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Guide to Insect Borers in North American Broadleaf Trees and Shrubs

J. D. Solomon
Research Entomologist (retired)
Southern Forest
Experiment Station
Southern Hardwoods Laboratory
Stoneville, Mississippi

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Store pesticides in original containers under lock and key–out of the reach of children and animals–and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat, drink, or smoke until you have washed them thoroughly. If you swallow a pesticide or get it in your eyes, follow the first-aid treatment given on the label and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing and wash skin thoroughly.

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This manual describes 300 species of insect borers and includes 244 photographic plates.

KEYWORDS: Wood borers; bark beetles; wood defects; decline; mortality; damage to forests, plantations, nurseries, shelterbelts, and urban plantings.

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Adler, C.L., Clemson University, Clemson, SC, reviewed family Buprestidae.

Antonelli, A.L., Washington State University, Puyallup, WA, provided photographs.

Bedding, R., Commonwealth Scientific and Industrial Research Organization, Hobart, Tasmania, Australia, provided photographs.

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Bishop, G.W., University of Idaho, Parma, ID, provided photographs.

Bordon, J.H., Simon Fraser University, Burnaby, BC, provided photographs.

Breakey, E.P., Washington State University, Puyallup, WA, provided photographs.

Brown, E.J., U.S. Department of Agriculture, Agricultural Research Service, Brownwood, TX, provided specimens for photographs.

Brown, L.R., University of California, Riverside, CA, provided photographs.

Brown, R.L., Mississippi State University, Mississippi State, MS, reviewed family Tortricidae and provided specimens for photographs.

Brown, R.M., Stockton, CA, provided photographs.

Burzynski, J., Instytut Badawczy, Warsaw, Poland, provided photograph.

Calcote, V.R., retired, U.S. Department of Agriculture, Agricultural Research Service, Stoneville, MS, reviewed families Bostrichidae and Lymexylidae and provided specimens for photographs.

Cashatt, E.D., Illinois State Museum, Springfield, IL, reviewed families Pterophoridae and Noctuidae.

Chellman, C.W., retired, Florida A&M University, Tallahassee, FL, provided photographs.

Chemsak, J.A., University of California, Berkeley, CA, reviewed family Cerambycidae and provided specimens for photographs.

Davis, D.R., Department of Entomology, Smithsonian Institution, Washington, DC, reviewed families Agonoxenidae, Argyresthiidae, Gelechiidae, Hepialidae, Momphidae, and Nepticulidae.

Dix, M.E., U.S. Department of Agriculture, Forest Service, Lincoln, NE, reviewed family Cossidae and provided photographs.

Donahue, J.P., Natural History Museum, Los Angeles, CA, provided infested wood

samples for photographs.

Eichlin, T.D., California Department of Food and Agriculture, Sacramento, CA, reviewed family Sesiidae and provided photograph.

Farrar, R.J., FMC Corporation, Yuma, AZ, provided photograph.

Funk, D.H., Stroud Water Research Center, Avondale, PA, provided photograph.

Galford, J.R., retired, U.S. Department of Agriculture, Forest Service, Delaware, OH, reviewed family Cossidae and provided photographs.

Ghidiu, G.M., Rutgers University, Bridgeton, NJ, provided photographs and infested wood samples for photographs.

Giese, R.L., University of Wisconsin, Madison, WI, provided photographs.

Godfrey, G.L., Illinois Department of Energy and Natural Resources, Champaign, IL, reviewed families Noctuidae and Pterophoridae.

Gorsuch, C.S., Clemson University, Clemson, SC, provided photographs.

Great Lakes Forestry Centre, Sault Ste. Marie, ON, provided photographs.

Haack, R.A., U.S. Department of Agriculture, Forest Service, East Lansing, MI, provided photograph.

Habeck, D.H., University of Florida, Gainesville, FL, provided specimens for photographs.

Hansen, J.B., U.S. Department of Agriculture, Forest Service, St. Paul, MN, reviewed family Agromyzidae.

Hanson, P.E., Oregon State University, Corvallis, OR, provided photographs.

Harman, D.M., University of Maryland, Frostburg, MD, reviewed family Tortricidae.

Harris, J.W.E., Canadian Forest Service, Victoria, BC, provided photograph.

Hart, E.R., Iowa State University, Ames, IA, provided photographs.

Hildahl, V., Department of Natural Resources, Winnipeg, MB, provided photographs.

Hodges, R.W., U.S. Department of Agriculture, Systematic Entomology Laboratory, Washington, DC, reviewed family Cossidae and guided access to National Museum specimens for photographs.

Holsten, E.H., U.S. Department of Agriculture, Forest Service, Anchorage, AK, provided photographs.

Hovore, F.T., Placerita Canyon Nature Center, Newhall, CA, reviewed family Cerambycidae and provided photographs and infested wood samples for photographs.

Jeffery, C.A., Department of Natural Resources, Winnipeg, MB, provided photographs.

Johnson, W.T., Cornell University, Ithaca, NY, reviewed family Sesiidae and provided photographs.

Kauffman, B., Tennessee Department of Agriculture, Division of Plant Industries, Nashville, TN, provided infested wood samples for photographs.

Kaya, H.K., University of California, Davis, CA, provided photograph.

Koehler, C.S., University of California, Berkeley, CA, provided photographs.

Kulman, H.M., University of Minnesota, St.

Paul, MN, provided photographs.

Lambert, W.E., Mississippi Forestry Commission, Jackson, MS, reviewed families Agonoxenidae, Argyresthiidae, Gelechiidae, Hepialidae, Momphidae, and Nepticulidae.

Marshall, P.T., Department of Natural Resources, Vallonia, IN, provided infested seedlings for photographs.

McKnight, M.E., U.S. Department of Agriculture, Forest Service, Washington, DC, provided photographs.

Middlekauff, W.W., University of California, Berkeley, CA, reviewed families Cephidae, Siricidae, Tenthredinidae, and Xiphydriidae.

