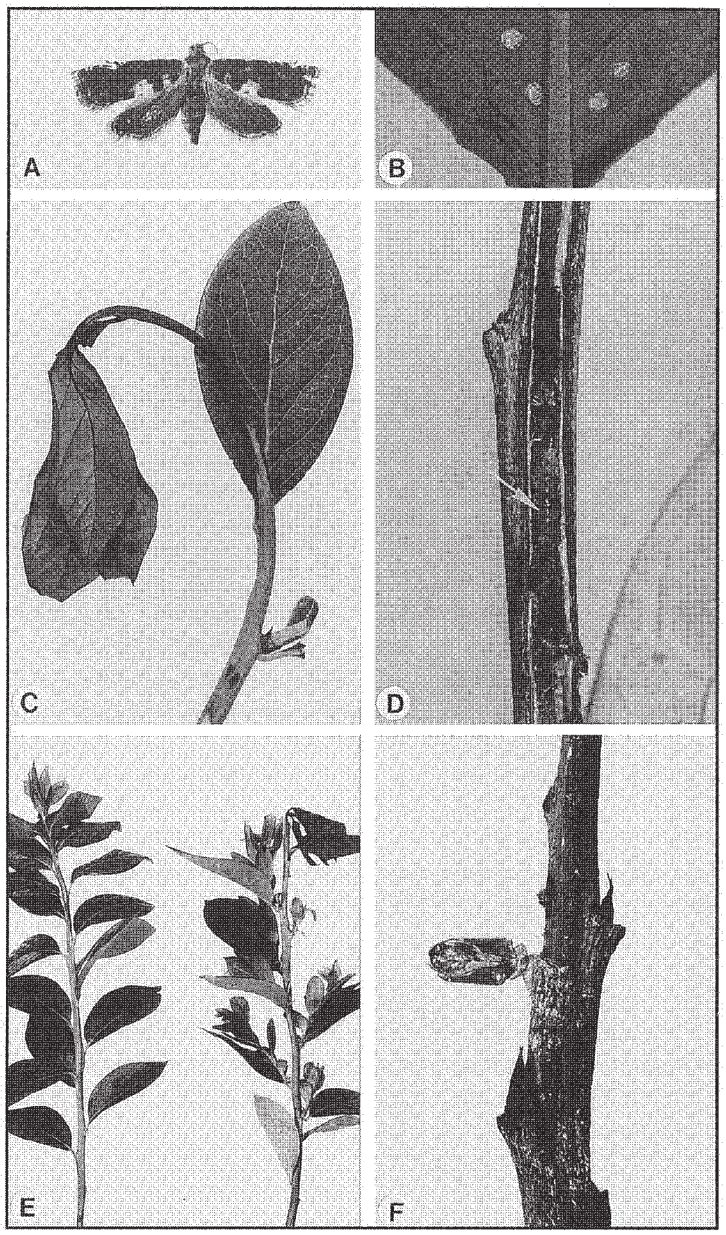


**Figure 60**—Hendecaneura shawiana, *[blueberry tip borer]: A, adult; B, eggs on underside of leaf; C, wilting shoot; D, burrow and larva; E, healthy shoot on left, infested shoot at right with dead tip and laterals beginning growth; F, pupal skin protruding from shoot (courtesy G. Schaefers).*

final instar (Schaefers 1962). Early instars pink with light brown heads but gradually become white with dark brown heads as development progresses. Each body segment possesses three lateral and four dorsal gray tubercles.

**Biology.** Adults emerge over a short period, mostly in early June (Schaefers 1962). Females deposit eggs singly on the lower surfaces of upper-shoot leaves. However, as many as 10 to 15 eggs are deposited on some leaves. Newly hatched larvae have been observed as early as June 10. Young larvae crawl from the leaves and burrow into the tender shoots 5 to 15 cm below the tips. As many as nine entrance holes have been found in the upper 15 cm of new shoots. Larvae may tunnel in either direction but mostly toward the base. Frequently, tiny channels encircle the shoots before the downward tunneling begins. Initially, several larvae may be found within a shoot, but cannibalism occurs, and by August only one larva survives. Larvae have five instars. Galleries are kept clean; excreta are deposited directly to the outside through the entrances. Completed galleries are 20 to 25 cm long. During November, mature larvae prepare emergence sites by chewing round exits 2 to 3 mm in diameter, leaving only a thin outer layer intact. Fifth-instar larvae overwinter within the galleries. About the time plants began to foliate in late April, larvae construct web channels within their burrows and pupate. Pupation continues into early June. This species has one generation per year.

**Injury and damage.** Earliest noticeable symptoms begin in June and consist of wilting and drooping of the current season's shoot tips (figure 60C) (Schaefers 1962). Close inspection reveals one or more tiny entrance holes in infested shoots. Frass with excrement pellets is ejected from the entrances, and by October, large amounts can be observed on the leaf surfaces immediately beneath infested shoots. Dissection of affected shoots shows burrows several centimeters long and one or more larvae (figure 60D). Affected shoots gradually darken, becoming purple and then black. Several lateral buds below the dead shoot tip begin growth, making the plant densely bushy (figure 60E). Brown pupal skins can be found protruding from exit holes in dead shoots during June (figure 60F). Economic impact has not been fully assessed, but in some instances, nearly 50% of growing tips have been killed. Secondary growth below points of injury increases plant density and shading, which delays the ripening of fruit and makes picking and pruning more difficult.

**Control.** Two hymenopterous parasites—*Bracon lutus* Provancher and *Macrocentrus delicatus* Cresson—and an entomogenous fungus have been observed, but nothing is known of their effectiveness in natural control (Marsh 1979, Schaefers 1962). The greatest factor limiting population growth presumably is cannibalism among larvae in shoots. Winter temperatures kill some larvae. Chemical controls may be needed in commercial blueberry production.

### *Hystricophora taleana* (Grote)

[indigobush twig borer] (figure 61)

**Hosts.** Indigobush. Indigobush is the only known host.

**Range**. Collected from Washington and Sharkey Counties in Mississippi and Chico County in southeastern Arkansas.

**Description.** ***Adult.*** Grayish brown moth that is somewhat bell shaped when wings at rest (Heinrich 1929). Leading apical half of forewing with three alternating orangish brown and metallic streaks; triangular orangish brown patch occurs in apical third of forewing, crossed by three metallic bars with distinct black dashes between bars. Leading basal half lighter than rest of wing. Hindwings uniformly grayish brown. Wingspans of 13 to 17 mm (figure 61A). Head and thorax semilustrous and uniformly colored orangish yellow to brown. ***Larva.*** Plump, pale white with brown head and light brown pinacula; about 14 mm long when mature (figure 61B). ***Pupa.*** Light brown and about 12 mm long (figure 61C).

**Biology.** Adult moths have emerged from plants kept in cages during May and June in Mississippi. Larvae develop in infested shoots and make only short tunnels in twigs and terminals. Pupation occurs in burrows, and the pupae move partly out of the shoots for moth emergence. Enlarged shoots have been found after May and June emergence, indicating delayed emergence or possibly more than one generation per year.

**Injury and damage.** Infested shoots appear stunted and curl apically. Apical portions of shoots often wither and die back. Clumps of fine brown frass may be present either at the shoot apex or at the juncture of a leaf petiole (figure 61D). Cutting open the swollen shoot reveals the burrow and sometimes the larva (figure 61E). Infested parts of terminals and twigs appear swollen and become greatly enlarged, sometimes reaching two or three times their normal diameter (figure 61F). Some shoots seem to be appropriated almost entirely for the development of larvae. Pupal skins often protrude from enlarged shoots (figure 61G). Heavy infestations can cause noticeable dieback of individual plants, but infestations are usually localized and rarely cause serious damage.

**Control.** Natural controls have not been observed, and direct controls have not been needed.

### *Gretchena bolliana* (Slingerland)

pecan bud moth

**Hosts.** Pecan, hickory, walnut. Pecan seems to be preferred (Heinrich 1923, Payne and others 1979).

**Range.** New York, south to Florida and west to Texas and Minnesota (Forbes 1923, Miller 1987).

**Description.** ***Adult.*** Small grayish moth with wingspan of 16 to 18 mm. Forewings powdery gray with three black streaks basally, medially, and apically, producing rather sinuate, longitudinal, broken, black stripe (Miller 1987). Upper front of head black overhung by prominent tuft of gray hairs between antennae (Forbes 1923). ***Larva.*** Slender, pale white, and about 12 to 14 mm in length when mature. Yellow head with black in ocellar area and black bar below each eye. Biordinal and triordinal crochets on anal and abdominal prolegs arranged in circle (MacKay 1959).

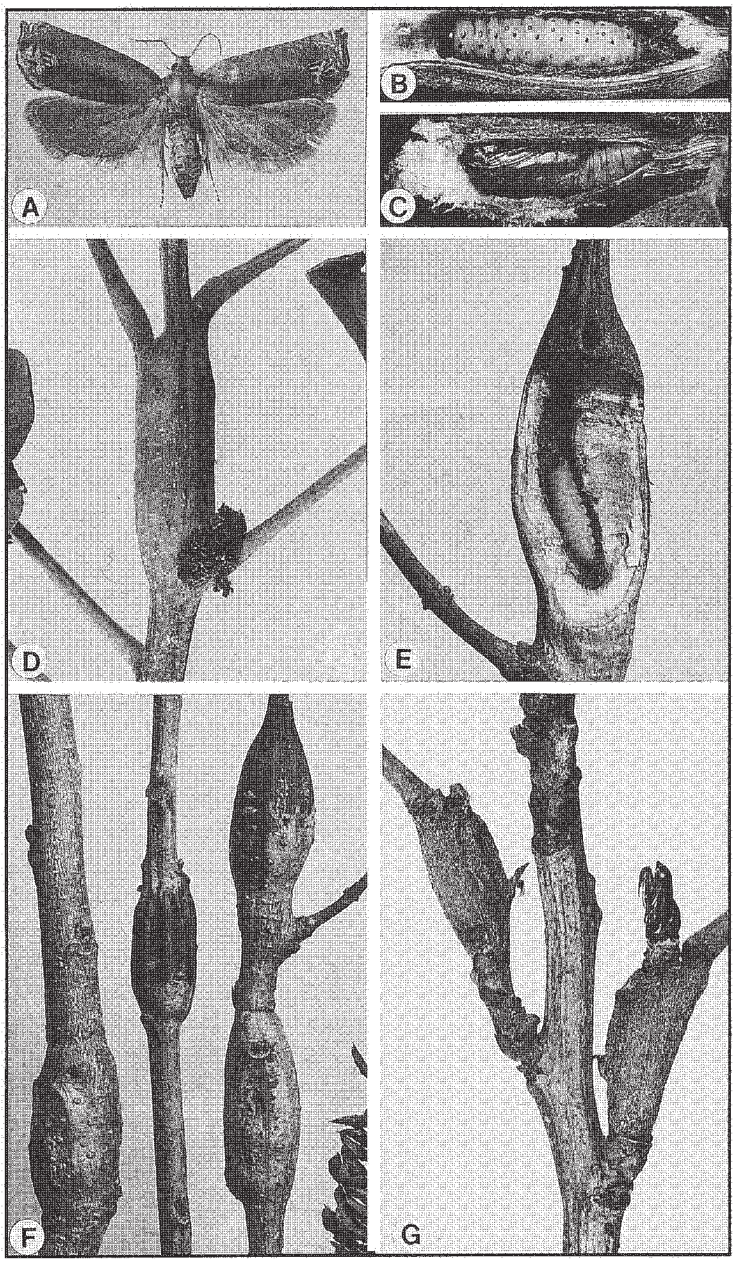


**Figure 61**—Hystricophora taleana, *[indigobush twig borer]: A, adult; B, larva; C, pupa; D, frass clump at base of petiole; E, larval burrow; F, gall-like swellings on stems; G, pupal skin protruding from enlarged stem.*

**Biology.** Adults apparently emerge in March and April. Females of overwintering generation deposit eggs during spring on twigs near unfolding buds. Moths of later generations often deposit eggs on upper surfaces of leaves (Matz 1918). Larvae of all generations bore into and destroy buds on young trees throughout the year, but on older nutbearing trees, they also feed on immature nuts in spring and on shucks in fall (Payne and others 1979). Larvae pupate in rolled-up leaves, buds, and occasionally under bark scales. Five to six generations annually have been reported in Florida (Matz 1918).

**Injury and damage.** Feeding injuries become noticeable during spring but may be observed throughout the growing season. Stunted or dead shoot tips and proliferation of new shoot growth near terminal buds, particularly on seedlings, are most noticeable evidence of infestation (Matz 1918). Larvae cause considerable damage to pecan nursery stock by feeding on the terminal buds, resulting in excessive branching and stunted growth. Serious injury is more common during dry seasons (Matz 1918). Damage to large trees is generally negligible.

**Control.** At least nine species of insect parasites have been recorded (Arnaud 1978, Krombein and others 1979). Proper cultivation of young nursery trees stimulates rapid growth and minimizes damage caused by this insect (Matz 1918). Insecticides may be needed occasionally to protect nursery stock and young outplantings but are seldom needed in older nut-producing groves (Payne and others 1979).

### *Ecdytolopha insiticiana* Zeller

locust twig borer (figure 62)

**Hosts.** Locust. Black locust probably the only host (Craighead 1950); wisteria has been mentioned as a possible host (MacKay 1959).

**Range.** Occurs throughout the eastern United States and recorded in Ontario and Manitoba (Craighead 1950).

**Description.** ***Adult.*** Grayish brown moth with wingspan of 17 to 26 mm (figure 62A). Forewings dark ashy brown with large, dull, pinkish white patch on outer part and several small blackish spots near middle of patch; hindwings uniformly gray (Craighead 1950, Miller 1987). ***Larva.*** Straw yellow initially, but becomes pink and finally crimson red and darkest along dorsal line (figure 62B). Head yellow brown or overlaid with darker pattern and thoracic shield honey yellow (Craighead 1950, MacKay 1959). Fully grown larva about 13 to 19 mm long. ***Pupa.*** Yellowish brown and 10 to 12 mm long and 2.6 to 3.0 mm wide (Bennett 1955). Cocoons consist of tough, fibrous, wool-like covering of humus, mineral soil, and dried leaves spun together with silk. Cocoons bean shaped, oval, and 7 by 13 mm.

**Biology.** Two generations occur per year in the southern range extending to Washington, DC, and west to Illinois; only one generation occurs per year in its northern range (Craighead 1950). First generation moths emerge from early May to late June; second generation moths emerge

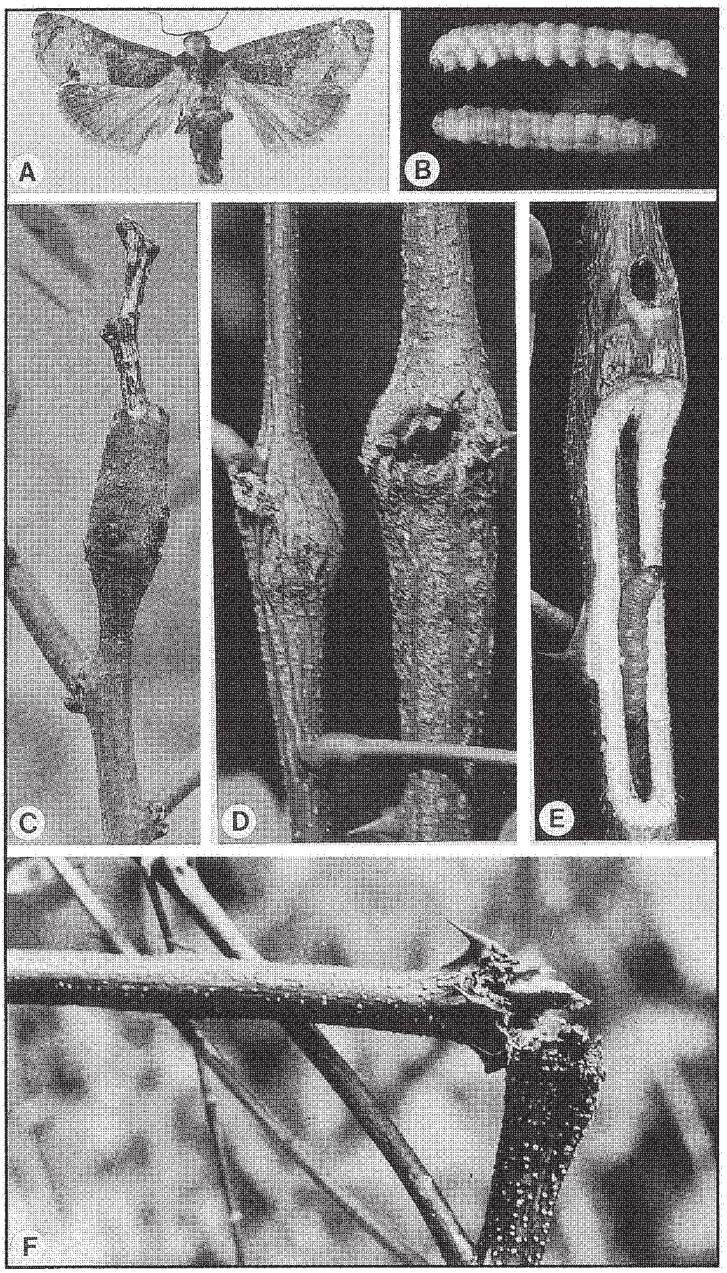


**Figure 62**—Ecdytolopha insiticiana, *locust twig borer: A, adult; B, larvae; C, gall-like swelling on terminal; D, swollen stems with entrance hole and frass; E, stem split to expose gallery; F, broken stem.*

from early July to early September (Thoeny and Nordin 1988). Eggs are deposited on the bark and hatch in 5 to 6 days. About 90% of the larval entrances in current shoots begin at thorn bases (Harman and Berisford 1979). Only the succulent apical portions of elongating terminals or branches are susceptible to attack. By late summer, increased lignification of shoots limits the succulent host material; nonetheless, some new attacks can be found late in the season. Larvae have seven instars. In the middle of its north-south range, larvae may be found in nearly all instars from late May to early November. In Maryland, however, the number of larvae in shoots drops sharply after August. Ninety percent of the galleries contain only one larva, 6% contain two larvae, and 4% contain three to five larvae (Harman and Berisford 1979). Where two or more larvae inhabit a gallery, they are usually at opposite ends or in different parts of the gallery. In some cases, separate galleries intersect. When they do, larvae commonly weave silken barriers to isolate themselves. Larvae may tunnel in either direction within a stem, but most tunnel apically. One larva can burrow in the shoot center for 10 cm or more. Development during summer when succulent food is plentiful can be completed in about 20 days. Second-generation borers overwinter as larvae. When mature, larvae leave shoots and move to the ground where they pupate under leaf litter. Pupal chambers are flattened, bean-shaped cocoons of evenly cut pieces of fallen leaves "sewn" together and lined with silk (Heinrich 1926).

**Injury and damage.** The injury can be recognized by elongate gall-like swellings 2.5 to 7.5 cm long on current stem and twig growth (figure 62C). An entrance hole is present at the upper or lower end of swelling from which frass is extruded by the feeding larva (figure 62D) (Garman 1916). As galls age, they sometimes crack open, creating an unsightly appearance (Shenefelt and Benjamin 1955). Even when the injury does not produce noticeable swellings, frass clumps adhering to the stems indicate attack. Cutting into injured twigs near attack sites exposes larval galleries in the centers (figure 62E). Yellowish to bright crimson larvae within the galleries leave no doubt about their identity (Garman 1916). Injury is often so severe in small stems and twigs that they die or break (figure 62F). Damage may be quite serious in nurseries or in plantations, where sprouts or young reproduction occurs. When attacks are heavy, tree growth is retarded and ornamentals may be disfigured. Often 50 to 75% of twigs are infested (Shenefelt and Benjamin 1955). Counts of black locust in separate areas in Maryland found twig borers in more than 80% (Harman and Berisford 1979).

**Control.** Two insect parasites—*Hypomicrogaster ecdytolophae* (Muesebeck) and *Pristomerus euryptychiae* Ashmead—have been reported, but little is known of their impact on populations (Carlson 1979, Marsh 1979). Mechanical and cultural controls by removing and destroying shoots containing larvae or raking leaves to destroy prepupae have been recommended (Craighead 1950, Garman 1916, Shenefelt and

Benjamin 1955). Such controls may be feasible for ornamental trees, nurseries, and other valuable settings but probably are of little use in forests. Residual insecticides properly timed could control the pest but have not been investigated.

### *Grapholita molesta* (Busck)

Oriental fruit moth (figure 63)

**Hosts.** Peach, plum, apricot, nectarine, cherry, apple, quince, pear, persimmon, photinia. Peach is preferred, followed by the other stone fruits (Neiswander 1936). Quince is sometimes seriously injured.

**Range.** Introduced into the United States from Japan on flowering cherry in Washington, DC, in 1912 or 1913 (Chapman and Lienk 1971). Within 10 years, had spread over the eastern United States and by the 1950's had become an important pest from coast to coast (Rice and others 1982, Snapp and Swingle 1929).

**Description**. ***Adult.*** Small grayish brown moth with predominant colors of gray, dusky blackish brown, and grayish brown (figure 63A) (Chapman and Lienk 1971). Wings figured with chocolate brown, wavy lines; wingspan 11 to 13 mm (Garman 1930, Metcalf and others 1962). ***Egg.*** Semitransparent to white, circular to oval, with upper surface convex and minutely roughened, 0.7 mm in diameter (Garman 1930). ***Larva.*** Varies from white or light brown to reddish pink and 10 to 12 mm long when mature (figure 63B). Head yellowish brown and overlaid with black markings. Yellowish thoracic shield occasionally marked with green or brown. Dark brown anal fork distinct with four or five spines. Crochets on fleshy abdominal prolegs of equal length and arranged almost in circle (MacKay 1959). ***Pupa.*** Uniformly brown and about 5 mm long (Garman 1930). Anterior margins of dorsum of abdominal segments 2 to 9 possess row of thick spines.

**Biology.** In Connecticut, moths of the overwintering generation emerge from mid-May to mid-June (Garman 1930); in central Georgia, they emerge early March to late April (Snapp and Swingle 1929). Females deposit up to 200 eggs singly, usually on the undersides of leaves within 15 cm of twig tips (Chapman and Lienk 1971). Eggs hatch in 3 to 4 days during midsummer. Larvae of the first and second generations feed mostly in shoot tips; those from later generations are found mostly in fruits. Larvae in twigs feed in the pith until mature; two or three twigs may be tunneled by a larva. In fruits, larvae excavate cavities of considerable size and fill them with excrement. Pupation occurs under bark scales on the tree trunk or on the ground in silken cocoons covered with bits of bark or other debris. The species has six to seven generations per year in Georgia (Snapp and Swingle 1929), but only four generations in Connecticut (Garman 1930).

**Injury and damage.** The first signs of attack are wilting foliage and dieback of twig tips (figure 63C) soon after trees blossom in spring (Metcalf and others 1962). Small entrance holes sometimes are visible (figure 63D), and clumps of frass are common around entrance holes (figure 63E). When

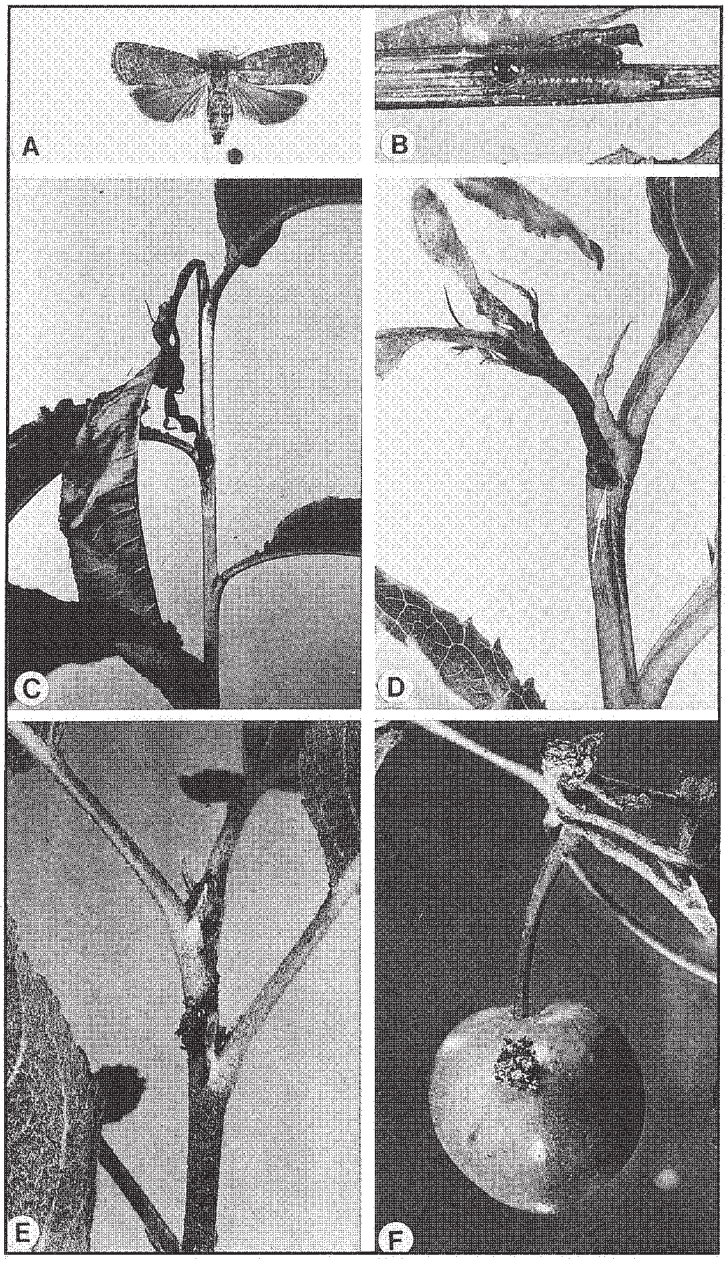


**Figure 63**—Grapholita molesta, *oriental fruit moth: A, adult; B, larva; C, wilting shoot tip; D, entrance hole in shoot; E, frass at entrance site; F, frass clump on infested fruit (A, specimen courtesy R. Hodges; B, E, & F, courtesy NY Agricultural Experiment Station).*

fruits begin to ripen, larvae frequently leave twigs and enter fruits (figure 63F) to complete development. Because of numerous internal larval galleries, after packing, the fruits deteriorate rapidly from brown rot. Boring injuries to twigs in spring are similar to those caused by *Anarsia lineatella*, but larvae of the former are pinkish or creamy white with brown heads, whereas the latter are entirely brown. The Oriental fruit moth is one of the most destructive pests of fruit trees, often destroying 50 to 70% of all terminal buds and growing tips and damaging significant amounts of fruit, particularly peach, apple, and quince (Garman 1930). Heavy shoot mortality can cause stunting, bushy growth, and asymmetry.

**Control.** Numerous insect parasites have been recorded (Arnaud 1978, Garman 1930, Krombein and others 1979). One braconid wasp—*Macrocentrus ancylivorous* Rohwer—mass colonized and released in orchards at 500 adults per acre, reduced injury 50 to 80% (Metcalf and others 1962). Early maturing varieties of trees have been planted to minimize injury in some areas. Cultivating orchards to a depth of 10 cm, 1 to 3 weeks before trees flower, will kill many overwintering larvae in the soil. Insecticides are usually needed to control infestations. Sex pheromone traps have been used in California to accurately determine moth emergence periods for timing insecticide applications and other controls (Rice and others 1982).

### *Grapholita packardi* Zeller

cherry fruitworm

**Hosts.** Apple, plum, cherry, blueberry, peach, hawthorn, rose, pyracantha. Cherry seems to be preferred, followed by apple and hawthorn (Brown and others 1983, Chapman and Lienk 1971, Heinrich 1926).

**Range.** New Hampshire south to Florida and west to Texas and Colorado (Chapman and Lienk 1971).

**Description.** ***Adult.*** Small grayish moth with wingspan of 8.0 to 10.5 mm (Heinrich 1926). Wings mottled grayish brown with indistinct dark brown band across middle. Resembles *G. molesta*, but male smaller with patch of black scales on hindwing (Chapman and Lienk 1971, Heinrich 1926, Miller 1987). Head, thorax, and abdomen densely covered with long dull gray to brown hairlike scales (Sanderson 1901a). ***Larva.*** Elongate, subcylindrical, and varies from dirty cream to light yellowish brown, tinged with pink, often giving rose appearance (Chapman and Lienk 1971, Sanderson 1901a). Larvae boring in rose tips are green (Forbes 1923). Head and spiracles shiny and light brown. Mature larvae up to 9 mm in length (Chapman and Lienk 1971).

**Biology.** Cherry fruitworms overwinter as full-grown larvae, usually in silklined tunnels in the tips of twigs, and less commonly in silken hibernacula covered with bark and soil particles in bark crevices on trunks and limbs (Sanderson 1901a). Pupation occurs in burrows or hibernacula during spring. Adult moths emerge 2 weeks later and deposit eggs, preferably on or

near terminal leaf buds. Larvae mine through the terminal buds and eventually 25 to 50 mm down the shoots. Broods develop in about 6 weeks. Larvae of the second and third broods are most destructive to buds and shoots (Slingerland and Crosby 1919). Three generations are produced in Arkansas and Delaware; two generations, in New York (Chapman and Lienk 1971). Late season brood larvae commonly feed in fruit.

**Injury and damage.** During heavy infestations, this fruitworm repeatedly attacks both the terminals of young trees and branch ends of older trees until growth is stunted, giving a knotty appearance that sometimes affects the symmetry of trees (Forbes 1923, Sanderson 1901a). Late in the season when top shoots begin hardening-off, basal sprouts attract the borer (Sanderson 1901a). Infestations often are detected most easily during winter, when one can observe numerous dead twig tips, frequently with leaf petioles attached (Slingerland and Crosby 1919). Also, overwintering larvae may be in their twig tunnels or in silken hibernacula on the bark. This species has been very destructive to shoots and fruit in apple orchards and to shoots in nurseries in Delaware, Maryland, Virginia, and Missouri (Slingerland and Crosby 1919).

**Control.** As many as 50% of the hibernating larvae are killed by the hymenopterous parasitoid *Bracon mellitor* Say (Slingerland and Crosby 1919, Sanderson 1901a). Six other insect parasites—*Chelonus grapholithae* McComb, *Euderus cushmani* (Crawford), *Glypta rufiscutellaris* Cresson, *Phanerotoma fasciata* Provancher, *Psychophagus omnivorus* (Walker), and *Scambus transgressus* (Holmgren)—have been recorded (Burks 1979, Carlson 1979, Marsh 1979). New orchards should not be established adjacent to heavily infested old orchards. However, if it is necessary to plant young trees close to old orchards, then all infested basal sprouts, terminals, and branch tips should be pruned and destroyed during winter. Chemical control may be needed in areas having a history of heavy damage.

### *Cydia gallaesaliciana* (Riley),

[willow gall moth]

**Hosts.** Willow. Willows are the only known hosts (Forbes 1923).

**Range.** Recorded from Massachusetts and New Jersey west to Michigan and south to Illinois and Missouri (Forbes 1923, Heinrich 1926, Miller 1987).

**Description.** ***Adult.*** Small grayish moth with white head and thorax and dark gray abdomen (Heinrich 1926, Miller 1987). Forewings grayish white except for dark brown basal spot on inner margin, and brownish black apical third from middle of inner margin to near apex. Hindwings light gray, paler than forewings, and gray beneath.

**Biology.** Adults present during June and July (Forbes 1923). The larvae are gallmakers but may also invade galls made by other insects to feed and develop (Heinrich 1926).

**Injury and damage.** Larvae produce small slender galls on the twigs of host plants (Forbes 1923, Heinrich 1926). Damage is negligible.

**Control.** Controls are not needed.

### *Episimus tyrius* Heinrich

[maple tip borer] (figure 64)

**Hosts.** Maple, cherry. Red maple appears to be favored (Kimball 1965), but silver maple and Carolina laurelcherry also serve as hosts (Brown and others 1983, MacKay 1959).

**Range.** New York south to Florida and west to Mississippi (Forbes 1923, Heinrich 1926, Kimball 1965).

**Description.** ***Adult.*** Small whitish gray moth with orangish markings and wingspan from 12 to 15 mm (figure 64A) (Forbes 1923). Orange-tinted forewings shaded with reddish orange along outer margins; hindwings dark gray. ***Larva.*** Pale white, sometimes with reddish or greenish pigmentation (figure 64B) (MacKay 1959). Head yellow with dark brown ocular areas, and thoracic shield yellowish brown. Late instars 12 to 14 mm long.

**Biology.** Evidence of infestation has been observed at Stoneville, Mississippi, as early as April 21. Larvae were collected from April to early June and again in September in Mississippi and in July and August in Georgia and South Carolina. Pupation occurs within the gallery, in silk-tied leaves, or under debris away from the tip as early as late May. Adult emergence in Mississippi has been recorded from late April to mid-July, and in Florida from May to mid-August (Brown and others 1983).

**Injury and damage.** The tender unfolding leaves at shoot tips begin to wilt, droop, and wither (figure 64C). These small leaves are typically pulled downward and tied together with silk around the shoot tips to form shelters (figure 64D). The leaves and tips gradually turn brown and then black. Examination of infested plants will reveal an entrance and gallery in the shoot tips (figure 64E). It usually kills the growing tips. Ornamental and nursery-grown maples have suffered during some years in Mississippi, but damage usually has been scattered and light.

**Control.** Evidence of predation, probably by woodpeckers, on larvae has been observed in Mississippi (figure 64F). Direct controls are seldom needed.

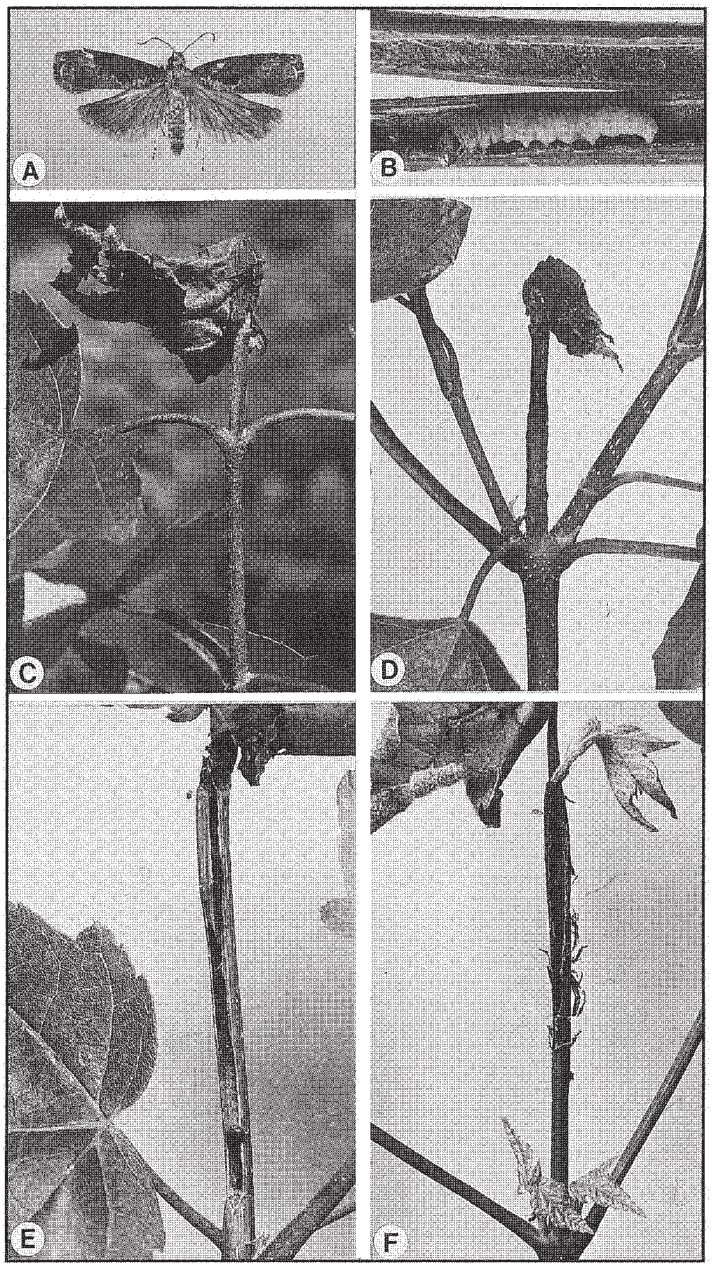


**Figure 64**—Episimus tyrius, *[maple tip borer]: A, adult; B, larva; C, withering shoot tip; D, silk-tied leaves around dead terminal; E, gallery exposed; F, stem shredded by predator, exposing gallery.*

## Family Pyralidae—Snout Moths

The pyralids are members of a large, diverse family, varying considerably in appearance, wing venation, habits, and other distinguishing characters. Adults are mostly moderate sized, drab-colored moths with elongate to triangular forewings (Borror and others 1981, Furniss and Carolin 1977). The proboscis is well developed and the maxillary palpi project forward and upward, presenting a snoutlike appearance. Larvae are elongate with abdominal prolegs on segments 3 to 6 and 10. They vary in color from dull white, purplish brown, pinkish gray to greenish brown with brown heads, thoracic shields, and pinacula. Many are shootborers, and some tunnel in the phloem and cambium of branches, trunks, root collars, and roots. Some also feed in fruits, nuts, and galls. The shoot and cambium species girdle and deform many seedlings and young trees and are particularly damaging to ornamentals, forest nurseries, and plantations.

### Genus and Species



### *Euzophera ostricolorella* Hulst

[root collar borer] (figure 65)

**Hosts.** Yellow-poplar. Yellow-poplar is the preferred, possibly only, host. Magnolia reported to be attacked (USDA FS 1985), but this is questionable. (It seems more likely that a related borer in magnolia, *E. magnolialis* Capps, was mistakenly identified as *E. ostricolorella*.)

**Range.** Probably occurs throughout the natural range of yellow-poplar in the eastern United States. Found as far north as New York and as far south and west as Louisiana and Arkansas.

**Description.** ***Adult.*** Typical pyralid moth with somewhat elongate rectangular forewings and wingspan of 29 to 40 mm (figure 65A). Forewings generally purplish brown with grayish dusting and wing tips bordered with long gray scales. Hindwings pale smoky black with fine dark marginal line (Heinrich 1956). ***Egg.*** Dull red, oblong, measures about 0.9 by 0.5 mm. ***Larva.*** Newly hatched about 3 mm long, but range from 23 to 33 mm when fully grown (Hope and Pless 1979). Mature larva mostly dull white and head dark brown with heavily chitinized black areas (figure 65B). Prominent spiracles and anal shield of larva smoky brown (Schuder and Giese 1962).