Miller, W.E., retired, U.S. Department of Agriculture, Forest Service, St. Paul, MN, reviewed family Tortricidae.

Mizell, R.F., III, University of Florida, Monticello, FL, reviewed families Pyralidae and Thyrididae and provided photographs and infested wood samples for photographs.

Morris, R.C., retired, U.S. Department of Agriculture, Forest Service, Stoneville, MS, reviewed family Tortricidae and provided photographs.

Neal, J.W., Jr., U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD, provided photographs.

Neel, W.W., retired, Mississippi State University, Mississippi State, MS, reviewed families Brentidae and Curculionidae.

Nef, L., University Catholique de Louvain, Louvain-La-Neuve, Belgium, provided photographs.

Neill, G.B., Prairie Farm Rehabilitation Administration, Indian Head, SK, reviewed family Sesiidae and provided photographs.

Nelson, G.H., College of Osteopathic Medicine of the Pacific, Pomona, CA, reviewed family Buprestidae.

Neunzig, H.H., North Carolina State University, Raleigh, NC, reviewed families Pyralidae and Thyrididae and provided specimen for photograph.

New York Agricultural Experiment Station, Entomology Department, Geneva, NY, provided photographs.

Nielsen, D.G., Ohio Agricultural Research Center, Wooster, OH, provided photographs.

Nord, J.C., U.S. Department of Agriculture, Forest Service, Athens, GA, reviewed families Platypodidae and Scolytidae and provided photographs and infested wood samples for photographs.

Norris, D.M., University of Wisconsin, Madison, WI, reviewed families Platypodidae and Scolytidae.

Oatman, E.R., University of California, Riverside, CA, provided photographs.

Oliver, A.D., retired, Louisiana State University, Baton Rouge, LA, provided photograph.

Oliveria, F.L., U.S. Department of Agriculture, Forest Service, Pineville, LA, reviewed families Agonoxenidae, Argyresthiidae, Gelechiidae, Hepialidae, Momphidae, and Nepticulidae and provided infested wood samples for photographs.

Ostry, M.E., U.S. Department of Agriculture, Forest Service, St. Paul, MN, pro-

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Palm, C.E., Jr., State University of New York, Syracuse, NY, provided specimens for photographs.

Palmer, W.A., Temple, TX, provided infested wood samples for photographs.

Papp, C.S., California Department of Food and Agriculture, Sacramento, CA, reviewed families Brentidae and Curculionidae.

Payne, J.A., U.S. Department of Agriculture, Agricultural Research Service, Byron, GA, provided photographs.

Penrose, R.L., California Department of Food and Agriculture, Sacramento, CA, reviewed family Cerambycidae and provided photographs and infested wood samples for photographs.

Peterson, R.V., U.S. Department of Agriculture, Systematic Entomology Laboratory, Washington, DC, reviewed family Agromyzidae and guided access to National Museum specimens for photographs.

Petty, J.L., Shelby, ID, provided photographs.

Pless, C.D., University of Tennessee, Knoxville, TN, reviewed families Pyralidae and Thyrididae and provided infested wood samples for photographs.

Pollet, D.K., Louisiana State University, Baton Rouge, LA, provided photographs.

Potter, D.A., University of Kentucky, Lexington, KY, provided photographs.

Purrington, F.F., Ohio Agricultural Research and Development Center, Wooster, OH, provided photographs.

Rexrode, C.O., retired, U.S. Department of Agriculture, Forest Service, Delaware, OH, provided photographs.

Rice, M.E., University of Idaho, Moscow, ID, provided photographs and infested wood samples for photographs.

Roling, M.P., Southwest Missouri State University, Springfield, MO, provided photographs and specimens for photographs.

Schaefers, G.A., New York Agricultural Experiment Station, Geneva, NY, provided photographs.

Scott, R.R., Lincoln College, Canterbury, New Zealand, provided photographs.

Scriven, G.T., University of California, Riverside, CA, provided photographs.

Shigo, A.L., retired, U.S. Department of Agriculture, Forest Service, Durham, NH, provided photographs.

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Simmons, G.A., Michigan State University, East Lansing, MI, provided photographs.

Smith, D.R., U.S. Department of Agriculture, Systematic Entomology Laboratory, Washington, DC, reviewed families Cephidae, Siricidae, Tenthredinidae, and Xiphydriidae and guided access to National Museum specimens for photographs.

Smith, E.L., California Academy of Sciences, San Francisco, CA, reviewed families Cephidae, Siricidae, Tenthredinidae, and Xiphydriidae and

provided photographs.

Smith, L., Washington State University, Wenatchee, WA, provided photographs.

Snow, J.W., U.S. Department of Agriculture, Agricultural Research Service, Byron, GA, reviewed family Sesiidae and provided specimen for photograph.

Stein, J.D., Jr., U.S. Department of Agriculture, Forest Service, Berkeley, CA, provided photographs.

Steyskal, G.C., U.S. Department of Agriculture, Systematic Entomology Laboratory, Washington, DC, reviewed family Agromyzidae.

Tedders, W.L., U.S. Department of Agriculture, Agricultural Research Service, Byron, GA, reviewed families Brentidae and Curculionidae and provided photographs.

Todd, J.W., University of Georgia, Tifton, GA, provided specimens for photographs.

Turnbow, R.H., U.S. Army, Fort Rucker, AL, reviewed family Cerambycidae.

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Vasvary, L.M., Rutgers University, New Brunswick, NJ, provided photographs and infested wood samples for photographs.

Wagner, D.L., University of Connecticut, Storrs, CT, reviewed families Agonoxenidae, Argyresthiidae, Gelechiidae, Hepialidae, Momphidae, and Nepticulidae and provided photographs.

Wallner, W.E., U.S. Department of Agriculture, Forest Service, Hamden, CT, reviewed family Agromyzidae and provided photographs.

Weber, B.C., U.S. Department of Agriculture, Forest Service, Washington, DC, provided photographs.

Wellso, S.G., U.S. Department of Agriculture, Agricultural Research Service, West Lafayette, IN, reviewed family Buprestidae and provided specimens and infested wood samples for photographs.

Westcott, R.L., Oregon Department of Agriculture, Salem, OR, reviewed family Buprestidae.

Whitehead, D.R., deceased, U.S. Department of Agriculture, Systematic Entomology Laboratory, Washington, DC, reviewed families Brentidae and Curculionidae and guided access to National Museum specimens for photographs.

Whitmore, J.L., U.S. Department of Agriculture, Forest Service, Washington, DC, provided photographs.

Wilkinson, R.C., retired, University of Florida, Gainesville, FL, provided infested wood samples for photographs.

Williams, L.H., U.S. Department of Agriculture, Forest Service, Gulfport, MS, reviewed families Bostrichidae and Lymexylidae.

Williams, R.N., Ohio Agricultural Research

and Development Center, Wooster, OH, provided photographs.

Wong, H.R., Canadian Forestry Service, Edmonton, AB, reviewed families Cephidae, Siricidae, Tenthredinidae, and Xiphydriidae and provided photographs.

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How to Use This Book

This book is an illustrated guide to 300 species of insect borers that attack hardwood trees, shrubs, and other woody angiosperms in North America. The major purposes of this guide are to identify insect borers and their damage and to provide information for controlling them. Readers most likely to find this guide useful are practicing foresters, entomologists, and others responsible for preventing or minimizing losses caused by these insects in forests, plantations, nurseries, urban plantings, and other settings where trees and shrubs grow. This book should also be a useful reference for extension agents, pest control specialists, arboriculturists, horticulturists, nursery managers, urban managers, forestry technicians, forest owners, homeowners, and teachers and students of forestry and entomology.

Although *Insects of Eastern Forests* (USDA FS 1985), *Western Forest Insects* (Furniss and Carolin 1977), *Insects That Feed on Trees and Shrubs* (Johnson and Lyon 1988), and other major references contain sections on insect borers, the information in these sources is brief and limited to the most-common species. This guide, on the other hand, focuses entirely on the insect borers of living North American broadleaf hardwood tree and shrub species (most of which are deciduous), including those used for timber, windbreaks, ornament, nut and fruit production, and other purposes.

The insects are arranged taxonomically by order and family, generally following the protocol and classification scheme used in other major texts, catalogs, and checklists (Arnett 1968, Borror and others 1981, Furniss and Carolin 1977, Hodges and others 1983, Krombein and others 1979, USDA FS 1985). Genera in families and species in genera are presented in the order of their relative importance as pests.

The discussion for each insect contains subsections on hosts, range, description of the life stages, biology, injury and damage, and control. Subsections on hosts, range, and description are abbreviated (most verbs and articles omitted). Some life stage descriptions are omitted where information is lacking. Biologies are summarized to help predict damage and to suggest plans for managing infestations. Natural, cultural, chemical, and other controls are discussed, but specific insecticides are not named because they are subject to constant change and vary from state to state. The parasites listed for individual borer species are insect parasites unless otherwise indicated, and most are parasitic on the larval and/or pupal stages of the host. Photographs illustrate (to the extent possible) the insects and their damage. Although not executed to exact scale, photographs of insect stages are printed to relative or proportional size.

The **Literature Cited** section (p. 699) will be useful to readers who want more information on specific insects. The **Glossary** (p. 635) is included to aid those unfamiliar with scientific terminology in this field (Ford-Robertson 1971, Torre-Bueno 1962).

This guide presents scientific names followed by common names for each insect borer. Common names approved by the Entomological Society of America (1989)

are used when available. *For species that have no approved common name, nomenclature in vernacular use is given in brackets [].* An index to both the scientific (Chemsak and Linsley 1982, Fisher 1928, Hodges and others 1983, Smith 1979, Spencer and Steyskal 1986, Wood 1982) and common names of the insects is presented (p. 681).

Although no keys are presented, a **Diagnostic Host Index** will help the reader identify insect borers (p.639). Where possible, host names follow the nomenclature in *Checklist of United States Trees (Native and Neutralized)* by Little (1979). Several other references on host nomenclature were used to supplement Little's checklist (Kartesz and Kartesz 1980, Kelsey and Dayton 1942, Terrell and others 1986, Van Dersal 1939, Vines 1960). A list of corresponding common and scientific names of host plants is also presented (p.689).

Introduction

Insect borers are important pests of hardwood trees, shrubs, and other woody angiosperms, causing defects in the wood that lower its value for lumber, veneer, and other products. Borer holes in lumber, for example, have been responsible for annual losses of $21 per thousand board feet in oaks harvested in the South (Morris 1977) and $24 per thousand board feet in Appalachian oaks (Donley 1974). At current values, the average losses are $45 per thousand board feet, which comes to $158 million dollars for the 3.5 billion board feet of oaks cut annually in the United States (U.S. Department of Commerce 1988).

Borer larvae construct tunnels in the terminal shoots, branches, trunks, and roots of woody plants of all sizes. Larvae of most borer species hatch from eggs deposited on the surface and then chew their way into the tissue. Adults of some species oviposit directly into the tissue, and others chew niches through the bark and then deposit eggs within the tissue. Naturally regenerated stands are sometimes heavily infested by girdler and pruner borers. Nursery stock and young plantings close to heavily infested natural stands or woodlots are especially vulnerable. Young transplanted trees are very susceptible to attacks by flatheaded borers and often require extra protection. Insect borers are also responsible for tree decline and mortality in windbreaks.

The consequences of borer infestation are multifold. Loss of terminals and main stems reduces growth and deforms trees in young hardwood plantations. Twig and shoot borers can drastically decrease the number of fruit- and nut-bearing branches and reduce the crops in orchards and nut-tree groves. Girdled branches die and must be removed around residences, and wormholes and healed-over bark scars diminish the esthetic value of shade and ornamental trees and shrubs.