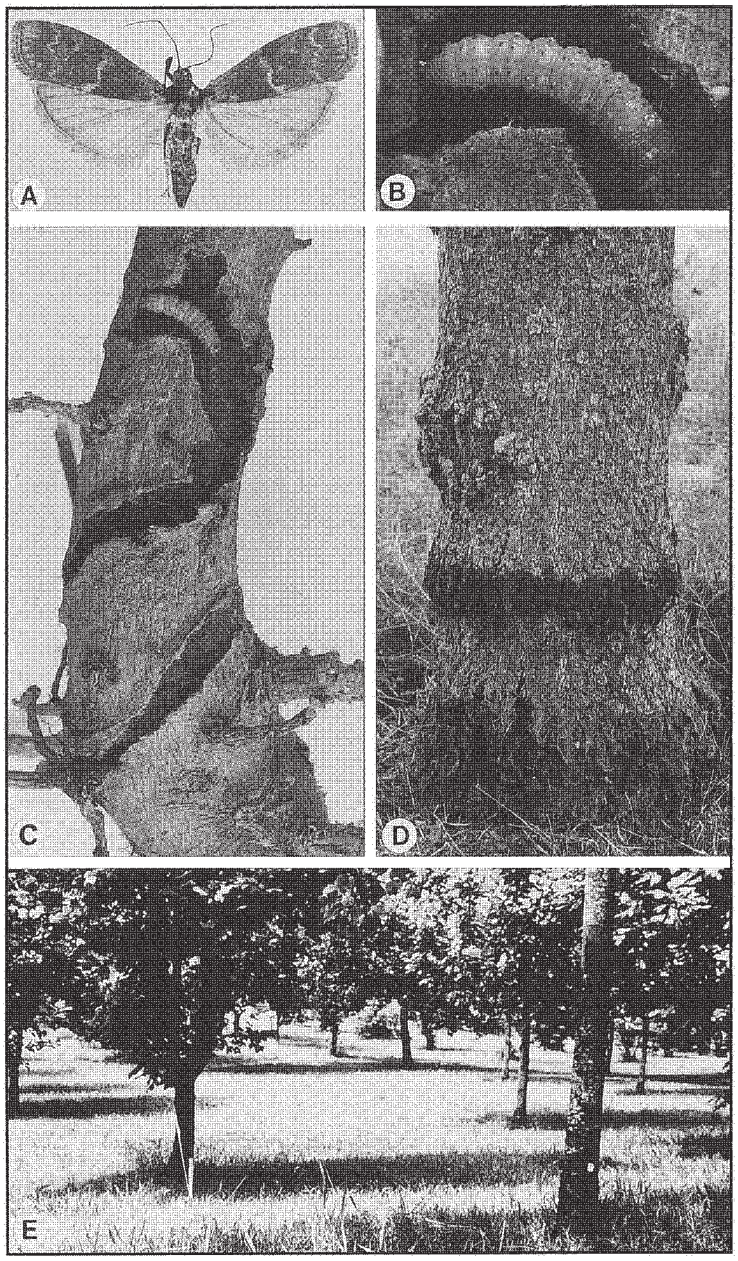


**Figure 65**—Euzophera ostricolorella, *[root collar borer]: A, adult; B, larva; C, spiral burrow in sapling; D, tree heavily infested at root collar; E, heavily infested yellow-poplar seed orchard (E, courtesy C. Pless).*

Larva with a pair of jointed legs on each thoracic segment and fleshy prolegs ending in numerous hooked spines (crochets) on abdominal segments 3 to 6 and 10; consequently, very mobile within and outside gallery.

**Biology.** Moths of the overwintering generation in Tennessee emerge from April 27 to June 8, with a peak in mid-May; moths of the summer generation emerge August 27 to October 10, peaking in mid-September (Hope and Pless 1979). Moths of the mid-September emergence have been caught in appreciable numbers in light traps in yellow-poplar seed orchards in Tennessee. Average lifespan of adult moths is about 8 days. Females oviposit at night in bark crevices. Eleven females studied in Tennessee laid an average of 39 eggs (Hope and Pless 1979). Eggs may be scattered over the bark up to 15 cm above ground level, and as many as 38 eggs have been observed on a tree (Hope and Pless 1979). Larval tunnels extend vertically or spirally above or below ground, seldom exceed 10 cm in length, and are about 6.3 mm in diameter. Most larval galleries are confined to the inner bark, and when they occasionally reach the wood surface, the larvae do not etch it except when forming the pupal chambers. Gallery walls and surrounding wood are stained black (Hay 1958). Small larvae are often found burrowing adjacent to old galleries; their tunnels may originate in the old-gallery cavities, and they push coarse frass into the old galleries but not to the bark surface (Hay 1958). In Tennessee, duration of overwintering broods is about 210 days, whereas summer generations are completed in as few as 91 days. Mature larvae cut emergence holes through the bark and cap them with bark particles and silklike materials. Larvae then return to pupal chambers in the inner bark, spin cocoons, and pupate for about 28 days. There are two complete generations from Tennessee southward and one generation per year in its northern range.

**Injury and damage.** Injury is often difficult to detect because most attacks are in a relatively narrow zone at the tree base, from about 16 cm above ground to about 7 cm below (figure 65C, D, and E). Trees from about 3 cm diameter at root collar to sawlog size may be attacked. Burrows in seedlings and saplings often spiral around the root collars (figure 65C). Recent larval attacks on vigorous trees may be accompanied by black ooze and frass from entrance holes (Hay 1958) and on heavily infested trees, bark just above the soil line may be loose, cracked, and appear fire scorched (figure 65D) (Schuder and Giese 1962). Because larval burrows are entirely in the succulent inner bark and cambium, they can be observed easily by cutting away the outer bark. White, loosely spun cocoons may also be observed in larval burrows. Numerous small exit holes, made by pre-pupal larvae for the adults' emergence, can be found at the bases of infested trees, but no empty pupal cases (skins) protrude from the holes, as they do with some wood-infesting moths. Another symptom of heavy infestation is a gradual yellowing of foliage and

crown dieback. Open-grown trees, such as those in seed orchards, are particularly susceptible (figure 65E). This borer was not recognized as an economic pest until 1954, when it was reported killing yellow-poplars, particularly trees larger than 25 cm in diameter, on a 2,228-ha timber tract in Kentucky (Hay 1958). Considerable dieback and mortality of yellow-poplars has been reported in northern Indiana woodlots (Schuder and Giese 1962). Also, extensive borer damage was found in 2.5-cm-diameter yellow-poplar grafting stock in seed orchards; as many as 10 larvae were observed in some trees (Churchwell 1966). A canker disease—*Fusarium solani* (Martins, [Appel and Wollenweber])—associated with borer damage killed 19, 22, and 50% of the high-value trees in three west Tennessee seed orchards (figure 65E) (Hope and Pless 1979). When attacks occur on the bole, callus tissue and ingrown bark produce small defects in the wood (Hay 1958). However, because few attacks occur above stump height, degrade is not a serious problem. Moreover, most defects in logs can be slabbed off or peeled away in veneer, and the result is minor value loss in wood products.

**Control.** In Tennessee studies, the hymenopterous parasites *Microcentrus delicatus* Cresson and *Venturia nigricoxalis* (Cushman) destroyed 18% of the overwintering brood and 36% of the summer brood (Hope and Pless 1979). Studies in a large timber tract in Kentucky showed that nearly every infested tree had signs of woodpecker predation (Hay 1958). In yellow-poplar timber stands where all heavily infested, weakened, and dying trees were removed in summer salvage cuts, the broods in stumps completed development and moved to uninfested residual trees (Hay 1958). Thus, brood-tree salvage cuts have not controlled this borer. However, spraying the basal trunk with oil-based residual insecticides has provided good control of established borers and prevented new attacks (Hay 1958, Schuder and Giese 1962). Insecticides recommended for peachtree borers have also provided effective control in yellow-poplar seed orchards (Churchwell 1966). Fumigants used in sawdust mounds around the root collars have also provided good control (figure 65E) (Hope 1978). Systemic insecticides and sticky-trap treatments generally have been ineffective.

### *Euzophera semifuneralis* (Walker)

American plum borer (figure 66)

**Hosts.** Plum, peach, cherry, Chinese plum, pear, mountain-ash, persimmon, apple, white mulberry, sycamore, apricot, walnut, pecan, olive, basswood, poplar, sweetgum, yellow-poplar, gingko, elm, oak. Although this borer has a wide range of hosts, plum and other drupe and pome fruit trees appear to be favored. However, pecan and sweetgum are sometimes heavily attacked all along the Gulf Coast region.

**Range.** Generally distributed throughout the United States, Canada, and parts of Mexico (Heinrich 1956).

**Description.** ***Adult.*** Gray moth with wingspan of 17 to 28 mm (figure 66A)

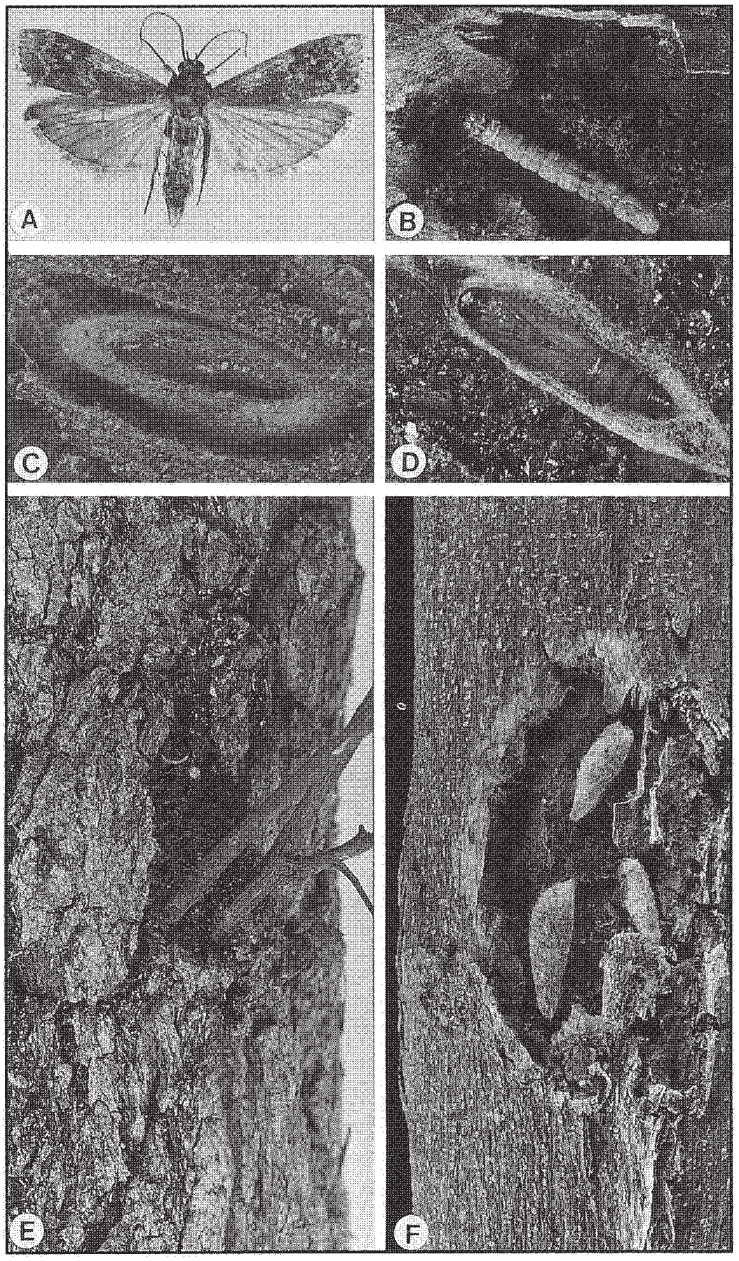


**Figure 66**—Euzophera semifuneralis, *American plum borer: A, adult; B, larva in burrow; C, cocoon with pupa inside; D, pupa; E, clump of dark frass on bark; F, white silken cocoons in burrows under bark.*

(Blakeslee 1915, Forbes 1890, Heinrich 1956). Forewings grayish brown with broad, wavy band of black and brown markings across outer third. Hindwings smoky with black marginal lines fringed with white. Head, thorax, legs, and abdomen dusky gray with bright bronze reflections. ***Egg.*** Oval, measures about 0.59 by 0.42 mm and opaque white and coarsely punctate. Mature egg dull red, but about 24 hours before hatching changes to dirty white with larval head plainly visible through the chorion and slight depression appearing in center (Blakeslee 1915). ***Larva.*** White with dark brown head when newly hatched; reddish color of alimentary tract clearly visible through integument. Mature larva with dark brown head, thoracic shield, plate, and tubercles, and reaches about 25 mm (figure 66B). Body color varies from dark pink or reddish gray to dusky green (Blakeslee 1915, Forbes 1890, Sanderson 1901b). ***Pupa.*** Ten to 12 mm long, possesses stout, hooked spines on end of abdomen and enclosed in white silken cocoon (figure 66C and D). Newly transformed pupa pale olive green but gradually changes to light brown, then to dark brown, and finally almost to black.

**Biology.** Moths in southern range emerge from April through September (Blakeslee 1915, Pierce and Nickels 1941). Females deposit 12 to 74 eggs singly or in small groups in cracks, crevices, or wounds in bark, and under bark scales; in the absence of such niches, eggs are loosely glued to smooth bark surfaces (Blakeslee 1915). Moths live 1 to 3 weeks but deposit most eggs during the first 2 to 4 days. Egg incubation requires 8 to 14 days. Larvae bore into bark at scars, wounds, or crevices where bark scales offer concealment and protection. Larval mines are very shallow and irregularly shaped, cave-type burrows between wood and the outer bark. Galleries usually are loosely packed with frass. Considerable frass is expelled from larval entrance holes (Sanderson 1901b). Larval feeding lasts 30 to 38 days. In the South, larvae of all sizes may be present throughout most of the growing season (Blakeslee 1915). They pupate in burrows under the bark in loosely spun silken cocoons partially surrounded by dark excrement pellets. The pupal stage lasts 24 to 33 days for the overwintering brood but may be completed in as few as 10 days for summer broods. Up to five generations occur annually in central Texas (Pierce and Nickels 1941), but only two generations in Virginia (Blakeslee 1915), Delaware (Sanderson 1901b), and Michigan (Biddinger and Howitt 1992).

**Injury and damage.** New attacks can be detected by oozing sap or "weepy spots" on tree trunks (Kelsey and Stearns 1960). The most obvious signs of infestation are accumulations of dark brown or black frass on bark at attack sites (figure 66E) (Blakeslee 1915, Pierce and Nickels 1941). The frass typically consists almost entirely of black excrement pellets that stick or adhere loosely together with sap exudate and silken threads. Attacks are limited largely to trees with mechanical wounds, frost damage, sunscalds, disease cankers, pruning wounds, and recent grafts and buds. Disease

cankers and other diseased patches of the cambium or partially girdled stem are sites favored for invasion. Lifting dead bark killed by disease or other injury exposes accumulations of frass, larvae, and larval burrows extending into the living tissue (figure 66F). The presence of one or more loosely woven cocoons of white silken threads is characteristic. White silken cocoons distinguish this borer from *Synanthedon scitula* and other sesiids, which have dark brown or black cocoons usually covered with dark frass. It attacks trees and branches of all sizes but most commonly the lower trunks, especially just above groundline. Usually not of widespread economic importance, but it can seriously damage trees in some localities. It is a major pest of cherry orchards in Michigan (Biddinger and Howitt 1992). In the late 1950's and 1960's, it seriously damaged many London plane trees in eastern cities. It prefers trees in poor health, particularly those with mechanical injuries and fungal diseases (Blakeslee 1915). Larvae on pecans may injure or destroy either grafts or patch-buds; in a Texas orchard, it destroyed two-thirds of 1,200 grafts and one-third of 3,000 patch buds (Pierce and Nickels 1941). Also, it girdles the base of sprouts that previously have been patch-budded; in a Texas pecan grove, it infested 322 of 616 sprouts on 24 top-worked trees. Deadening and felling trees and cutting back branches before top-working lower vitality and lead to maintenance of high populations of this borer (Pierce and Nickels 1941).

**Control.** Because eggs and first-stage larvae occur at or near the bark surface and later stages develop just under outer bark, this borer is subject to considerable parasitism and predation. Hymenopterous parasites—including *Idechthis nigricoxalis* (Cushman) and *Mesostenus thoracicus* (Cresson) in Virginia and *Itoplectis marginatus* (Prov.), *Mesostenus gracilis* Cresson, and *Pimpla* sp. in Georgia—destroy upwards of 14% of the larvae (Blakeslee 1915, Carlson 1979). Woodpeckers, ants, and larvae of *Tenebroides corticalis* Melsh. effectively reduce populations. Use of recommended pruning, grafting, and cultivation procedures and good cultural practices in general help to prevent infestations. Tree shakers used on nut-and-fruit-producing trees should be properly adjusted or padded to avoid bruising and breaking the bark. Prompt trimming and painting of bark wounds with tar-based tree paint provide some control (Wiener and Norris 1983). Pesticides give mixed results but have provided control when properly timed and carefully applied (Kelsey and Stearns 1960, Pierce and Nickels 1941, Wiener and Norris 1983).

### *Euzophera magnolialis* Capps

[magnolia borer] (figure 67)

**Hosts.** Magnolia. Southern magnolia mentioned specifically as the host, but other magnolias probably also serve as hosts (Kerr and Brogdon 1958).

**Range.** Reported from Florida, Georgia, Louisiana, and North Carolina (Capps 1964) and probably occurs throughout the natural range of southern magnolia in the United States.

**Description.** ***Adult.*** Grayish brown

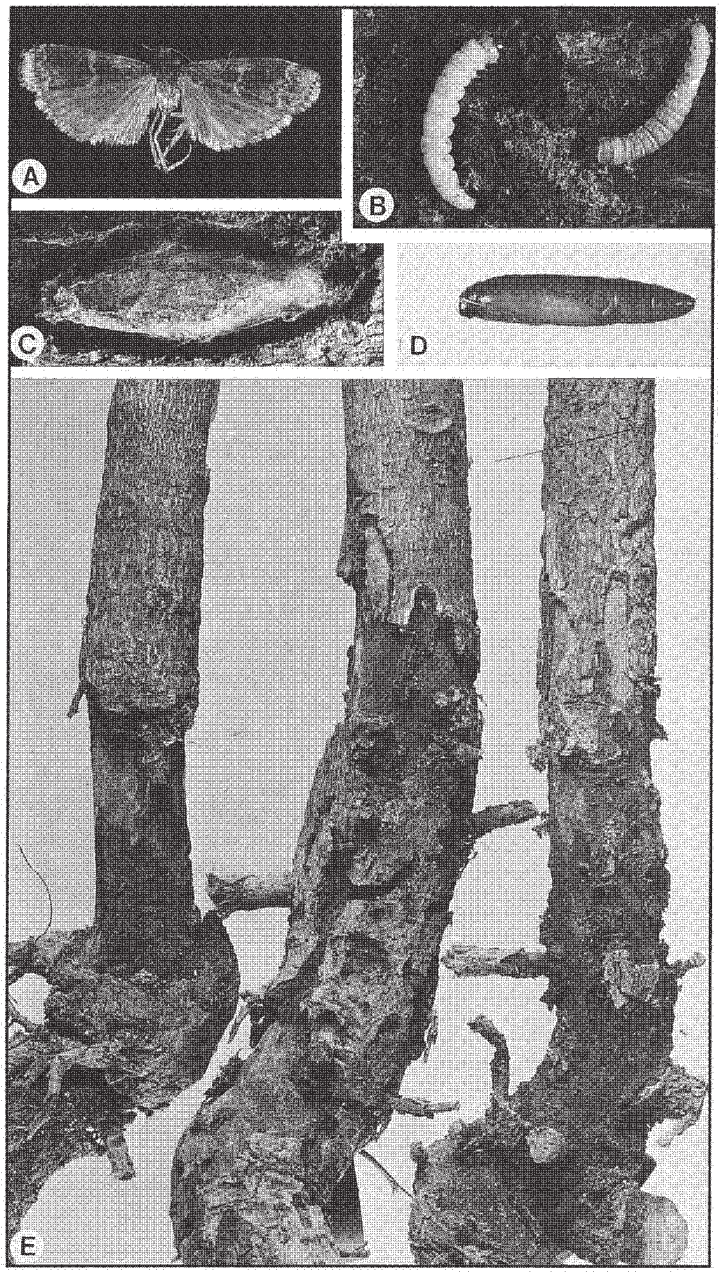


**Figure 67**—Euzophera magnolialis, *[magnolia borer]: A, adult; B, larvae in burrows; C, white silken cocoon in pupal cell; D, pupa; E, extensive injury at root collar of nursery-grown magnolias (A, specimen courtesy R. Hodges; B-E, specimens courtesy R. Mizell).*

moth with wingspan about 25 mm (figure 67A) (Capps 1964). Forewings purplish brown with grayish dusting predominating over basal half and from outer margin inward almost to postmedial line. Transverse postmedial line dull white and sinuate; an antemedial line of similar color. Hindwings pale, smoky black with fine dark lines along terminal margins. Head, thorax, and abdomen brownish black tinged with purple.

***Larva.*** White to dull white and about 28 mm long when mature (figure 67B). Brown body slightly flattened and tapers gradually posteriorly. Brown head with broad, dark black, lateral band from stemmata to hind margin. Thoracic and anal shields and pinacula brownish to amber. Three pairs of jointed legs on thorax. Fleshy prolegs on abdominal segments 3 to 6 bear complete ring of triordinal crochets. ***Pupa.*** Brown, hooked spines on last abdominal segment, measuring about 12 mm long and enclosed in white silken cocoon (figure 67C and D).