Borers sometimes invade the cambium and callus tissue around new grafts and prevent the union of scion and stock. Trees recently topworked with new grafts may suffer serious damage. Trees stressed by borer attacks and other agents are susceptible to bark and ambrosia beetles. Bark beetles transmit the fungal pathogen—*Ceratocystis ulmi* (Buisman) C. Moreau—for Dutch elm disease, which has killed countless elms across North America.

Insect borers are commonly concealed beneath the bark or in the wood, making them difficult to detect and costly to control. However, damage by many borer species can be greatly minimized by following recommended cultural practices in both artificial plantings and natural stands.

The cryptic habits of insect borers have hampered efforts to document their activities. Information about them is widely scattered, much of it in older, not readily accessible literature. The information in this guide is based on a careful survey of the literature and on 30 years of personal experience studying borers in the field. For many species, information in the guide is presented for the first time.

By far, the greatest numbers of insect

borer species covered in this guide are in the orders Lepidoptera (moths) (99) and Coleoptera (beetles) (182). Smaller numbers of borer species are in the order Hymenoptera (sawflies and horntails) (14), and still fewer species in the order Diptera (flies) (5).

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

Hepialidae *3*
Nepticulidae *13*
Momphidae *17*
Agonoxenidae *20*
Gelechiidae *22*
Argyresthiidae *28*
Sesiidae *29*
Cossidae *111*
Tortricidae *134*
Pyralidae *166*
Thyrididae *192*
Pterophoridae *195*
Noctuidae *202*

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 *3*
argenteomaculatus Harris *6*
thule Strecker *8*
Hepialus
californicus (Boisduval) *10*

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

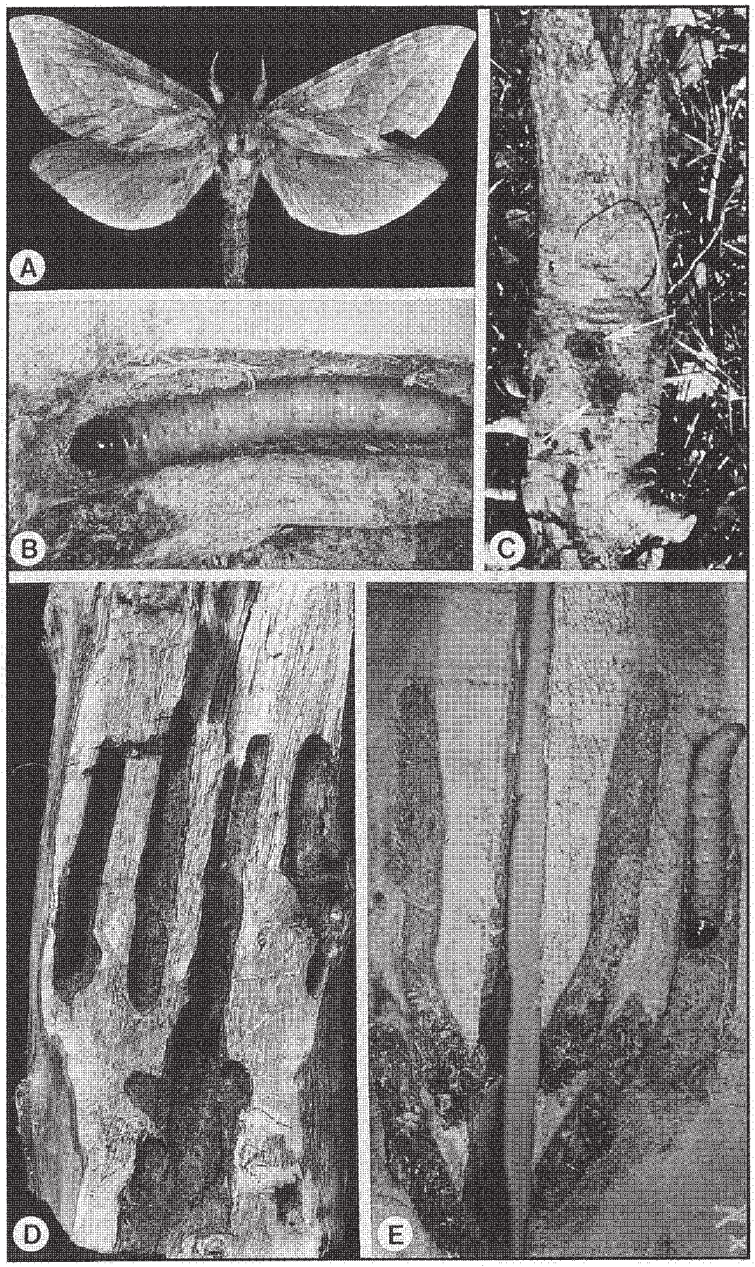

Figure 1—Sthenopis quadriguttatus, *[poplar ghost moth]: A, adult; B, larva in gallery; C, rootstock with entrance holes; D, multiple galleries in root collar; E, H-shaped gallery with larva (A, specimen courtesy R. Hodges; B-E, courtesy G. Vallee and R. Beique).*

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

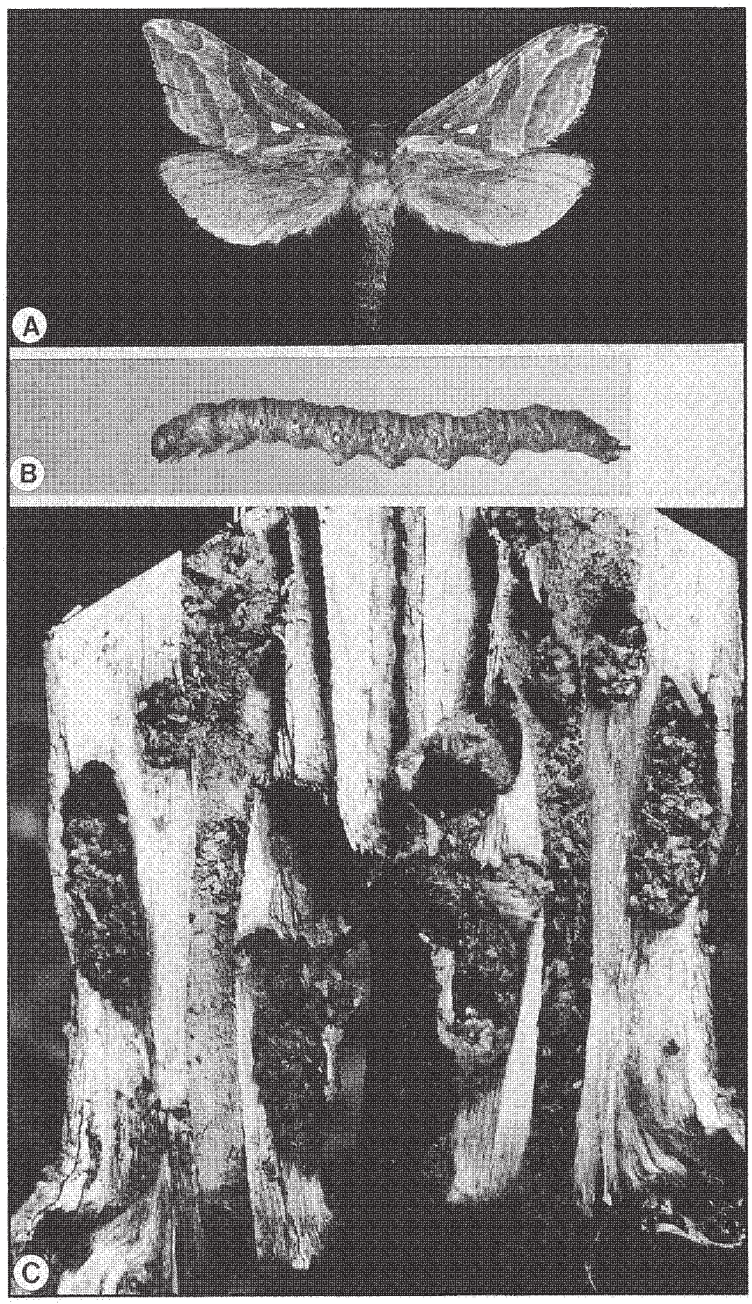

Figure 2—Sthenopis argenteomaculatus, *[alder ghost moth]: A, adult; B, mature larva; C, multiple galleries at base of trunk (specimens, courtesy R. Hodges).*

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

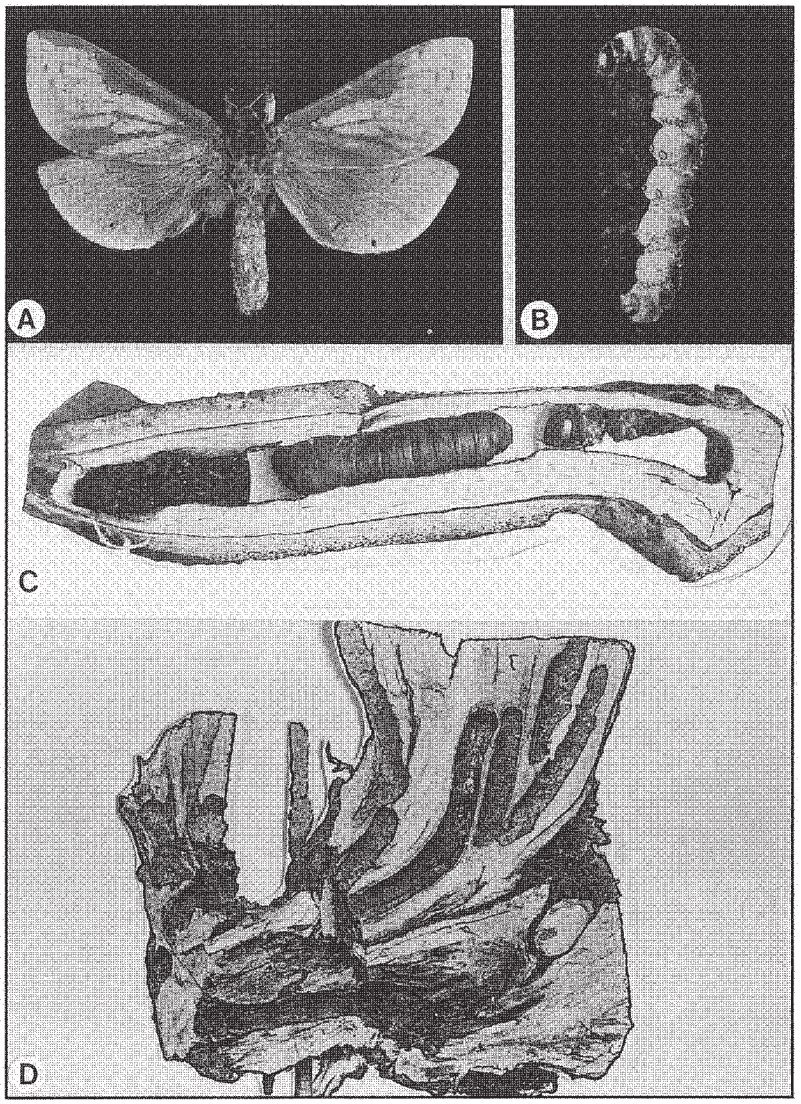

Figure 3—Sthenopis thule, *[willow ghost moth]: A, adult; B, larva; C, tunnel with pupa in root; D, root collar mass with multiple galleries (A, specimen courtesy R. Hodges; B-D, reproduced from Swaine [1909]).*

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.