**Biology.** Large larvae and pupae are found as early as February 1, in Florida (Kerr and Brogdon 1958). Also, larvae and pupae (10 larvae, 3 pupae) were removed from infested plants at Cairo, Georgia, on February 3.* Thus, they overwinter as mature larvae and pupate in January and February. In Florida, adults emerge February to late March (Capps 1964, Kerr and Brogdon 1958). Larvae bore in at the root collar and feed in the cambium beneath the bark. Irregular burrows extend in all directions from about 6 cm above ground to about 8 cm below soil level. Larvae feed in separate burrows that commonly intersect. Little else is known of its biology, but the life cycle and number of generations are probably similar to that of its close relative, *Euzophera ostricolorella*, which has two generations per year (Hope and Pless 1979, Kerr and Brodgon 1958).

**Injury and damage.** To date, young trees (particularly nursery plantings 1 to 2 m tall) have been most heavily damaged. Yellowing of foliage and premature leafdrop are often the earliest symptoms. Even though larvae mine under the bark, rarely penetrating the wood, damage is often difficult to detect because the winding galleries are at the base of the tree, often below the soil (Kerr and Brogdon 1958). However, infestations in the inner bark are easily found by pulling soil away from the base and exposing gallery entrances (figure 67E). One or more white silken cocoons containing pupae or pupal skins may be found under the bark. Heavily infested trees are often completely girdled at the root collar and killed. The magnolia borer severely damages or kills many young southern magnolia trees, 1 to 2 m in height in commercial nurseries in northeast Florida (Kerr and Brogdon 1958). Also, it has infested up to 40% of potted magnolias in nursery plantings in Cairo, Georgia.*

**Control.** Nothing is known of natural enemies. Cultural practices that maintain good tree growth should help to minimize injury. Moderately damaged plants will often

*Mizell, R. F. February 3, 1986. (personal communication). University of Florida, Monticello, FL.

recover if given good cultural maintenance and protection. Chemical control with properly timed insecticides will help to prevent and control infestations.

### *Acrobasis demotella* Grote

walnut shoot moth (figure 68)

**Hosts.** Walnut, hickory, pecan. Black walnut is preferred (Neunzig 1972). Hickories, especially bitternut and pignut hickories, are sometimes attacked; pecan is infested less frequently.

**Range.** Throughout the range of its hosts, but scarce to absent in the warmer regions of the United States even though an occasional host tree may be present (Neunzig 1972). Reported from Ontario south to North Carolina and west to Missouri and Michigan (Martinat and Wilson 1978).

**Description.** ***Adult.*** Brownish gray moth with wingspan of 20 to 24 mm (figure 68A) (Heinrich 1956). Forewings have brownish gray background with three reddish brown, contrasting patches basally, medially, and distally (Heinrich 1956, Martinat and Wallner 1980). Head and thorax dirty white with pink or reddish suffusion darker in females than in males. ***Egg.*** Elliptical, ivory white, convex above and flattened below, with reticular pattern on surface; 0.28 by 0.71 mm (Martinat and Wallner 1980). ***Larva.*** Purplish brown, 17 mm long when mature, with head capsule width 1.39 to 1.52 mm (figure 68B). Reddish brown to brown head with dark brown spots. Dorsal body surface purplish brown with greenish undertones; underside pale, sometimes mostly green. Thoracic shield yellow brown with dark brown lateral margins. Pinacula pale brown to brown and same color as or darker than surrounding integument (Martinat and Wallner 1980, Neunzig 1972). ***Pupa.*** Reddish brown and 7.5 to 8.5 mm long (figure 68C). Head small and rounded distally. Prothorax and mesothorax distinctly wrinkled (Neunzig 1972).

**Biology.** Adults emerge from late May through mid-June in Missouri (Kearby 1978), during the first half of June in Massachusetts (Neunzig 1972), and from late June to late July in Michigan (Martinat and Wallner 1980). Females deposit eggs singly on the undersides of expanding leaflets, usually adjacent to the leaf midrib on the basal half (Martinat and Wallner 1980). Laboratory-reared eggs hatch after 11 days' incubation, but incubation is probably longer in the field. Newly hatched larvae wander a short distance from the egg chorions and construct trumpet-shaped enclosures of frass "plastered" onto a silken framework. The larvae feed on the lower epidermis, skeletonizing leaflets. First- and second-instar larvae move to buds in fall and construct gray hibernacula 1.1 to 1.5 mm long on the terminal buds or in the axils of lateral buds (figure 68D). Larvae overwinter in hibernacula, emerge in spring about the time of bud swell, and third-instar larvae feed in expanding buds (figure 68E). As shoots elongate in April and May, fourth-instar larvae enter shoots, usually where leaf petioles are attached. Larvae bore downward in the pith of the shoot for 2 to

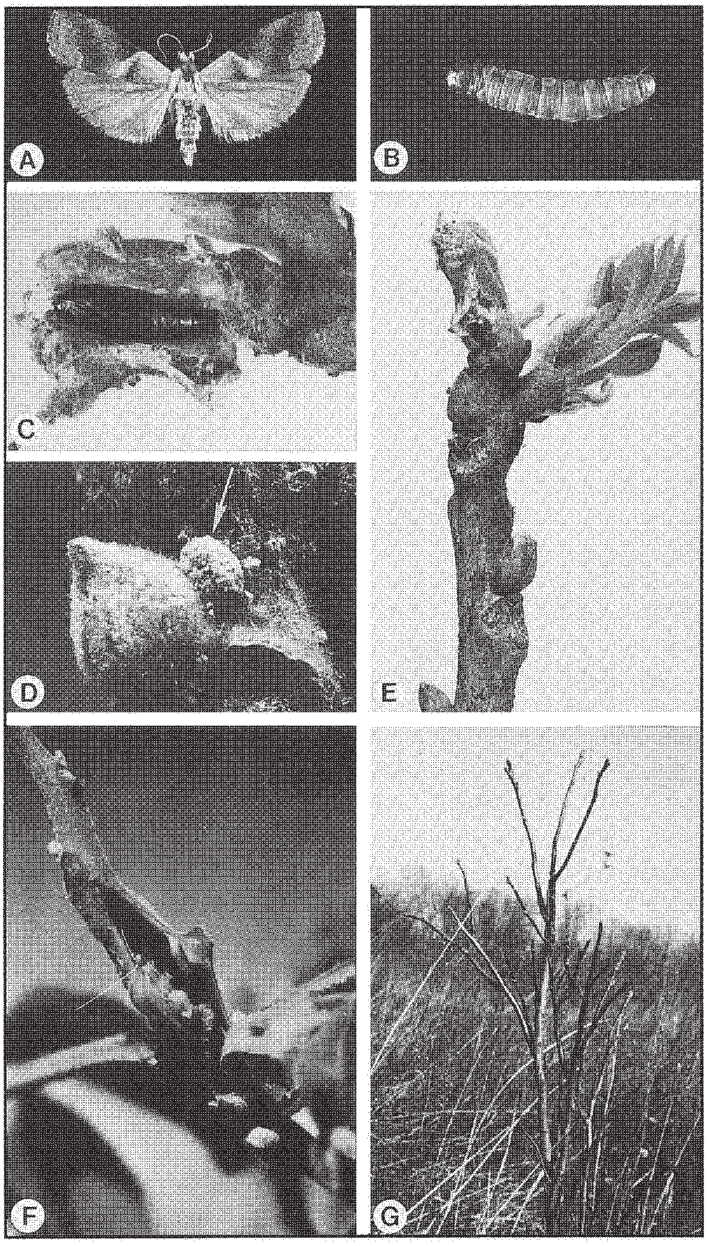


**Figure 68**—Acrobasis demotella, *walnut shoot moth: A, adult; B, larva; C, pupa inside shoot; D, hibernaculum in bud axil; E, infested terminal bud failing to elongate; F, hollowed shoot; G, young tree damaged by attacks (A, specimen courtesy R. Hodges; D & G, courtesy G. Simmons; F, courtesy B. Weber).*

5 cm, and small, loose mounds of frass mixed with silk collect at entrance holes. Shoot tips beyond the larval tunnels usually wilt and die. Mature (fifth-instar) larvae complete feeding in shoots by late April in Missouri (Kearby 1978) and by mid-June in Michigan (Martinat and Wallner 1980) and then vacate shoots through entrance holes. Mature larvae pupate just below the soil surface in thin cocoons composed of soil particles. One generation per year has been recorded in Missouri (Kearby 1978) and in Michigan (Martinat and Wallner 1980).

**Injury and damage.** In spring, early-stage larvae bore into swelling, unfolding buds and terminal-bud clusters (figure 68E). From one to all buds in a cluster may be killed, resulting in blunt shoots or forked tops (Kearby 1978). Wilting and dying foliage on small succulent shoots is further evidence of attack. Infested shoots may be completely hollow (figure 68F). Small mounds of frass and silk collect near larval entrance holes in buds and in leaf axils (Neunzig 1972). If the attacked bud or shoot is not killed immediately, it is usually hollowed out and subject to breaking by wind (Weber and others 1980). On young black walnut trees, repeated attacks cause forking, branching, reduced growth, and ultimately misshape trees and greatly diminish their value for timber (figure 68G) (Martinat and Wallner 1980). The basal 4 to 6 m of a black walnut must be straight and free of forks and excessive branches to qualify as a prime sawlog or veneer log; thus, damage by this borer when trees are in the seedling and sapling stage can be ruinous (McKeague and Simmons 1979).

**Control.** No parasites have been reared from larvae and pupae, which is surprising because numerous parasites have been reared from the closely associated species, *A. juglandis* (LeBaron) (Martinat and Wallner 1980, Neunzig 1972). To minimize infestation culturally, new black walnut plantings should be relatively isolated from existing stands of *Carya* and *Juglans*. Where trees are grown for high-quality timber or veneer logs, corrective pruning is an effective alternative to insecticides (McKeague and Simmons 1978, 1979). Managers should prune soon after the current season's damage has been done and new shoots have grown enough to make it possible to leave the best of several shoots. Proper timing will permit pruning wounds to heal by the end of the growing season. Workers should leave the strongest shoot that is closest to the original damaged terminal to reestablish apical dominance and maintain a straight trunk and good form. Insecticides have been used successfully in Michigan to protect young black walnut plantings (McKeague and Simmons 1978).

### *Acrobasis nuxvorella* Neunzig

pecan nut casebearer (figure 69)

**Hosts.** Pecan is the principal (possibly only) host (Neunzig 1970).

**Range.** Occurs throughout the range of its host from Florida west to Texas and northward to southern Illinois (Neunzig 1972).

**Description.** ***Adult.*** Grayish brown

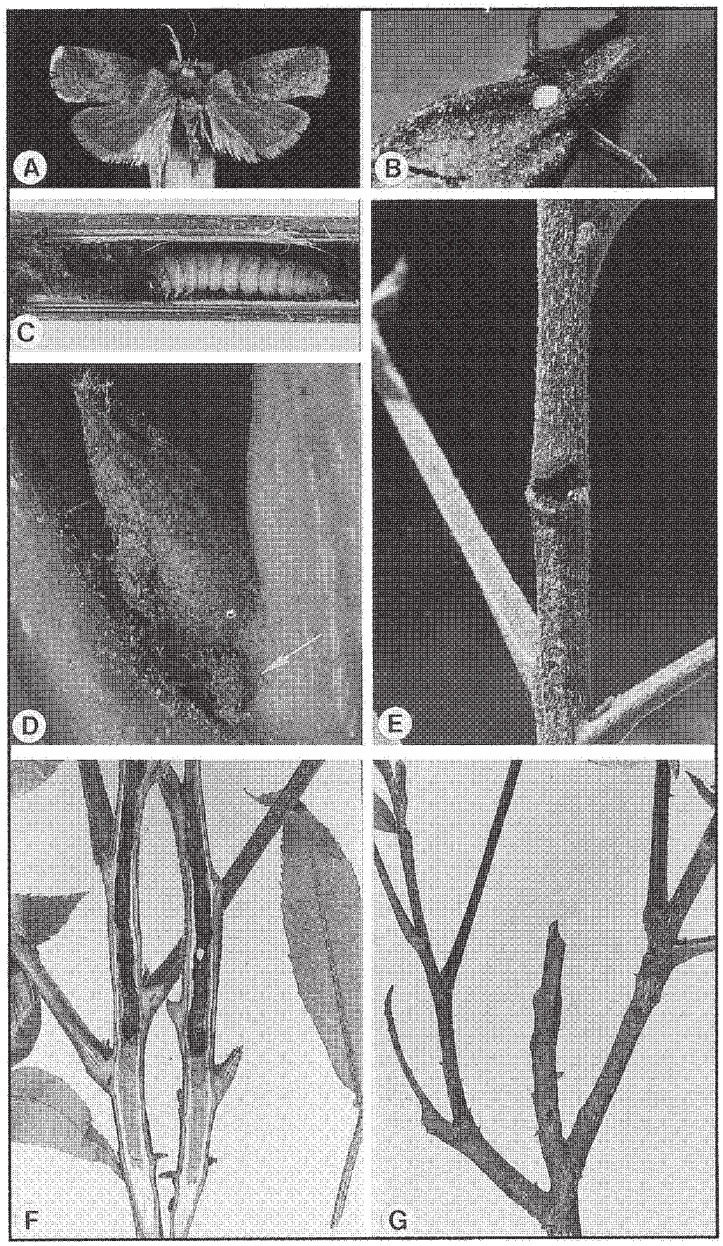


**Figure 69**—Acrobasis nuxvorella, *pecan nut casebearer: A, adult; B, egg on nutlet; C, larva; D, hibernaculum at base of lateral bud; E, entrance hole in shoot; F, hollowed shoot; G, terminal shoot killed (A, specimen courtesy R. Hodges; B & D, specimens courtesy V. Calcote; C, specimen courtesy E. Brown).*

moth with body length of about 7.6 mm and wingspan from 12 to 19 mm (figure 69A) (Neunzig 1972). Forewings light (Roseberg and Schaffner 1964) to dark gray (Payne and others 1979) with ridge of dark brown scales across wing about one-third distance from base. Head and body brown. ***Egg.*** Elliptical, convex above, flattened below with fine surface reticulations; about 0.56 by 0.34 mm (figure 69B). Greenish white when deposited, becoming reddish as incubation progresses (Gill 1925). ***Larva.*** Pale to dark purplish brown with greenish undertones and 11 to 17 mm long when mature (figure 69C). Head yellowish brown with brown to dark brown spots coalescing into bandlike maculations. Thoracic and anal shields brownish yellow to brown with some dark brown maculations. Pinacula pale brown. Circle of biordinal crochets on prolegs on abdominal segments 3 to 6 and 10 (Neunzig 1972). ***Pupa.*** Yellowish brown and 6.9 to 8.1 mm long. Head slightly wrinkled with distal region slightly produced anteriorly and rounded.

**Biology.** The number of generations per year varies: from four in Texas, three and occasionally a partial fourth in Florida and south Georgia, to three in eastern North Carolina (Neunzig 1972). Adults of the overwintering generation emerge from late April to mid-May in Texas and during the last 3 weeks of May in eastern North Carolina. Within a few days of emergence, females deposit their eggs (usually one or two per site) near the base of the calyx lobes of newly formed nuts. On hatching, the larvae feed and develop in small nuts. Moths emerge through the enlarged larval entrance holes, leaving empty pupal skins in the nuts (Gill 1925, Neunzig 1972). Over its range, first-generation adults emerge late May to July. After a brief period, first-generation adult females lay eggs on the nuts, about the time nuts are half grown. Moths of the second generation emerge from these eggs from late July through early September, and oviposit on large nuts and sometimes on leaves and buds. Third-generation larvae feed sparingly on the husks and reach their second stage with fall weather; they move to twigs to construct hibernacula near lateral buds, often between a bud and the twig (figure 69D). Occasionally, this borer partially or entirely completes a fourth generation in the southern range. Larvae overwinter in hibernacula and, as buds swell in spring, feed on them and then bore into expanding shoots. If shoots have elongated rapidly before larval attack, larvae enter at the base of leaf petioles. Some larvae of the overwintering generation pupate in injured shoots; others move to pupate under the platelike bark scales (Gill 1925, Neunzig 1972).

**Injury and damage.** Main external evidence of shoot infestation is wilted or dead small shoots soon after bud burst and during elongation in spring. Entrance holes may or may not contain small masses of frass and silk (figure 69E). Green shoots may be completely hollow (figure 69F) and often break from the wind. Larval galleries can be seen in the broken ends. Both terminal and side shoots may be killed, adversely

affecting tree form (figure 69G). The most severe injury, however, is the hollowing out of newly formed nuts by first-generation larvae. The nuts are small, blackened, and usually have a small hole near their bases covered by silk webbing and frass. Some later-generation larvae also feed on succulent shoots and leaf petioles; bud injury is usually light (Gill 1925). Although common throughout the Pecan Belt, populations of this borer are greatest in its western range, particularly in Texas and Oklahoma, where moderate losses sometimes occur (Payne and others 1979).

**Control.** Parasites are important natural controls; over 30 species of insect parasites have been reared from larvae and pupae (Neunzig 1972). Insecticide application is recommended when 3% or more of the previous year's shoots are infested with overwintering larvae or when there is a history of serious infestation (Payne and others 1979, 1982).

### *Acrobasis caryivorella* Ragonot

[hickory shoot moth] (figure 70)

**Hosts.** Hickory, pecan, walnut. Most abundant on mockernut hickory, pignut hickory, and pecan (Neunzig 1972). Occasionally found on walnut.

**Range.** Occurs in southern Canada, throughout the eastern United States (USDA FS 1985), and as far west as New Mexico (Heinrich 1956).

**Description.** ***Adult.*** Grayish marked moth with wingspan of 19 to 24 mm (figure 70A) (Heinrich 1956). Forewings dark bluish gray with grayish white and orangish red patches. Hindwings whitish gray, darker in females. ***Larva.*** Purplish green with thorax darker than abdomen; from 13 to 19 mm long when mature (figure 70B). Thoracic and anal shields brown with dark brown maculations. Pinacula on thorax and abdomen transparent to pale brown, contrasting in color with surrounding integument (Neunzig 1972). ***Pupa.*** Reddish brown, 8.6 to 10.3 mm long. Head wrinkled; distal region distinctly produced anteriorly.

**Biology.** Moths of the overwintering generation usually emerge in April and May in Florida and Texas, late May in North Carolina, and July in Connecticut (Neunzig 1972). First-, second-, and third-generation moths have been reared during late June to July, August, and September to October, respectively, in Texas (Nickels 1951). Larvae from a summer generation have been collected during August in North Carolina and Connecticut (Leiby 1925, Neunzig 1972). Females deposit eggs in masses of 10 to 70 on the upper or lower surface of leaflets. Small larvae of summer broods feed on the underside of leaflets and form frass tubes along midribs. Large larvae pull and tie together with silk several leaves, which they partially eat. They pupate in chambers of frass and silk, usually in the leaf enclosure near the shoot base. Larvae of the last summer brood overwinter in hibernacula 3 mm long attached either to buds or to the tree trunk several centimeters above or below the soil surface (Leiby 1925, Nickels 1951, Phillips and others 1960). In early spring, larvae leave the hibernacula and enter opening buds and later tunnel into succulent shoots (figure 70C).

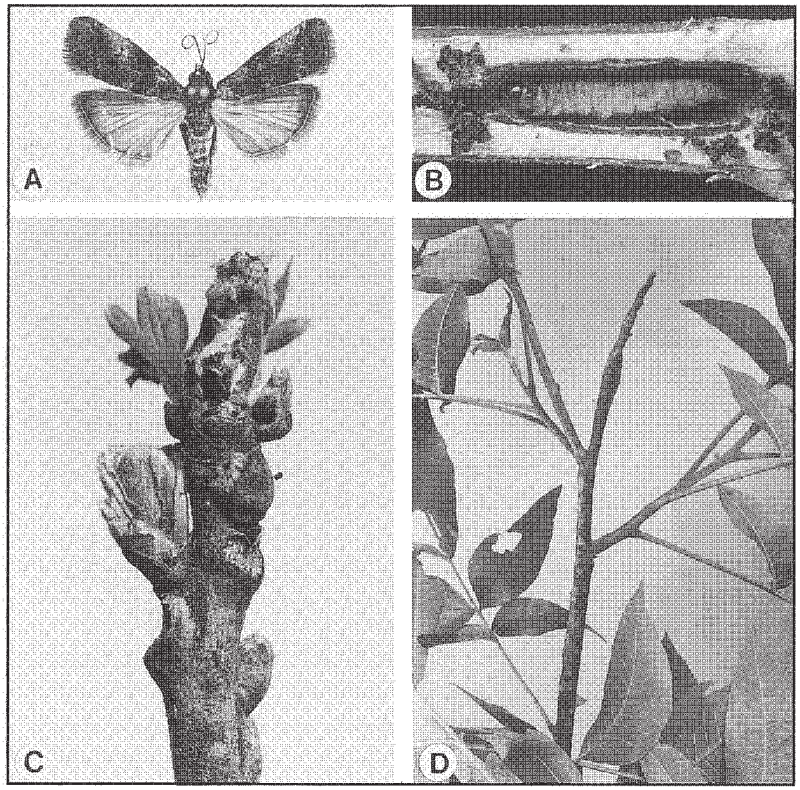


**Figure 70**—Acrobasis caryivorella, *[hickory shoot moth]: A, adult; B, larva; C, buds and shoot apex hollowed out; D, shoot mortality (A, specimen courtesy H. Neunzig).*

**Injury and damage.** Prefers vigorously growing trees, and larvae are most abundant on young trees (Neunzig 1972). Unsightly masses of dead leaves held together and pulled up around current shoot growth with loose strands of silk indicate attack (Neunzig 1972). Close inspection reveals that buds at the base of current year's shoots have been hollowed out and petioles of expanding leaves are shallowly tunneled. Eventually, all leaves of an infested shoot are pulled in about it with silk and parts of the leaflets eaten. Frass collects in the drawn-together leaves; often, several larvae inhabit the haphazardly constructed silk enclosure. Tunneled shoots become stunted, distorted, or die (figure 70D), adversely affecting tree form—an important consideration for timber purposes (Neunzig 1972). Young trees, particularly sprouts in recently cut-over areas, are especially vulnerable to injury. The insect has also severely damaged pecan seedlings in nurseries in Florida and Texas (USDA FS 1985).

**Control.** Parasites are probably the most effective natural controls of this borer; numerous hymenopterous and dipterous parasites have been reared from the larvae and pupae (Arnaud 1978, Krombein and others 1979, Neunzig 1972). Young trees, especially nursery stock, should be kept vigorous to help them overcome and outgrow the injuries with fewer adverse effects (Phillips and others 1960). Chemical controls can help minimize injury.

### *Hypsipyla grandella* (Zeller)

[mahogany shoot borer] (figure 71)

**Hosts.** Mahogany, Spanish cedar. Many species of mahogany and Spanish cedar in the family Meliaceae are highly susceptible (Grypma and Gara 1970, Holsten and Gara 1975).

**Range.** South Florida and throughout the American Tropics, wherever its food plants grow (Heinrich 1956, Sliwa and Becker 1973).

**Description.** ***Adult.*** Brown to grayish brown moth with wingspan 23 to 45 mm (figure 71A) (Chellman 1978, Heinrich 1956). Forewings grayish brown shaded with dull rust red, especially on lower part. Wing veins distinctly overlaid with black. A dusting of whitish scales on middle to outer portion of forewings and black dots toward wing ends. Hindwings hyaline to white with narrow dark margin. ***Egg.*** Oval, flattened, white initially but red within 24 hours; 0.98 mm long, 0.50 mm wide. ***Larva.*** Creamy white when young, becoming light bluish to blue with maturity; reach about 25 mm long (figure 71B). ***Pupa.*** Brownish black and enclosed in silken cocoon (figure 71C).

**Biology.** Moths live 7 to 8 days, are nocturnal, and remain hidden in tree foliage and grass during the day (Holsten 1976). After mating, females deposit about 300 eggs during evening and early morning. Eggs are laid singly or in small clusters of three to four in or on leaf axils, on leaf scars, and adjacent to the midrib or side veins of leaflets. Eggs hatch in about 4 days, and the young larvae bore in new shoots, usually at leaf axes. Larvae enter the pith

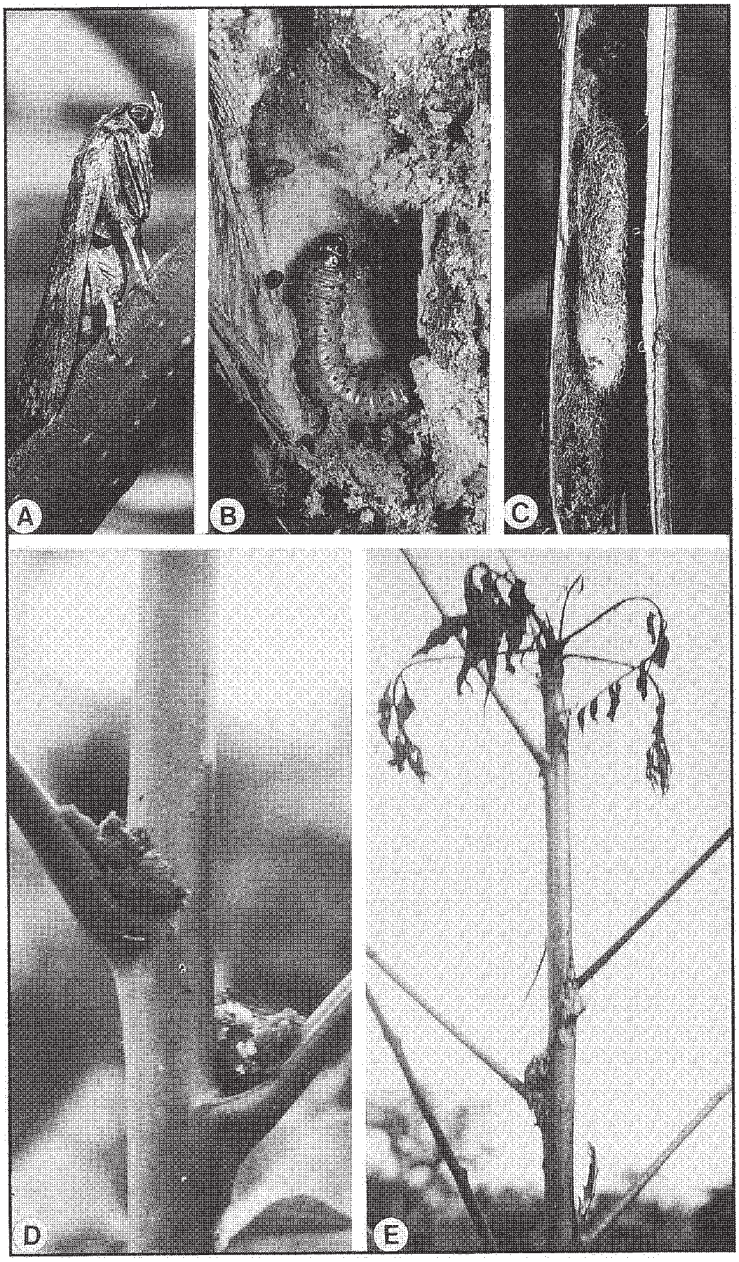


**Figure 71**—Hypsipyla grandella, *[mahogany shoot borer]: A, adult in resting position; B, larva in burrow; C, silken cocoon in shoot gallery; D, clumps of frass on infested shoot; E, dying shoot (A-C, courtesy E. Holsten; D-E, courtesy J. Whitmore).*

and tunnel down the shoots, feeding on the unlignified parts of the stems, axils, and pith. Larvae spend up to about 10% of their time outside the stems feeding and web-building. Seed capsules may also be attached. Entrance holes are always protected by a covering of silk, plant particles, and frass. There are five to seven larval instars. The larval stage lasts 20 to 30 days. Final-instar larvae usually spin silken cocoons at upper end of tunnels, where they pupate. Most larvae pupate in their galleries, but some pupate in the soil under the tree. The pupal stage lasts about 10 days. In Florida, there is evidence of at least two generations per year, with the heaviest brood beginning in March or April and peaking in May (Howard 1991).

**Injury and damage.** Clumps of frass silked together at leaf axils on the shoots provide good evidence of infestation (figure 71D) (Holsten 1976). Scraping away frass reveals larval entrance holes. Dissection of infested shoots exposes the larvae and galleries. Tender terminals and branches on young trees are apt to be attacked. Dead and dying shoots become noticeable during heavy infestations (figure 71E). Attacks on developing shoots reduce growth and generally stunt plants (Holsten and Gara 1975). Seedlings and saplings 1 to 5 years old are damaged most, and many plants under 3 m tall are killed (Allan and others 1973). Resprouting followed by repeated attacks results in numerous side branches and, consequently, in badly formed trees unsuitable for timber. This insect is a formidable obstacle to growing mahogany in many regions and has prevented establishment of plantations in some areas.

**Control.** Natural controls—including egg, larval, and pupal parasites, fungal diseases, and entomogenous nematodes—help to reduce populations but often do not prevent economic losses. Cultural control through pruning and destroying infested twigs and fruits, planting best suited sites, and planting least susceptible species will minimize losses. Soil-applied systemic insecticides and protective sprays directed at the spring brood are sometimes necessary to establish new plantations (Allan and others 1973, Chellman 1978, Howard 1991).

### *Elasmopalpus lignosellus* (Zeller)

lesser cornstalk borer (figure 72)

**Hosts.** Black locust, dogwood, tupelo, sycamore, pine, redcedar, Arizona cypress, and baldcypress. Corn, peanuts, and many other legumes and grasses are attacked, but plants in the grass family are preferred; attacks trees only occasionally (Dixon 1982b, Luginbill and Ainslee 1917).

**Range.** Throughout the southern half of the United States but most damaging in sandy soil along the south Atlantic and Gulf Coasts. Also occurs throughout Central and South America (Luginbill and Ainslee 1917).

**Description.** ***Adult.*** Brownish moth with wingspan of 17 to 25 mm (figure 72A) (Luginbill and Ainslee 1917). Forewings narrow and elongate with oblique distal margins; yellow ochre to light brown in males and dark brown in females. Hindwings whitish with gray to brown anterior

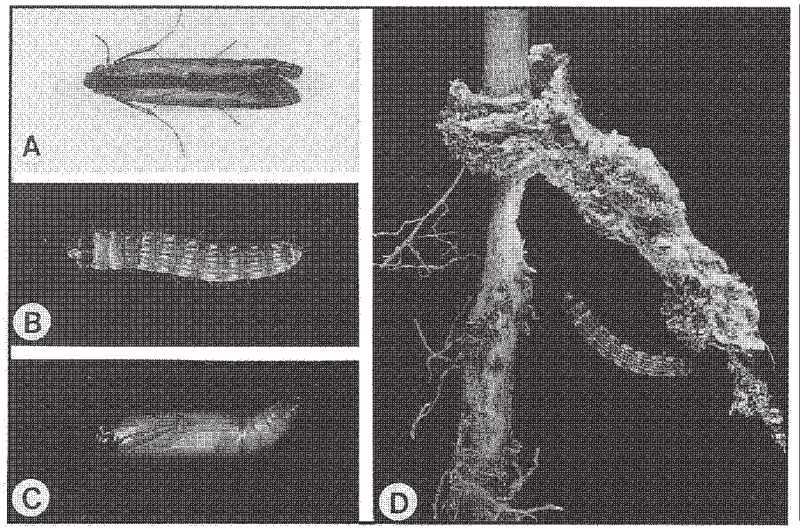


**Figure 72**—Elasmopaplus lignosellus, *lesser cornstalk borer: A, adult; B, larva; C, pupa; D, seedling injured at root collar with silken feeding tube (specimens courtesy J. Todd).*

and distal margins. Head brown to black. ***Egg.*** Oval, 0.7 mm long by 0.2 mm wide, with sculptured surface; pale green when first deposited, becoming iridescent crimson at maturity. ***Larva.*** Greenish brown and about 16 mm long when mature (figure 72B). Head and cervical shield shiny brownish black; body pale green with longitudinal, somewhat broken white and purple stripes. ***Pupa.*** Pale yellowish green initially, gradually becoming dark brown, with six hooked spines on abdomen tip, and about 8 mm long (figure 72C).

**Biology.** Moths emerge during early June in southern Georgia and are caught almost continually in light traps through August (Leuck 1966). Average life of adults is 10 days, and each female deposits about 125 eggs. Eggs are generally deposited singly on the upper and lower sides of leaves, at any point along the stem, and in soil just below the surface with grains of sand adhering to them. Eggs hatch within a week, and early-instar larvae mine lower branches or begin to feed on stem and roots below the soil surface (Dixon 1982a). Larvae construct radiating tubelike shelters of silk, soil, and excrement near the root collar just below the soil surface. Feeding by larvae on woody tree seedlings is characterized by surface or subcortical burrowing and girdling and often results in gall-like swellings and callus tissue around the feeding site (Snyder 1936). Larvae pass through six instars, and total larval development requires 13 to 24 days (Dupree 1965, Leuck 1966). The pupal stage is 8 to 10 days. By late summer, most life stages are present in infested plants as generations overlap. The winter is passed in either the larval or pupal stage in soil or soil litter. It completes two to four generations per year (Dixon 1982b).

**Injury and damage.** The first sign of infestation in forest tree nurseries is wilting foliage. As seedlings begin to die, they may remain upright or fall over. Removing soil from around the base of the seedlings reveals larval burrows girdling the stem and gall-like swelling and callus tissue at wound sites. Sometimes, seedlings are severed just below ground (Snyder 1936). Close inspection of the soil near feeding sites exposes small tubes, composed of silk and soil particles, radiating from the injured seedling (figure 72D). Only one larva is found in a silken tube. Larvae squirm vigorously when disturbed (Dixon 1982a). When adults are disturbed and forced to fly during daylight, they fly with short, jerky movements (Dixon 1982a). During the 1930's, 1 to 2% of the black locust seedlings in forest tree nurseries in Mississippi, Arkansas, and Louisiana and up to 10% of those in North Carolina nurseries were killed (Snyder 1936). More recently, in a central Florida forest tree nursery, this borer killed about 1 million hardwood and softwood seedlings and injured as many more (Dixon 1982b). Mortality of flowering dogwood in the Florida nursery was 70%, and the remaining 30% suffered injury.

**Control.** Parasites are abundant (Arnaud 1978, Krombein and others 1979). In Texas, larval mortality from insect parasites ranges from 5 to 9%, and pupal mortality averages about 5% (Johnson and

Smith 1981). Culturally, selected covercrop rotation, late-fall clear-fallowing, proper soil fertilization, and irrigation will help to ameliorate the factors conducive to infestation. When such practices fail, granular insecticides can be incorporated in the soil before covercrops are sown. In serious borer infestations, insecticides can be applied to nursery beds as soil drenches; this may have to be repeated several times because adequate exposure of larvae to the chemical is difficult, as they retreat into their silklined shelters when disturbed (Dixon 1982b).

### *Nephopteryx carneella* Hulst

[willow gall inquiline]

**Hosts.** Willow. Willow only known host (Heinrich 1956).

**Range.** Maine and Massachusetts west to Wisconsin and Indiana and in Ontario and Manitoba (Heinrich 1956).

**Description.** ***Adult.*** Powdery gray moth with reddish markings (Forbes 1923, Heinrich 1956). Forewings light brown color to bluish gray with small reddish and blackish markings; hindwings smoky white with faint yellowish tint. Wingspan ranges from 20 to 23 mm. Females slightly darker than males. Immature stages have not been described.

**Biology.** Adults are present from April to July (Heinrich 1956). Larvae burrow into galls made by gallmaking sawflies (*Euura* spp.) on host plants. Here they live, feed, and complete their development.

**Injury and damage.** Fine frass and small openings in host galls may provide evidence of infestation. Opening galls will reveal larval burrows, frass, and sometimes the larvae. This species bores in galls made by other insects on host plants. It has no known economic consequence.

**Control.** Controls are not needed.

### *Meroptera cviatella* Dyar

[poplar bud borer]

**Hosts.** Poplar. Cottonwood listed, but other poplars probably susceptible (Heinrich 1956). Leadplant mentioned as a host but believed to be so only by accident.

**Range.** Known only from Illinois and Mississippi (Heinrich 1956).

**Description.** ***Adult.*** Reddish brown and gray moth with wingspan of 23 to 25 mm (Forbes 1923, Heinrich 1956). Forewings bright reddish brown with purplish gray shading toward outer margin, which may have indistinct lines dusted with blackish and whitish scales. Hindwings pale smoky brown, darkened towards outer margin. Immature stages have not been described.

**Biology.** Adults are present in June and July (Heinrich 1956). The larvae tunnel and feed in buds and new shoots.

**Injury and damage.** Failure of buds and shoots to develop is evidence of infestation. Small holes and burrows in buds and new shoots can be found on close examination. Damage has been negligible.

**Control.** Controls have not been needed.

### *Terastia meticulosalis* Guenee

[bucare twig borer] (figure 73)

**Hosts.** Coralbean, kapok. These are the only recorded hosts (Chellman 1978,

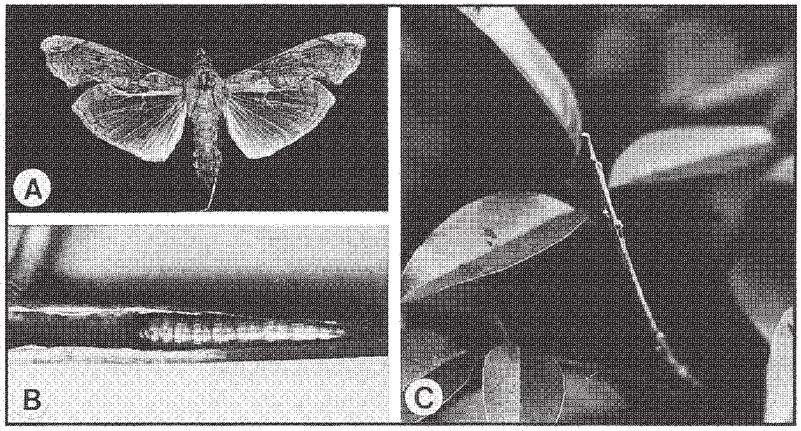


**Figure 73**—Terastia meticulosalis, *[bucare twig borer]: A, adult; B, larva in twig gallery; C, twig killed by larva (A, specimen courtesy R. Hodges; B & C, courtesy C. Chellman).*

Kimball 1965).

**Range.** In North America known only from Florida, where it is most common in the Peninsula and Keys (Chellman 1978, Kimball 1965). Also occurs in Honduras, Santo Domingo, Ceylon, Java, the Philippines, Hawaii, and India (Swezey 1923).

**Description.** ***Adult.*** Light brown moth with prominent dark brown markings on forewings (figure 73A) (Chellman 1978). Wings peculiarly shaped and quite distinct. Wingspan approximately 37 mm. ***Larva.*** Whitish to light reddish (figure 73B). Mature larva about 25 mm long.

**Biology.** Moths lay eggs on the twigs of host plants. Young larvae bore into tender twigs and immature seed pods and completely hollow them, causing much twig dieback. Mature larvae exit their galleries and move to the ground where they spin large silken cocoons where they pupate (Swezey 1923). This twig borer has at least two generations per year in southern Florida (Chellman 1978).

**Injury and damage.** Browning and dying twigs provide evidence of infestation (figure 73C) (Chellman 1978). Examination of the dying twigs reveals tunnels and larvae. All the new growth on some plants may be killed back (Swezey 1923). Heavy populations give infested trees a ragged appearance. Severe infestations can sometimes kill small plants.

**Control.** Clipping and destroying infested twigs on ornamentals while larvae are present help to alleviate the problem, especially if done on a neighborhood basis (Chellman 1978). Several insecticides will control the pest, but spray applications must be carefully timed and applied before the young caterpillars bore into twigs.

### *Ostrinia nubilalis* (Hübner)

European corn borer (figure 74)

**Hosts.** Sycamore, poplar, yellow-poplar, peach, apple, pear. This polyphagous species feeds on plants representing 131 genera of 40 families including grains, grasses, weeds, herbaceous plants, flowers, and trees (Hodgson 1928). Corn is the preferred nonwoody plant. Trees are attacked only occasionally unless growing near heavily infested preferred hosts (Anonymous 1979, Tedders and others 1981).

**Range.** Introduced into the United States during the early 1900's and spread throughout the corn-growing areas east of the Rocky Mountains (Baerg 1951).