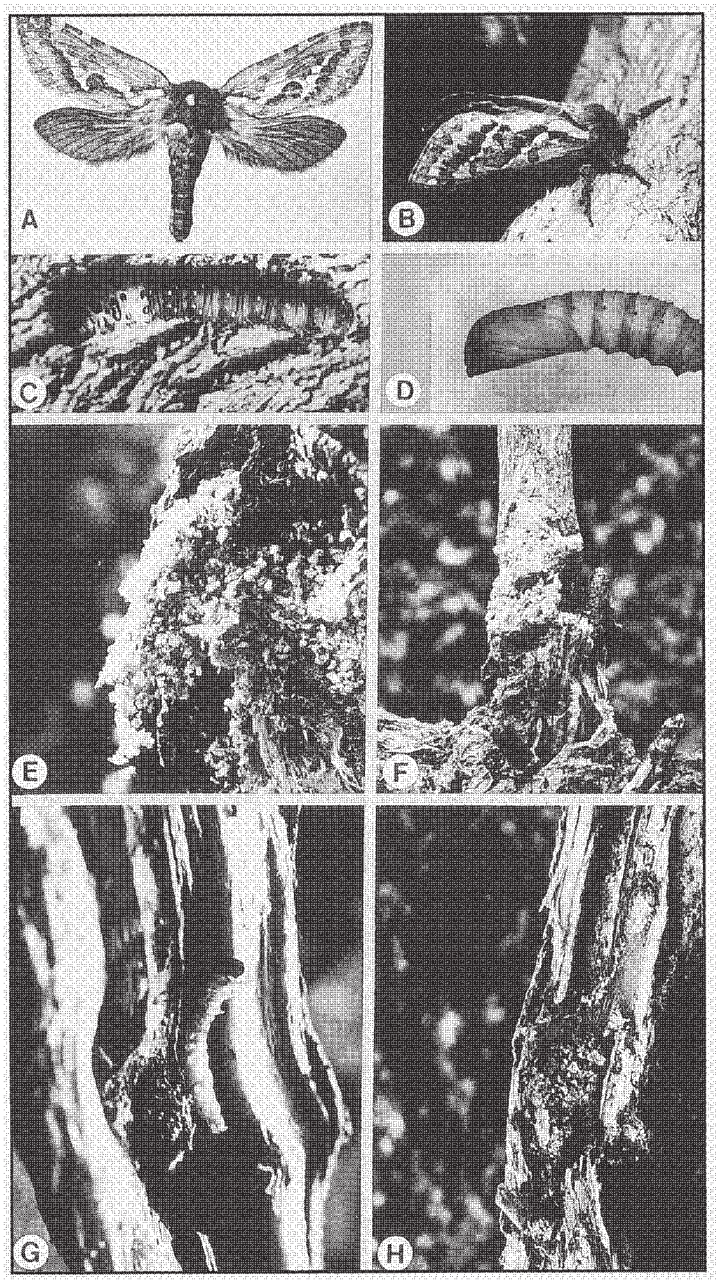

Figure 4—Hepialus californicus, *[lupine ghost moth]: A, adult; B, newly emerged moth in resting position; C, larva; D, pupa; E, frass clump; F, attack sites around branch crotches; G, split stem with galleries; H, protruding pupal skins (courtesy D. Wagner).*

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 (Chambers) *13*
Ectoedema populella Busck *15*

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

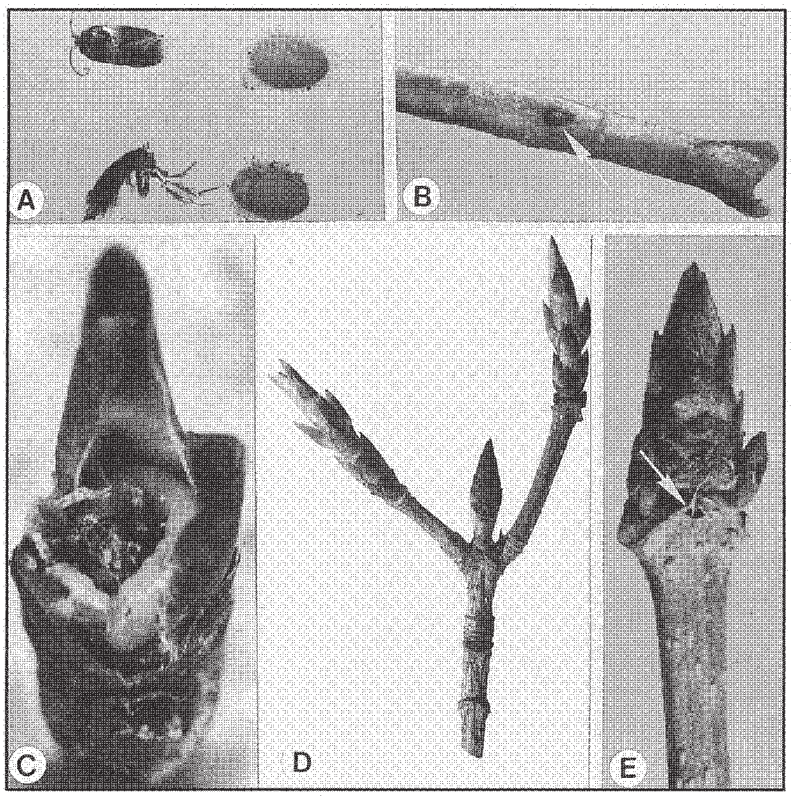

Figure 5—Obrussa ochrefasciella, *hard maple budminer: A, adults and cocoons; B, egg on leaf petiole; C, larva burrowing in maple bud; D, terminal bud killed allowing fork to develop; E, larval exit just below terminal bud (courtesy H. Kulman).*