**Description.** ***Adult.*** Brownish moth with 24- to 29-mm wingspan (figure 74A) (Vinal and Caffrey 1919). Forewings yellowish and brown with some streaking, banding, and spotting; hindwings grayish brown (Vinal and Caffrey 1919). Head covered with light yellowish brown scales. Dorsum of thorax cinnamon brown in males and light yellowish brown in females. ***Egg.*** Circular to oval and slightly convex on upper surface, averaging 0.97 mm long and 0.74 mm wide. Egg surface sculptured with shallow pentagonal pits. When first deposited, eggs opaque to iridescent white and within 2 days assume yellowish tinge (Vinal and Caffrey 1919). ***Larva.*** Measures about 25 mm long with head capsule width of about 2.2 mm when

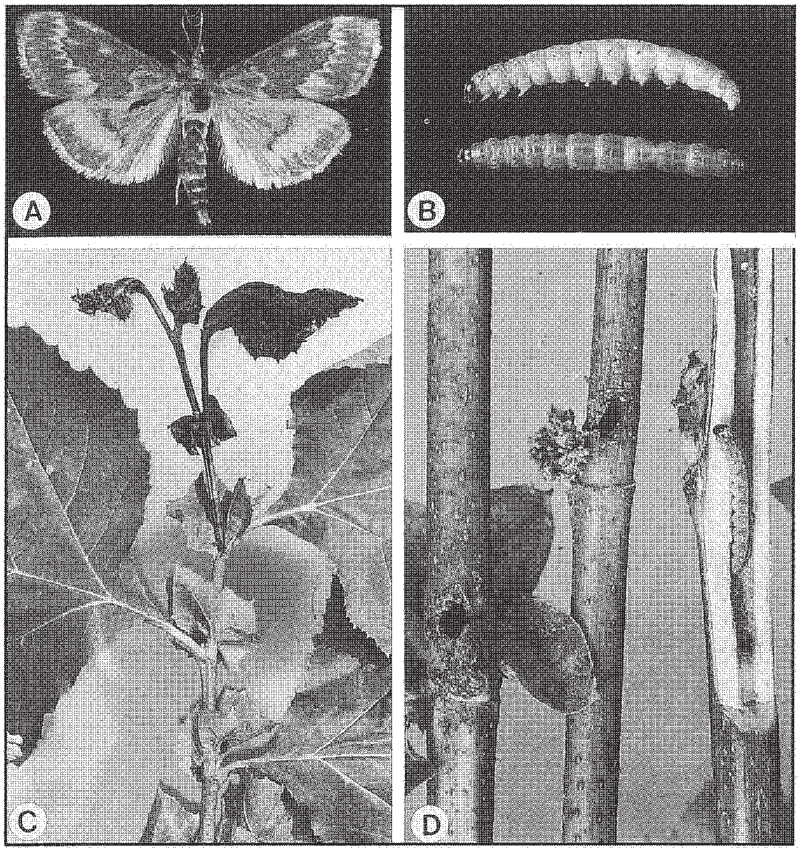


**Figure 74**—Ostrinia nubilalis, *European corn borer: A, adult; B, larvae; C, seedling terminal killed by larva; D, entrance holes, frass, and gallery in sycamore seedlings (A, specimen courtesy R. Hodges; B-D, specimens courtesy P. Marshall).*

mature (figure 74B). Head and thoracic shields shiny brown and mottled with black. Dirty white to pink body, gray or light brown with narrow, dark brown median line on dorsum; broad, pale brown to pink subdorsal line; and narrow, pale brown lateral line. Fleshy abdominal prolegs bear almost complete circle of crochets (Peterson 1962, Vinal and Caffrey 1919). ***Pupa.*** Light to dark brown and about 14 to 17 mm long. Tenth abdominal segment extended to form dark brown to black cremaster bearing eight long, hooked spines.

**Biology.** This borer overwinters within tunnels in its host as mature larvae, which pupate in May and emerge as adults during June in Illinois. Females deposit 500 to 600 eggs on leaves of host plants; egg incubation is about 1 week. In herbaceous hosts, young larvae feed on tassels and leaf sheaths and later burrow in stems and fruits. Development of first generation is completed in July; most moths emerge during August. Larvae of the second generation feed on, or within, hosts until the advent of severe winter weather. Larval feeding is resumed during spring. This borer has one or two generations per year (Baerg 1951, Vinal and Caffrey 1919).

**Injury and damage.** On tree seedlings, the first sign of infestation is rapid wilting and dying of foliage, terminal leaders, and lateral branch tips, which at first may appear to be caused by a leaf disease (figure 74C). Closer inspection reveals large holes, up to 6.5 mm in diameter, in stems just above the lateral leaf axils, or occasionally just below the leaf axils (figure 74D). Noticeable quantities of large granular frass and excrement accumulate near entrances. The larval tunnel, kept relatively free of frass, extends in the pith from the entrance hole almost to the terminal bud and may extend several centimeters below the entrance hole.* On peach seedlings, injury can range from 2-mm-diameter holes in the bark to injuries that cause 10-mm-diameter limbs to break under their own weight. A conspicuous gummy exudate mixed with frass accumulates at larval feeding sites (Tedders and others 1981). In northern Italy, it causes considerable injury in tree nurseries by boring into succulent stems and lateral shoots of poplar seedlings, particularly clones that have strongly developed medullary tissue like that in eastern cottonwood (Anonymous 1979). About 90% of the limbs on 1- and 2-year-old trees in a Georgia peach orchard were damaged by larvae that had migrated late in the season from browntop millet that had been interplanted among the trees (Tedders and others 1981). In a similar case, 30% of the terminal shoots of 1-year-old sycamore nursery stock, and some yellow-poplar seedlings, were tunneled by larvae in an Indiana nursery.* In every recorded instance of significant damage to tree seedlings, more preferred hosts such as corn, cover crops, or weeds, either grew nearby or were interplanted with the trees. In such cases, the trees were attacked in late summer by larvae

*Marshall, P.T. August 31, 1978. (personal communication). Indiana Department of Natural Resources, Vallonia, IN.

that had migrated from the herbaceous plants.

**Control.** Numerous parasites have been recorded (Arnaud 1978, Krombein and others 1979). Several insect parasites have been introduced from Europe to control the borer, and appreciable results have been obtained in some areas. Populations are adversely affected by dry summers and cold winters. Crows and other birds are effective larval predators (Baerg 1951). Despite many natural enemies of this borer, populations have to be controlled by insecticides, cultural methods, and planting resistant plant varieties. Cultural controls include plowing under infested herbaceous host plants and shredding or storing hosts in silos to destroy hibernating larvae. Several insecticides are registered for control and are effective when properly timed and applied.

## Family Thyrididae—Window-winged Moths

This family consists of a small group of moths similar to the pyralids. The adults have clear spaces or hyaline patches and striae on the wings (Borror and others 1981, Holland 1968). The labial palpi extend straight forward or are obliquely upturned and sometimes twice the length of the head. Larvae have five pairs of abdominal prolegs and burrow in twigs, stems, flowers, and seeds.

### Genus and Species



### *Hexeris enhydris* (Grote)

[seagrape borer] (figure 75)

**Hosts.** Seagrape, pigeon plum. Seagrape seems to be the major host (Chellman 1978).

**Range.** Central and south Florida (Johnson and Lyon 1988).

**Description.** ***Adult.*** Pale brown to yellowish brown moth with wingspan of 34 to 38 mm (figure 75A) (Chellman 1978, Grote 1875). Forewings have rusty wavy lines on yellowish background and somewhat mottled or subreticulate. Median brown line bent at middle of wing, and united with outer line from costa to form noticeable crooked Y. Undersides of wings with same line marks but narrower than those on upper surface. Labial palpi extend straight forward for more than twice length of head. Antennae simple and short (Grote 1875). ***Larva.*** Head light brown; body pale brown and partially translucent; measures

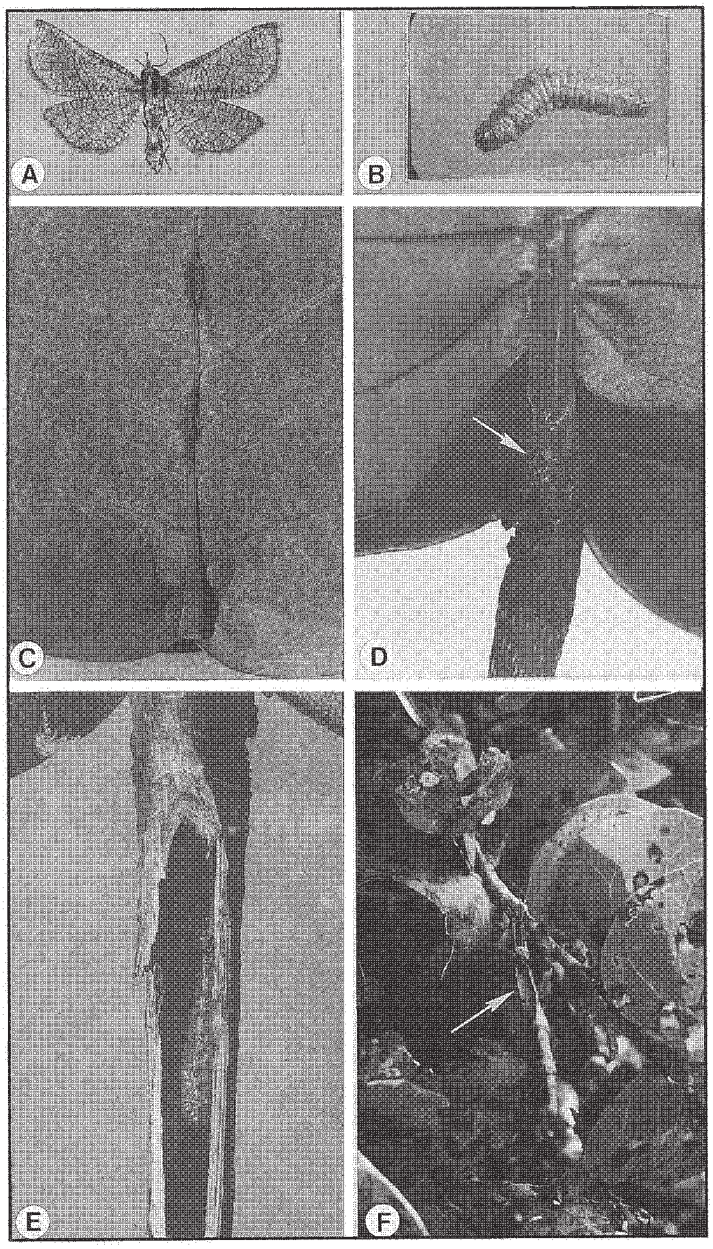


**Figure 75**—Hexeris enhydris, *[seagrape borer]: A, adult; B, larva; C, early injury to leaf midrib; D, entrance hole in infested shoot; E, closeup of gallery with larva; F, seagrape shoot hollowed out by larva (A, specimen courtesy R. Hodges; B-E, courtesy W. Johnson; F, courtesy C. Chellman).*

15 to 16 mm in length when mature (figure 75B) (Chellman 1978, Johnson and Lyon 1988).

**Biology.** Adults are present from March to May, July to September, and again in December (Johnson and Lyon 1988). Larvae feed and develop primarily in twigs and leaf petioles and less frequently in main leaf veins. Feeding larvae sometimes completely hollow out leaf petioles and twigs, leaving only shells. Larvae chew one or more small holes along galleries to eject their frass. Pupation occurs within stem galleries. The seagrape borer has at least three generations per year in southern Florida (Chellman 1978).

**Injury and damage.** Small stems, leaf petioles, and leaf midribs may be attacked (figure 75C) (Chellman 1978, Johnson and Lyon 1988). One or more small round holes with or without small clumps of frass may be found on infested stems (figure 75D). Splitting infested stems reveals the tunnels and sometimes larvae (figure 75E). Infested stems often split, flare open, and die back (figure 75F). When leaf petioles are attacked, the leaves turn brown, causing flagging, which is an excellent diagnostic symptom. Repeated attacks cause serious twig dieback and sometimes mortality of young plants. This borer is the most important pest of seagrape. Infested stems are left weakened and subject to breaking in the wind.

**Control.** Plants should be frequently inspected throughout the year for evidence of infestation. Infested twigs and leaves should be clipped and destroyed while larvae are present to minimize damage. It can also be controlled with insecticides, although repeated sprayings will probably be necessary. Best control is obtained when sprays are applied before young caterpillars penetrate into twigs.

## Family Pterophoridae—Plume Moths

The pterophorids are a small family of frail, elegant moths whose divided wings suggest feathers (Borror and others 1981, Craighead 1950). Forewings are deeply cleft, and the hindwings are split into three feather-like divisions. At rest, the wings are folded close together and held horizontally at right angles to the body. The larvae are dull white with brown or purple markings and bear two forcep-like prongs and long setae on the anal plate. They bore into the stems and roots of shrubs and small trees.

### Genus and Species



### *Oidaematophorus balanotes* (Meyrick)

[baccharis borer] (figure 76)

**Hosts.** Baccharis, bayberry. Baccharis and bayberry groups reported as hosts (Cashatt 1972, Forbes 1923); recent unpublished findings suggest that eastern baccharis is a major host.

**Range.** Primarily a southeastern species, found from southern Florida north to Maryland and New Jersey and west to Texas and Arizona (Barnes and Lindsey 1921, Cashatt 1972, Forbes 1923, Kimball 1965).

**Description.** ***Adult.*** Largest of stem-boring pterophorids, slender-bodied moth with long legs and narrow wings (figure 76A) (Barnes and Lindsey 1921, Cashatt 1972, Meyrick 1908). Forewings cleft and brownish white with dark spots at vein tips and indistinct brown dash line extending from base to near cleft. Hindwings pale brown. Wingspan varies from 30 to 42 mm. Light brown to brownish white or tan with indistinctly striped abdomen, whitish antennae, and pale brown legs. ***Egg.*** Yellowish white, oval, and about 0.54 by 0.33 mm. ***Larva.*** Creamy white with brown markings and 18 to 25 mm long when mature (figure 76B). Head dark brown around the mouthparts, with light brown mottling elsewhere. Thoracic shield with brown granulations. Anal plate brown and hardened with two prominent prongs and ringed with long hairs. Crochets in uniordinal semicircle. ***Pupa.*** Slender, tannish brown, and 16 to 22 mm long (figure 76C).

**Biology.** Adults emerge every month, depending on location (Barnes and Lindsey 1921, Cashatt 1972). In Florida, moths have been found during all months, but mostly in late winter and spring. Emergence is recorded during July and August in Maryland, August in Arizona, July and October in South Carolina, and from June to November in Texas; reared entirely during September in Mississippi. Moths deposit eggs on the bark of hosts. Larvae enter the bark and make long, narrow, nearly straight galleries in wood. Most attacks occur in the main stem and less frequently in branches. Entrance holes have been found from just above the groundline to 1.5 m (figure 76D). Larval galleries always enter bark and wood at an oblique angle, and nearly always extend downward into the roots, sometimes as

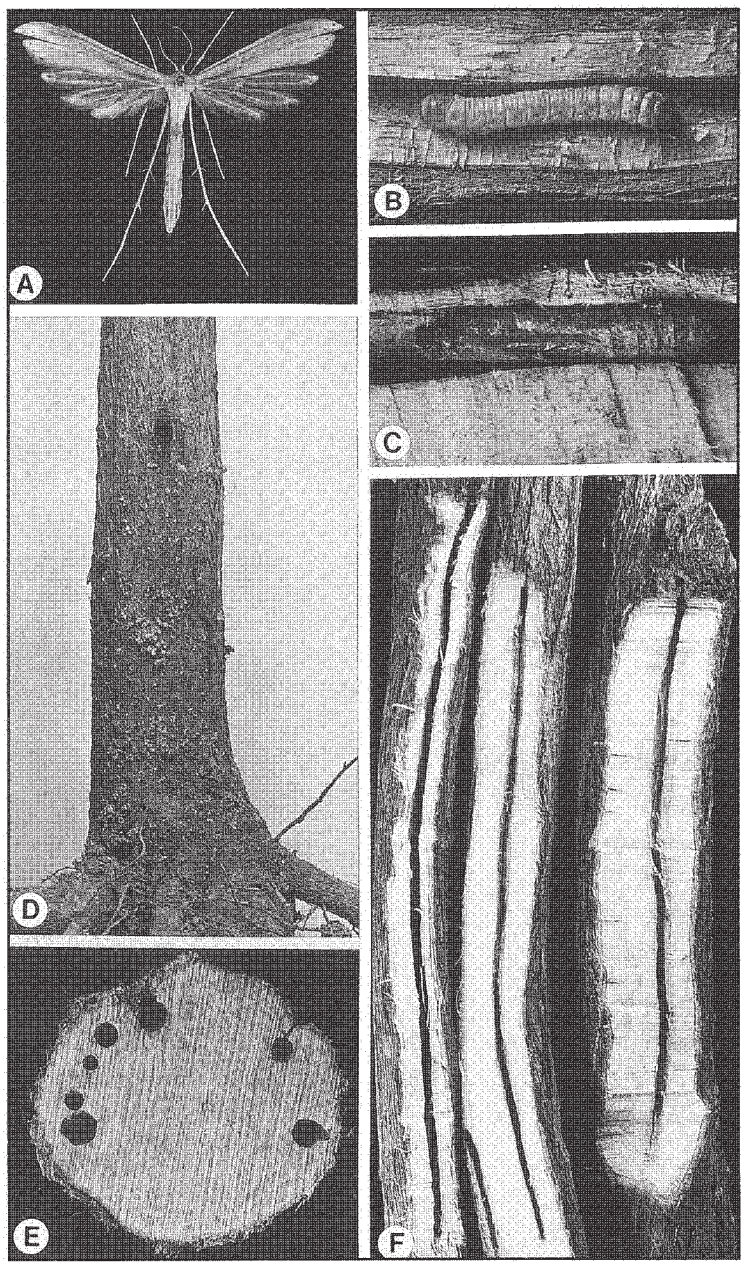


**Figure 76**—Oidaematophorus balanotes, *[baccharis borer]: A, adult; B, larva; C, pupa; D, entrance hole in baccharis stem; E, cross section of stem showing seven round galleries; F, long narrow galleries exposed.*

much as 10 cm below ground. Although the galleries are in the xylem, they are usually only a few millimeters beneath the wood surface (figure 76E). Completed galleries range from 15 to 23 cm long and 4 to 5 mm in diameter. Pupation occurs freely within the gallery for 16 to 19 days, without a pupation chamber. Empty pupal skins at various locations in galleries indicate that moths eclose from the pupae within galleries, unlike many other woodboring Lepidoptera in which the pupae move to the exit holes for adult emergence. There appears to be one generation per year, with considerable overlapping of broods in some areas.

**Injury and damage.** The earliest evidence of attack is sap-stained spots, often mixed with fine frass on bark. Later, round to oval entrance holes 2 to 4 mm in diameter, often with yellowish white frass adhering to bark below entrances, become noticeable. Dissection of infested stems reveals the long cylindrical nearly straight galleries and sometimes tunneling larvae (figure 76F). Bark occasionally cracks open along shallow galleries and forms long bark scars that show evidence of previous infestation. Small stems, particularly branches, sometimes break at injured sites. Heavy infestations have been found recently in thickets of eastern baccharis near Jackson, Mississippi.

**Control.** Ichneumonid parasites—*Telelucha* sp.—have been reared from specimens in Mississippi, but rates of parasitism have been low. Direct controls have not been needed. This borer is being studied by Australian scientists as a possible biocontrol agent for weed *Baccharis* spp. in pastures.

### *Oidaematophorus kellicottii* (Fish)

[goldenrod borer] (figure 77)

**Hosts.** Baccharis, goldenrod. Goldenrod is mentioned as the host in early reports, but recent unpublished findings suggest that baccharis, especially eastern baccharis, is a common host (Barnes and Lindsey 1921, Bennett 1963, Cashatt 1972, Kimball 1965).

**Range.** Like the closely related *O. balanotes*, primarily an eastern species reported from Massachusetts and New York south to southern Florida and west to Colorado and Utah (Barnes and Lindsey 1921, Cashatt 1972). Also recorded from Quebec (Forbes 1923).

**Description.** ***Adult.*** Slender-bodied moth with long legs, narrow wings, and cream colored with slightly darker brown markings (figure 77A) (Cashatt 1972, Fernald 1898). Forewing brownish white with indistinct brown dash extending from base, which fades out toward cleft. Hindwings uniformly brownish white with silky luster. Wingspan ranges from 14 to 29 mm. Body light brownish white dusted with brown scales. Distinguished from other stem-boring pterophorids by its smallness and distinct spot at base of wing cleft. ***Larva.*** Creamy white and light brown, and 12 to 18 mm long (figure 77B). Head, thoracic shield, and dorsum of caudal four or five abdominal segments brown. Abdomen terminates into a dark brown anal plate with two pronglike processes and long hairs. ***Pupa.*** Long (10 to 15 mm) and

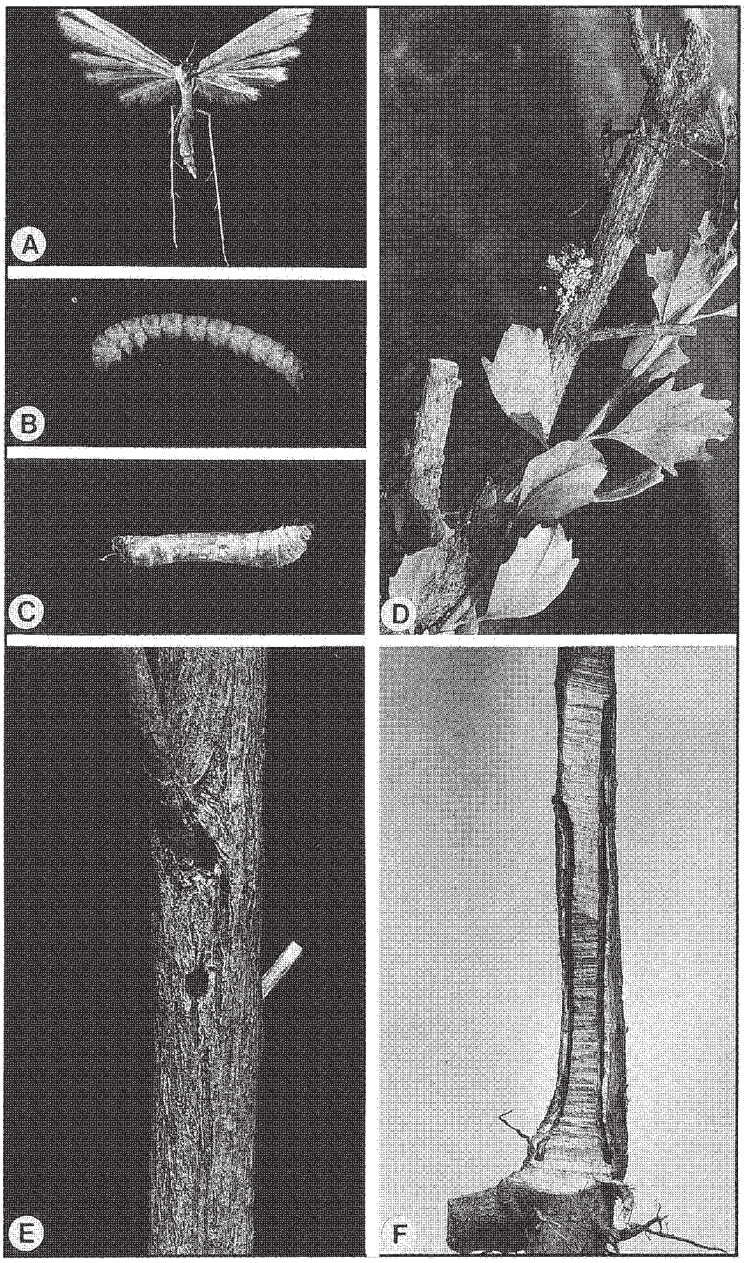


**Figure 77**—Oidaematophorus kellicottii, *[goldenrod borer]: A, adult; B, larva; C, pupa; D, clump of frass on baccharis stem; E, entrance hole on stem; F, stem sawn open to expose two galleries (A, specimen courtesy R. L. Brown).*

slender, light brown (figure 77C).

**Biology.** Moths emerge during most months, depending on latitude (Cashatt 1972, Kimball 1965). Although most specimens have been collected during June and July, emergence has occurred as early as February in Florida and as late as October in New York. In goldenrod, larvae initially bore into branches (Fernald 1898), but by mid-September they abandon the branches, move down the plant, and bore into the main stem a few centimeters above the groundline. Here, larvae bore downward into the roots, where they overwinter. During spring, larvae work their way back to the aboveground entrances, enlarge the galleries, plug openings loosely with frass and debris, and pupate in the galleries. Empty fresh galleries in main stems of baccharis have been found during fall, indicating the possibility of larval movement. Galleries in baccharis are long and cylindrical, similar to those made by *O. balanotes*, but slightly smaller. This borer has one generation per year.

**Injury and damage.** New attack sites in baccharis can be recognized by sap oozing from the bark and fine yellowish brown frass in bark crevices. Frass becomes coarse granular and is often clumped at round gallery entrances (figure 77D and E). Long, slender galleries are just beneath the wood surface (figure 77F). Larvae tunnel in the main stem and branches, sometimes causing breakage of host parts.

**Control.** Nothing is known of natural enemies, and direct controls have not been needed.

### *Oidaematophorus grandis* (Fish)

[coyote brush borer] (figure 78)

**Hosts.** Coyote brush. Coyote brush is the only host recorded (Cashatt 1972, Grinnell 1908).

**Range.** Southwestern species recorded only from coastal California, Mexico, and Guatemala (Fernald 1898, Lange 1939). Florida and Maryland have been mentioned in its distribution (Barnes and Lindsey 1921, Lange 1939), but these locations seem unlikely.

**Description.** ***Adult.*** Slender-bodied moth with long slender legs and narrow forewings cut by fissure or cleft in outer margin (figure 78A) (Cashatt 1972, Fernald 1898, Grinnell 1908). Forewings brownish white, paler toward inner margin with faded dark spots at wing tips. Hindwings pale brownish white to grayish white. Wingspans 30 to 36 mm. Body brownish white with indistinct brown longitudinal line on abdomen. ***Egg.*** Oval, glossy, pale yellowish, and averages 0.52 mm long and 0.31 mm wide (Lange 1939). ***Larva.*** Creamy white with reddish brown or purplish markings (Lange 1939, Peterson 1962, Williams 1909). Mature larvae with dorsal purplish longitudinal line, oblique subdorsal purplish dash on each abdominal segment, purplish dash cephalad on each spiracle, and brown head and thoracic shield (figure 78B). Abdominal segments 9 and 10 transformed dorsally into dark brown chitinous plate equipped with two forceplike prongs and long periphery hairs. Mature larvae 16 to 20 mm long. ***Pupa.*** Long, slender, and cylindrical with head end obliquely truncate.

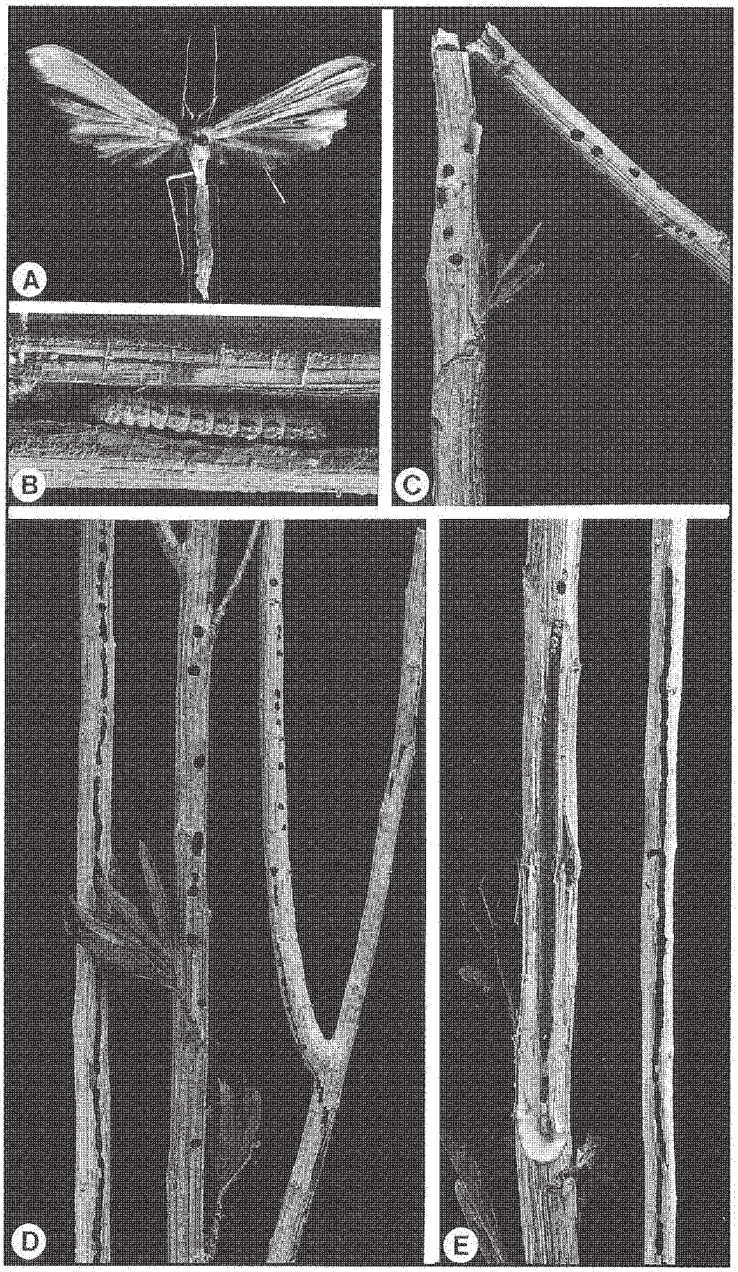


**Figure 78**—Oidaematophorus grandis, *[coyote brush borer]: A, adult; B, larva in gallery; C, stem broken at weakened site; D, series of holes in coyote brush; E, galleries exposed in stems (A, specimen courtesy R. Hodges).*

**Biology.** In California, adults emerge May to September with the peak in June (Lange 1939, Williams 1909). Moths mate at night, and females deposit eggs on the underside of leaves and on the bark of hosts. Eggs hatch in about 21 days. Larvae bore through the bark and produce long smooth cylindrical galleries in the woody part of the stem just slightly beneath the surface of the sapwood. Galleries sometimes extend below ground level. Several parallel galleries often occur in large stems and are generally quite straight and almost invariably open to the underside of the branch or the leaning side of the trunk. Larvae move freely within the long smooth burrows, which they keep free of frass. Mature larvae pupate within the gallery without forming a pupation chamber. Pupae are generally found some distance from the bottom of the gallery but they are very active and may move considerably within the gallery. There is one generation per year.

**Injury and damage.** Initially, attack sites can be recognized by oozing sap that stains the bark. Later, white to pale yellowish frass may accumulate at entrances and beneath infested plants (Williams 1909). Broken stems frequently call attention to infestations (figure 78C). Galleries enter the stem at an oblique angle, usually on the underside of branches and the leaning side of main stems. Attacks are most prevalent in the base of the main stem and lower branches (Tilden 1950). Infested stems usually have a series of small holes, more or less in a straight line (figure 78D). Galleries are long and narrow and usually in the center of stems (figure 78E). Weakened stems occasionally break or die back, but most injured parts heal over and recover. First- and second-instar larvae sometimes live as inquilines in stem galls made by other insects, resulting in destruction of the gall interior and its inhabitants (Tilden 1950).

**Control.** A hymenopterous parasite—*Pimpla pterophorae* Ashmead—has been reared from infested stems (Lange 1939). Other hymenopterous parasite cocoons have been found within larval galleries, but none has been identified (Williams 1909). Direct controls have not been needed.

## Family Noctuidae—Owlet Moths

Noctuidae is the largest family of Lepidoptera, but only a few species are borers in trees. The nocturnal habits of the moths and the ability of their eyes to shine brightly in the dark have suggested the name "owlet moths" (Borror and others 1981, Craighead 1950). Moths vary in form, size, and color, but most are medium sized, heavy bodied, and dull in color. The forewings are strong and narrower than hindwings, and when at rest, the wings are held rooflike over the abdomen in a triangular outline. Most larvae are naked with only scattered setae and have five pairs of prolegs. Borer species tunnel in the shoots of host plants.

### Genus and Species



### *Papaipema nebris* (Guenée)

stalk borer (figure 79)

**Hosts.** Sycamore, maple, elm, ash, poplar, catalpa, willow, boxelder, sumac, elder, apple, peach, plum, hawthorn. A polyphagous species that attacks both herbaceous and woody plants; recorded from 176 plant species representing 44 families (Decker 1931, Filer and others 1977). Corn is a preferred cultivated host; other Gramineae and giant ragweed are favored wild hosts. This borer less commonly attacks hardwood trees.

**Range.** A native insect, occurs throughout the United States east of the Rocky Mountains (Metcalf and other 1962) and from Nova Scotia west to Manitoba (Decker 1931).

**Description.** ***Adult.*** Moderately robust brownish moth with wingspan of 25 to 40 mm (figure 79A) (Decker 1931). Fore-wings varying shades of olive red or purplish brown sprinkled with gray; some have a group of white spots in medial area. Small white spots along distal third of anterior wing margin and white to yellowish line curves toward hind margin. Body reddish brown with white-tipped scales, producing overall mouse gray color. ***Egg.*** Globular, 0.6 by 0.4 mm, and pearly white when first deposited, gradually turning to brownish gray or amber. ***Larva.*** Head light brown with dark brown streak extending from the ocelli to ventral margin of cervical shield (figure 79B) (Peterson 1962). Dirty white body with four broad purplish brown stripes (dorsal and subdorsal) interrupted by distinct band of purplish brown around third thoracic and first three abdominal segments; from 26 to 32 mm long when mature. Prothoracic shield broad, partly divided, and yellowish to light brown with dark lateral stripe. Anal shield yellowish to pale brown. ***Pupa.*** Heavy bodied, brown, and 16 to 22 mm long.

**Biology.** Moths emerge from mid-August to mid-October (Solomon 1988b). Up to 2,000 eggs are deposited by each female, usually in creases of folded or rolled leaves of dead, dry grasses and weeds (Metcalf and others1962). Eggs overwinter

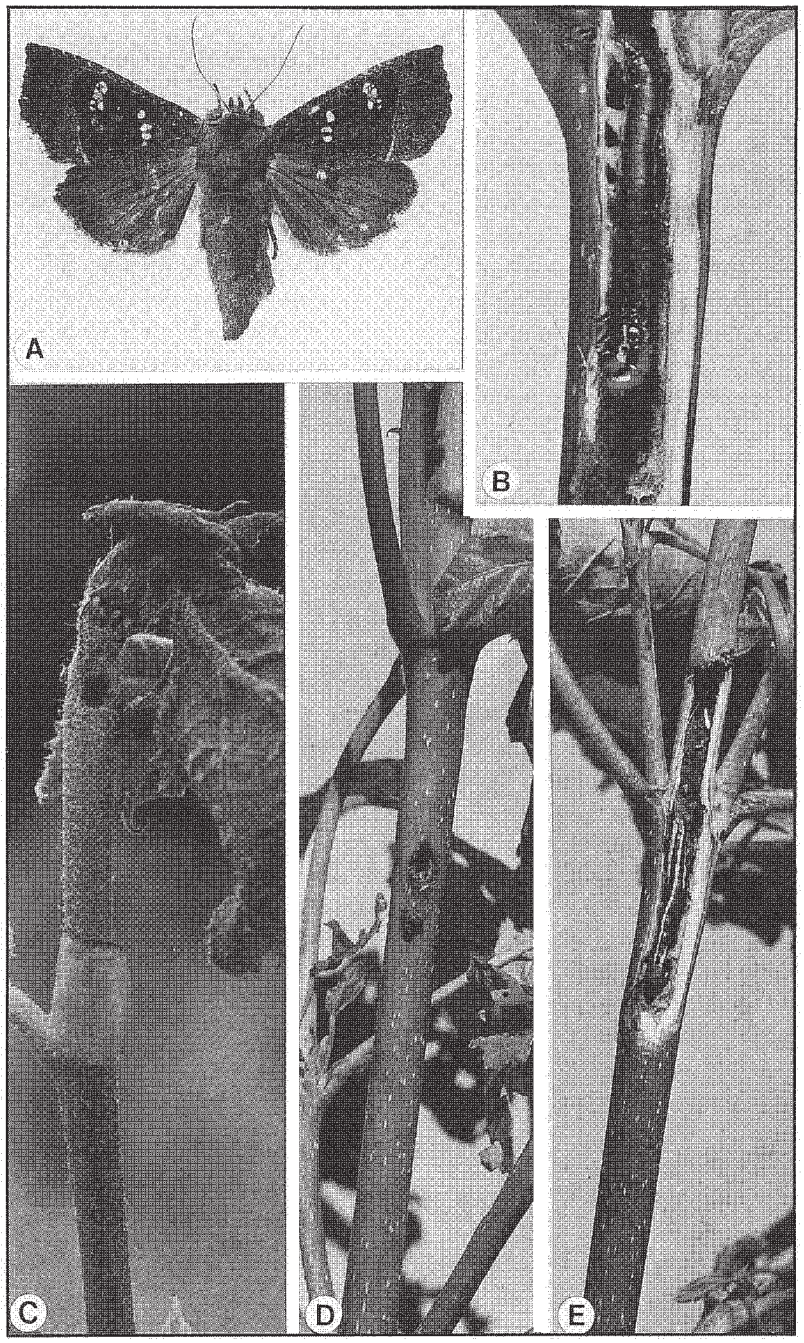


**Figure 79**—Papaipema nebris, *stalk borer: A, adult; B, larva in gallery; C, dying sycamore shoot with entrance hole; D, entrance hole with frass in silver maple; E, gallery exposed.*

and hatch the following May or June. Newly hatched larvae burrow in the stems of grasses and small-stemmed weeds and continually seek larger succulent stems as they grow (Decker 1931). It is usually during the late stages of development that larvae migrate from herbaceous plants and attack young trees. Larvae wander considerably during development, and each may feed on several shoots of the same plant, several plants, or on many different species of plants (McDaniel 1935). Small larvae usually enter herbaceous plants near their base and burrow upward; however, as larvae grow, they may bore into stems at any point, usually burrowing toward tips (Decker 1931). Larvae keep their galleries fairly free of frass, expelling it from the entrance holes. Larvae have been reported to molt from 7 to 14 times and require from 60 to 130 days to develop (Decker 1931). Full-grown larvae usually abandon their hosts and move to the ground, where they form oval cells below the soil surface in which to pupate. Occasionally, larvae will remain in their hosts, forming pupal chambers of frass and silk at the bottoms of their tunnels (Decker 1931). Pupation occurs from late July to late August and averages 25 days (Decker 1931). This species has one generation per year.

**Injury and damage.** Sudden wilting, drooping, and dying of succulent current year's growth, particularly terminals, on young trees during late spring and summer is the first evidence (figure 79C) (Filer and others 1977, Solomon 1988b). Closer inspection reveals larval entrance holes about 3 mm in diameter near the base of injured terminals or branches. Frass with distinct excrement pellets mixed with sap are ejected from entrance holes and are often present on the bark or foliage beneath (figure 79D) (McDaniel 1935). Larvae tunnel in the stem center (figure 79E) and often consume most of the woody contents of shoots; such weakened branch tips break off readily. Many branch tips on young trees can be damaged in a short time. Larvae prefer thick-stemmed herbaceous plants. This borer occasionally infests succulent current-year shoots of young deciduous trees and woody shrubs. Economically significant damage to trees rarely occurs over wide areas, but noticeable losses sometimes occur in nurseries and young plantations and, to a lesser extent, to young trees in natural stands (Solomon 1988b).

**Control.** The most important control in forest tree nurseries and young hardwood plantations is to destroy breeding sites by thoroughly cleaning up host weeds in fall and winter. Mowing fence rows and field borders is effective but must be done about mid-August just before oviposition. Mowing too early will drive larvae into susceptible crops (Metcalf and others 1962). Damage can sometimes be reduced on young trees if the wilted tips are promptly pruned below the injury and destroyed. Populations are adversely affected by many hymenopterous and dipterous parasites (Arnaud 1978, Krombein and others 1979); predaceous birds, mammals, and insects; and diseases (Decker 1931). Chemical controls may be needed occasionally.