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-

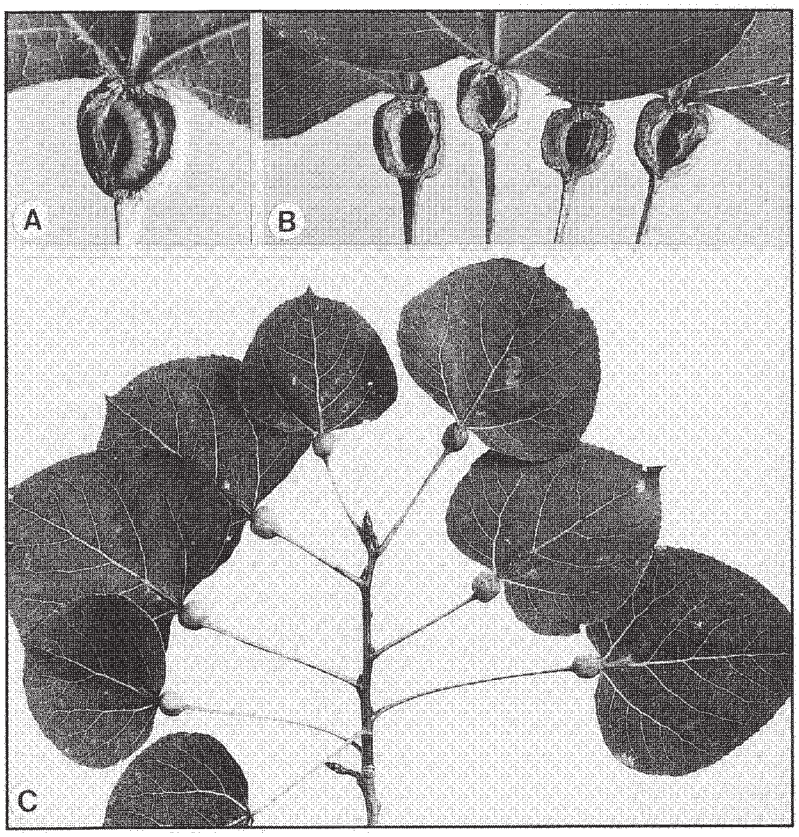

Figure 6—Ectoedemia populella, *[aspen petiole gall moth]: A, closeup of larva feeding inside gall; B, galls dissected to expose cavities and tabletlike frass mass on one side; C, pea-sized galls on petioles of aspen (specimens courtesy D. Wagner).*

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

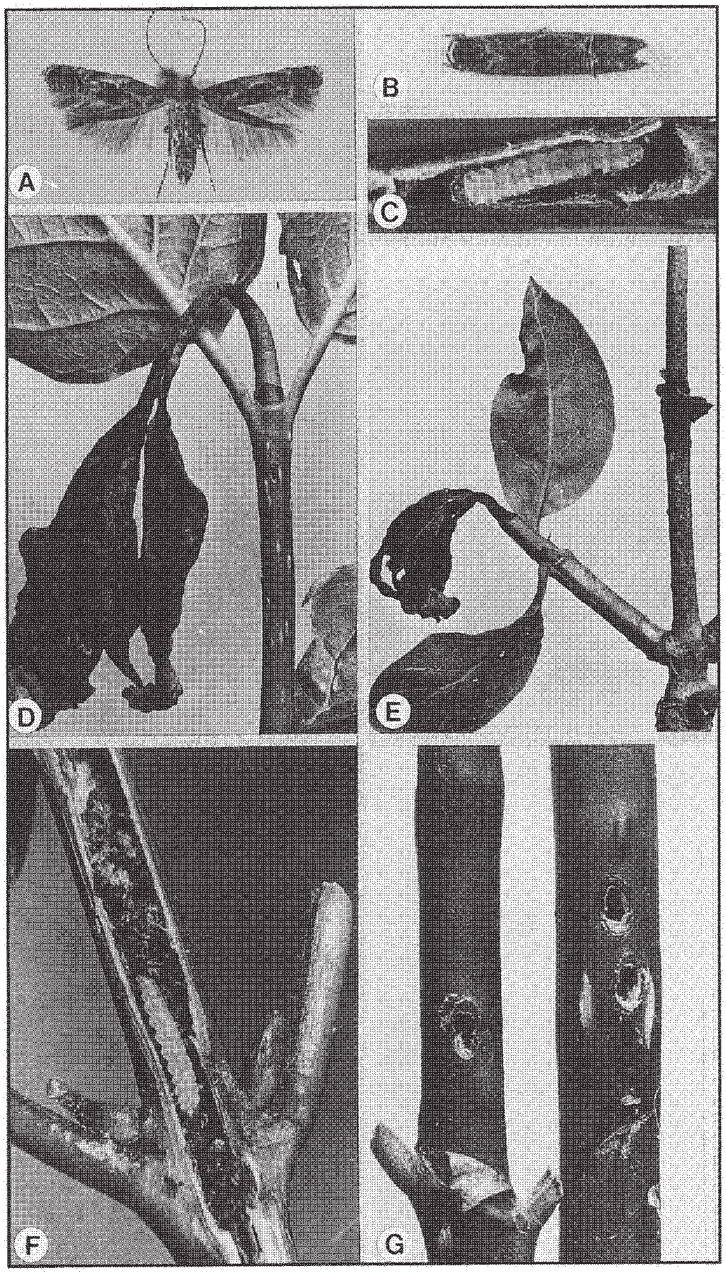

Figure 7—Mompha *n. sp., [buttonbush shoot borer]: A, adult; B, adult in resting position; C, larva in gallery; D, wilting, drooping terminal shoot; E, lateral shoot dieback; F, shoot hollowed out and loosely filled with frass; G, closeup of larval exit holes.*

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.