### *Papaipema cataphracta* (Grote)

burdock borer (figure 80)

**Hosts.** Cottonwood, boxelder, elder. Over 30 hosts—mostly large-rooted thick-stemmed herbaceous plants—have been reported (Tietz 1972). Burdock and thistle are favored wild hosts (Bird 1898). Broadleaf trees are occasionally attacked.

**Range.** Occurs from the northeast Atlantic Coastal region west through New York and Pennsylvania to Minnesota and Colorado (Forbes 1954) and south to Mississippi.

**Description.** ***Adult.*** Moderately robust yellowish brown moth with wingspan of 30 to 35 mm (figure 80A). Forewings generally straw yellow, scaled, with grayish brown markings (Forbes 1954). Yellow spot on apex of each forewing. ***Larva.*** About 29 to 35 mm long (figure 80B). Head pale yellowish brown with darker brown at posterior margin. Cervical shield light brown with darker brown longitudinal stripes along each side. Pale white body with four broad purplish brown stripes along entire length of body. These continuous body stripes distinguish *P. cataphracta* from *P. nebris*, which has stripes interrupted on first three abdominal segments by purplish brown band (Decker 1931). ***Pupa.*** Chestnut brown, generally smooth except for dorsal punctations, about 14 mm long, cremaster with two small downward-pointing spines.

**Biology.** Moths emerge from early September to early October (Decker 1931, Drake and Decker 1927, Knutson 1944). Females deposit up to 2,000 eggs in the creases of rolled or folded leaf blades of dead grasses and weeds; there, eggs overwinter and hatch the following spring. Initially, newly hatched larvae burrow into stems of weeds. When the larvae are 2 to 6 weeks old, they leave their initial herbaceous hosts and move to new hosts, which can be thick-stemmed woody plants. Most reports indicate May as the time that larvae infest tree shoots, but infestations have been observed through July and early August (Solomon 1988b). Field and cage studies show that typical larvae wander considerably during development and repeatedly burrow into susceptible shoots for 1 to 2 weeks, abandon them, and seek larger shoots. In cages over clumps of cottonwood sprouts, single larvae have tunneled up to 12 separate shoots. In late July to early September, full-grown larvae in cottonwood shoots usually abandon galleries and move to the ground, where they form pupation sites of loose silk and frass just below the soil surface or under debris. A few larvae remain in their hosts and simply enlarge tunnels in the shoots to form pupation chambers. The pupal stage lasts 25 to 33 days. This borer has one generation per year.

**Injury and damage.** Injury in cottonwood nurseries in Mississippi usually becomes noticeable from late April to early May, when coppice sprouts are 30 to 60 cm tall (figure 80C) (Solomon 1988b). Injured stems are easily detected by wilting and drooping shoots with browning or blackening leaves. Examination of damaged shoots often reveals round entrance holes 2 to 3 mm in

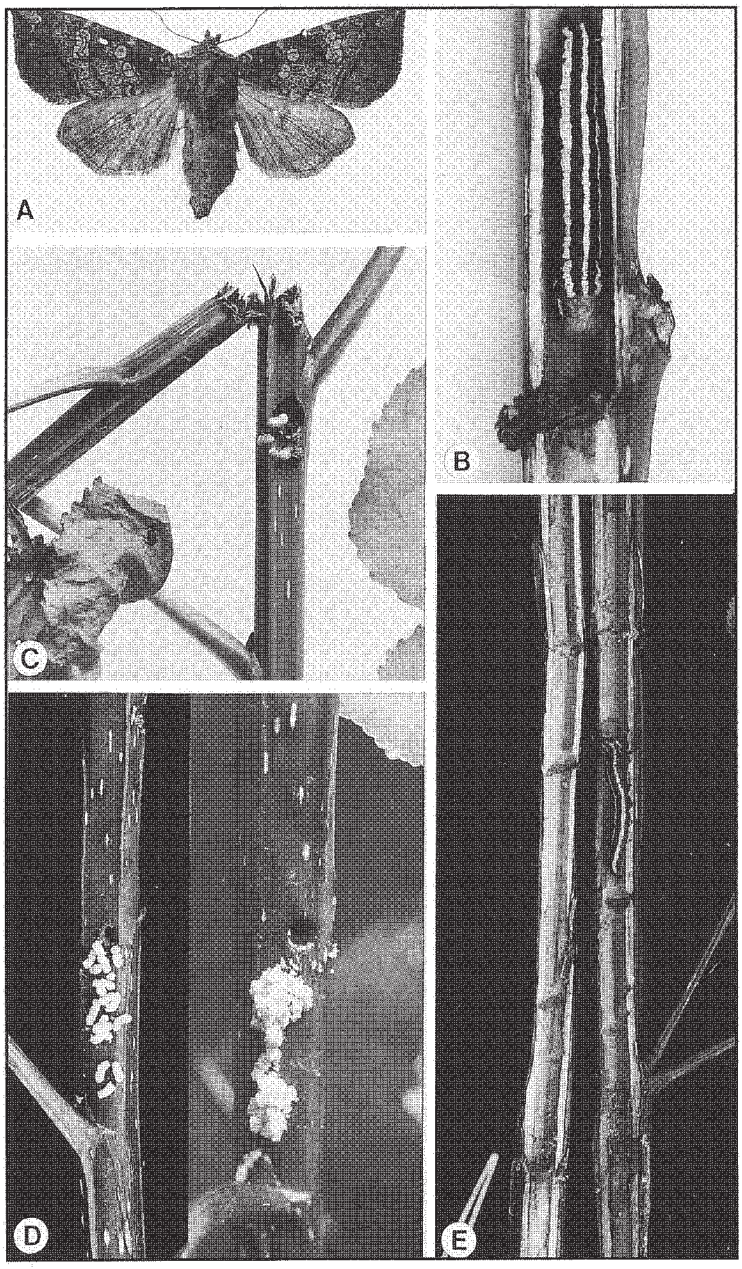


**Figure 80**—Papaipema cataphracta, *burdock borer: A, adult; B, larva in gallery; C, cottonwood shoot broken at weakened site; D, entrance holes with frass on infested shoots; E, stem split to expose tunnel and larva.*

diameter and 8 to 30 cm below the shoot tops (figure 80D). Entrance holes usually are kept open but occasionally loosely plugged with frass. Frass is sometimes fragmented and mixed with oozing sap on the stem just below entrance holes. More typically, frass consists mostly of distinctly white, cylindrical excrement pellets 1 to 2 mm in diameter and 2 to 3 mm long near entrance holes and on the ground below. Dissection of damaged cottonwood shoots reveals galleries in the centers extending in either direction from the entrance holes but usually upward or distally (figure 80E). Active galleries are kept open and mostly free of frass, and are 2 to 4 cm long. Occasionally branch tips and the aboveground part of seedling tree stems are killed (Washburn 1910). Young cottonwood trees have been moderately infested and damaged in some areas. In surveys, 4 to 12% of the coppice shoots in cottonwood nurseries in Mississippi have been attacked. About three-fourths of the infested shoots die back or break (Solomon 1988b).

**Control.** Larvae are extensively parasitized by *Chasmias scelestus* (Cresson) (Carlson 1979), *Exorista* sp., *Gyrmnochaeta ruficornis* (Williston), *Lixophaga variabilis* (Coquillett), *Lydella radicis* (Townsend), and *Winthemia rufopicta* (Bigot) (Arnaud 1978, Washburn 1910). Tree nurseries and young plantations can be protected from infestation by plowing under cover-crop refuse and weeds adjoining new plantings during autumn or early spring. Fence rows of weeds and grasses near tree plantings can also be burned during winter to destroy borer eggs (Drake and Decker 1927). Insecticides timed to correspond to earliest attacks can help minimize losses.

### *Papaipema furcata* (Smith)

[ash shoot borer] (figure 81)

**Hosts.** Ash, boxelder, buttonbush. White, black, and green ashes reported as hosts (Bird 1915, Leonard 1928). Also observed recently in boxelder and buttonbush.

**Range.** Occurs from New Hampshire west to Iowa, Minnesota, and Manitoba and south to Mississippi (Forbes 1954).

**Description.** ***Adult.*** Robust yellowish brown moth with wingspan of 33 to 45 mm (figure 81A) (Forbes 1954). Forewings light straw yellow, dusted with pale brown, with gray-brown wavy markings and several white dots. ***Larva.*** Head yellowish brown with dark chestnut brown markings (figure 81B) (Franklin 1908). Cervical shield yellowish brown with darker margins and with small dark spot on each side. Body mostly pale grayish flesh color to light purple; about 30 mm long when mature. Mid-dorsal pale stripe absent on anterior abdominal segments in all except first instar (Crumb 1956). This character distinguishes *P. furcata* from *P. nebris*, which has a mid-dorsal pale stripe. Black anal shield.

**Biology.** Moths emerge from late August to early September (Forbes 1954) and deposit eggs in early fall, presumably near branch tips (Bird 1915). Eggs lay dormant through winter and hatch early the following May. Newly hatched larvae enter succulent

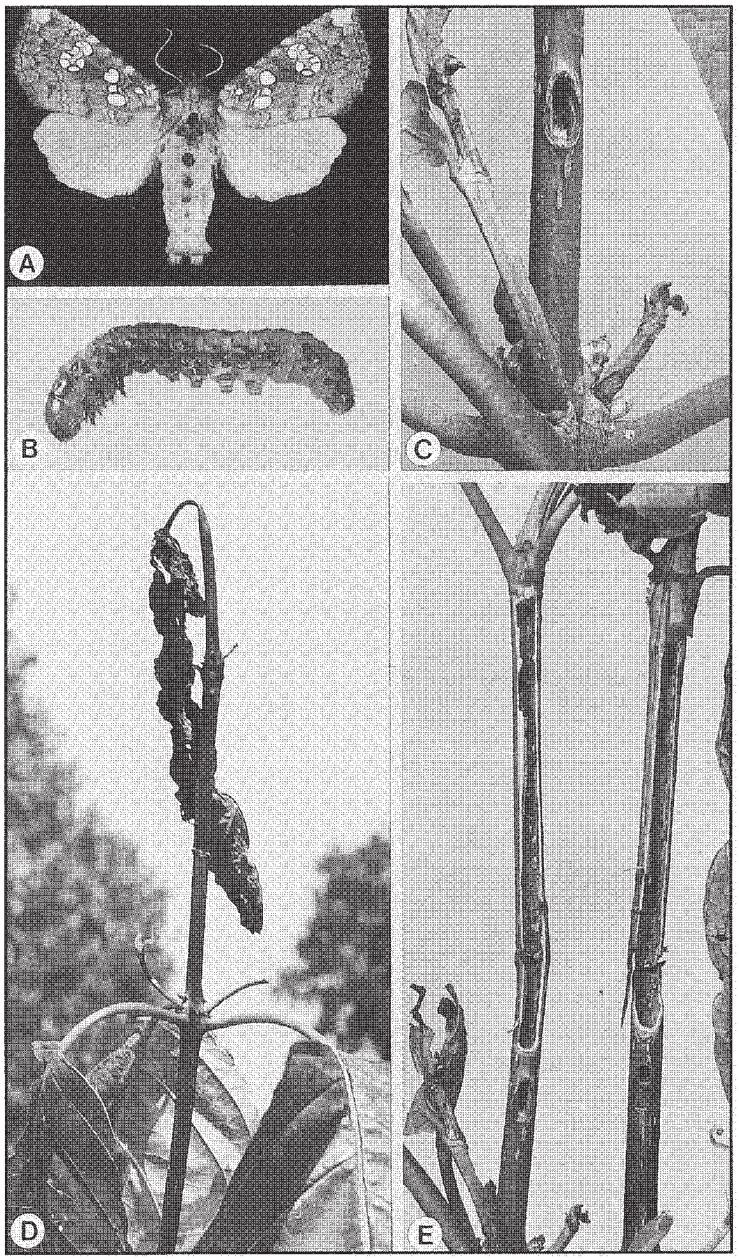


**Figure 81**—Papaipema furcata, *[ash shoot borer]: A, adult; B, larva; C, entrance hole in shoot; D, buttonbush shoot killed by larva; E, galleries exposed in shoots (A, specimen courtesy R. Hodges).*

new growth near the attachment of terminal leaves; they feed for a short time, leave the current growth, and move to the previous year's growth, where they usually enter just below the site of the winter bud. Mature larvae vacate their tunnels through oval exit holes (figure 81C) and move to the soil where pupation occurs for about 30 days. The ash shoot borer has one generation per year (Knutson 1944).

**Injury and damage.** The first signs of infestation are withered and dead leaves near the tips of the current shoot growth (figure 81D). Open round entrance holes about 2 mm in diameter are found several centimeters below shoot tips (figure 81C). Young larvae expel considerable frass from entrance holes on the new growth. Frass extrusion is not as apparent when older larvae leave the new growth and enter the previous year's growth (Bird 1915). Dissection of infested shoots will reveal the tunnels usually extending toward the apex (figure 81E). New growth on hundreds of young ash trees in nurseries has been destroyed by this borer (Knutson 1944). Scattered light damage has been observed in natural stands of young green ash, boxelder, and buttonbush in Mississippi.

**Control.** There is little information on natural enemies. The severity of injury to young trees might be reduced by carefully inspecting new growth in late May and June and then pruning and destroying infested tips before larvae begin to enter older wood. Properly timed application of insecticides may be needed occasionally in nurseries and young plantations.

### *Achatodes zeae* (Harris)

elder shoot borer (figure 82)

**Hosts.** Elder, alder. Elders, both wild and ornamental, are the major hosts (Silver 1933, Tietz 1972). Alder and some herbaceous plants may rarely be hosts.

**Range.** Maine south to Florida and Alabama and west to Louisiana, Iowa, and Wisconsin (Silver 1933). Its range appears to correspond to that of American elder, one of its preferred hosts.

**Description.** ***Adult.*** Robust reddish brown moth with hairy body and wingspan ranging from 28 to 34 mm (figure 82A); female slightly larger than male (Silver 1933). Forewings rusty red and mottled with gray with brownish yellow spot near tips; hindwings yellowish gray. Head and thorax reddish, mixed with yellow. Abdomen fiery red above and dark brown below. ***Egg.*** Round and somewhat flattened with surface roughened and pebblelike around periphery and smooth and glossy in center. Eggs change from white to tan soon after deposition and measure about 0.61 mm in diameter. ***Larva.*** Yellowish white with black head, thoracic shield, anal shield, pinacula, thoracic legs, and spiracles; 23 to 33 mm when fully grown (figure 82B). The thoracic shield is broad with a well-defined median line. The strongly chitinized anal shield has a rough surface and bears six prominent tubercles on the posterior margin (Godfrey 1987). ***Pupa.*** Initially tan but gradually changes to reddish brown and range from 17 to 21 mm long. The abdomen terminates in a short, broadly truncated ridge or process bearing four short, heavy spines.

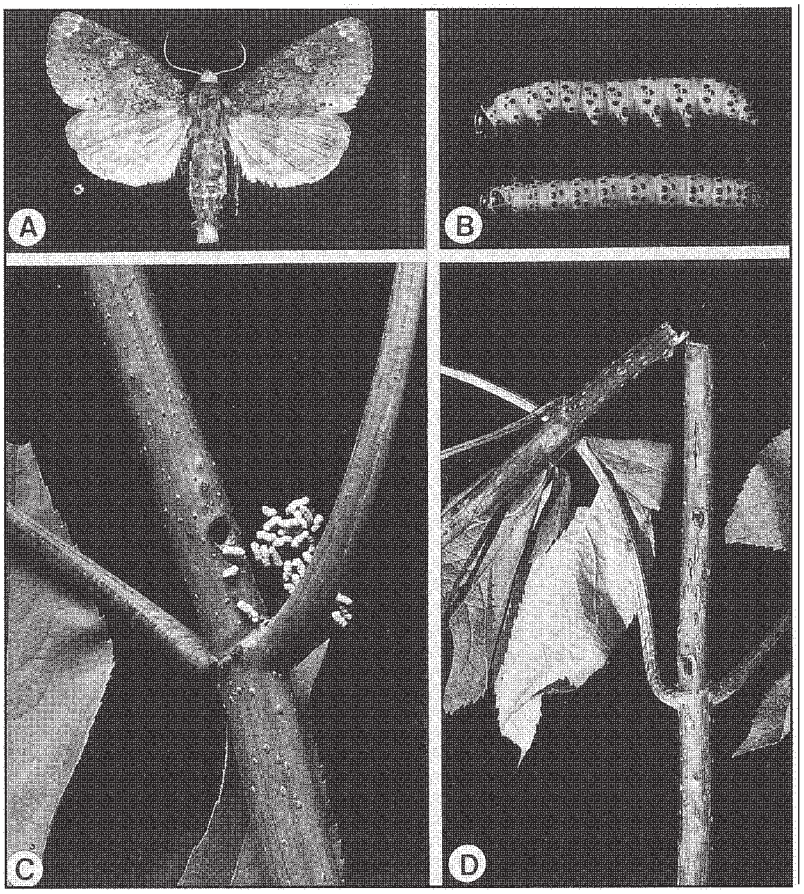


**Figure 82**—Achatodes zeae, *elder shoot borer: A, adult; B, larvae; C, entrance hole in elder shoot with white excrement pellets; D, stem broken at weakened site (A, specimen courtesy R. Hodges).*

**Biology.** Moths emerge during July, mate, and oviposit nocturnally (Silver 1933). Females deposit 150 to 500 eggs in small clusters averaging about 18 eggs per cluster; adjoining eggs occur in more or less straight rows that do not overlap. Eggs, deposited in crevices or tight bark folds of dead branches or shoots, usually between the inner bark and wood, are held firmly in place in a gluelike substance secreted by the female (Breakey 1930). Eggs deposited in July overwinter and hatch in late April and early May. Newly hatched larvae feed inconspicuously among unfolding leaves of lateral branches until the third or fourth instar and then migrate to succulent sprouts (Silver 1933). Larvae usually make entrance holes near the base of new sprouts, typically 3 to 5 cm above ground level. Although larvae may tunnel in either direction, most move upward, sometimes nearly to the apex of shoots. Larvae usually complete development in single large shoots but may vacate small shoots and seek others to complete their feeding. Occasionally, two or more larvae will develop in a shoot. Larvae feed for 35 to 68 days, completing development about the first week of June (Herrick 1935). When ready to pupate, larvae abandon current shoots and seek dry, dead, vertical shoots that they enter through holes made by larvae of previous infestations. Larvae burrow through the pith of the old, dry shoots for up to 20 cm, packing frass behind them. Eventually, larvae turn sharply and cut exit holes, either completely through or almost through, to the bark surface where pupation occurs. Exit holes are partially or completely plugged with loose, coarse frass, or occasionally closed-off with thin layers of tightly woven silken threads. Pupation lasts about 15 to 18 days. It completes one generation per year (Breakey 1930, Herrick 1935).

**Injury and damage.** Earliest signs of attack consist of holes 2 to 3 mm in diameter with sappy frass being ejected. Eventually, round holes 3 to 5 mm in diameter and large quantities of frass, consisting mostly of white excrement pellets, become noticeable (figure 82C). Infested shoots often wilt, droop over, and sometimes die or break off (figure 82D). Heavily damaged ground sprouts may not succumb but often fail to produce new shoots the next year (Breakey 1930, Silver 1933). By slicing infested stems longitudinally during summer, one can observe long larval galleries in the pith. Galleries are kept partially clear of frass. Although injury by this borer is most common in wild hosts, economically damaging injury has been reported only where elder has been grown commercially or where ornamentals have been destroyed or badly disfigured (Silver 1933).

**Control.** Birds, rodents, and parasites are important natural enemies. Studies have shown that as many as 20% of the pupae are destroyed by woodpeckers. Four hymenopterous larval parasites and seven hymenopterous pupal parasites were reported in Wisconsin studies (Breakey 1930, Krombein and others 1979). Several

tachinid parasites have also been found in other localities (Arnaud 1978). This borer can be controlled by collecting and burning, during fall and winter, old dead elder branches and shoots on which eggs have been deposited (Herrick 1935, Silver 1933).