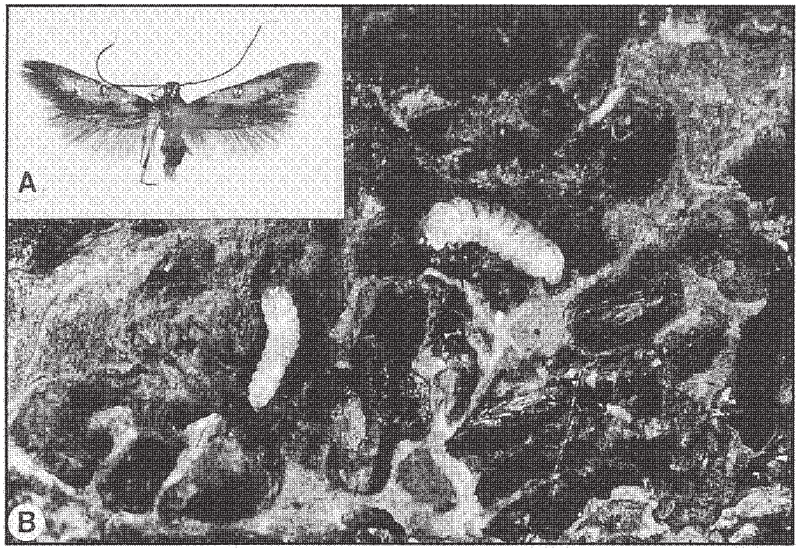

Figure 8—Glyphipteryx linneella, *[linden bark borer]: A, adult; B, outer bark removed to expose the larvae and burrows in the inner bark (A, specimen courtesy R. Hodges; B, courtesy Great Lakes Forestry Centre).*

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 *22*
Gnorimoschema baccharisella Busck *25*
Coleotechnites baccharisella (Keifer) *25*

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

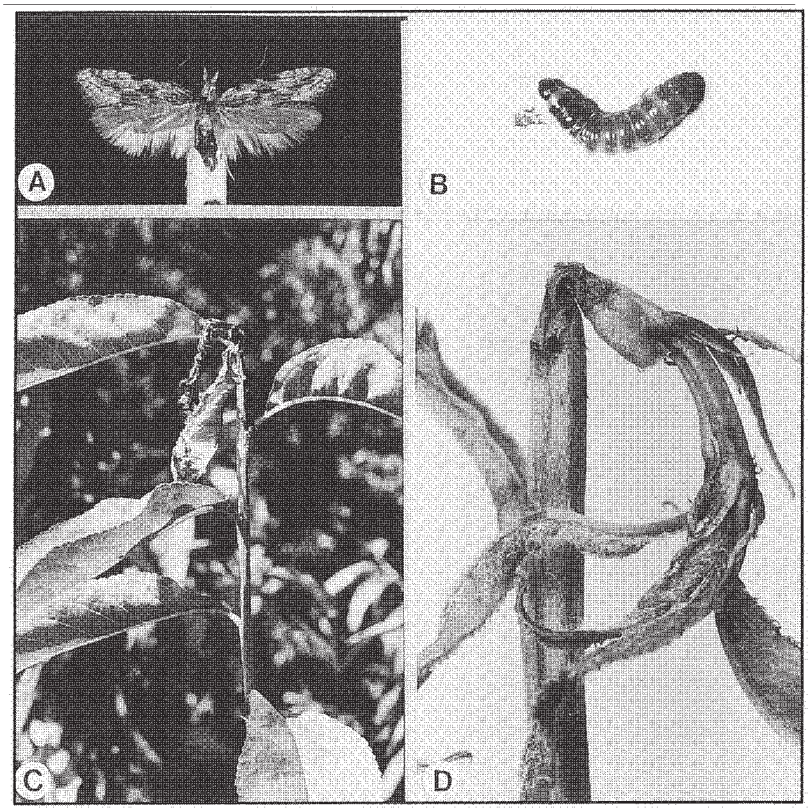

Figure 9—Anarsia lineatella, *peach twig borer: A, adult; B, larva; C, peach shoot wilting and drooping; D, dying shoot with hole in stem (A, specimen courtesy R. Hodges; B, courtesy L. Smith).*

(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).

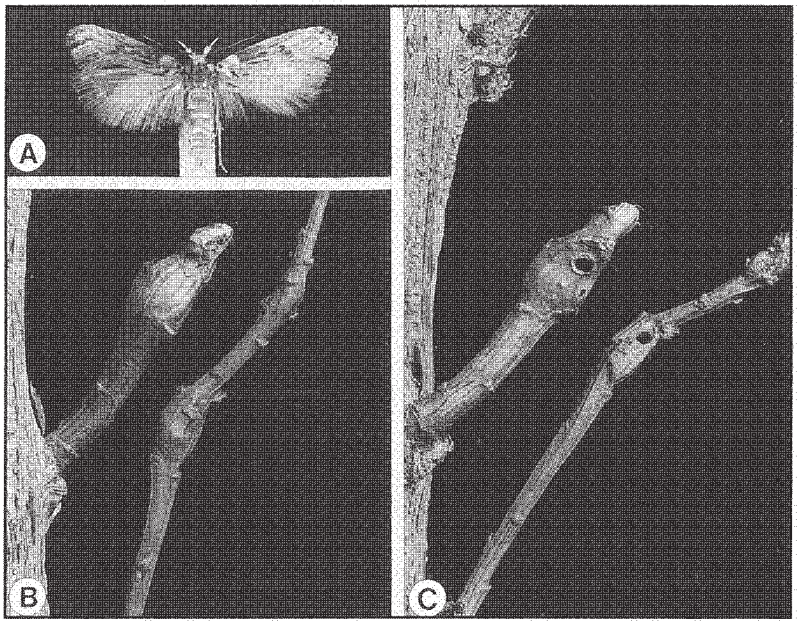

Figure 10—Gnorimoschema baccharisella, *[coyote brush gall moth]: A, adult; B, galls on shoots; C, exit holes in shoot galls (A, specimen courtesy R. Hodges).*

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) *30*
- *aureocincta* Purrington and Nielsen *33*

Paranthrene
- *simulans* (Grote) *35*
- *pellucida* Greenfield and Karandinos *38*
- *asilipennis* (Boisduval) *40*
- *tabaniformis* (Rottemburg) *42*
- *dollii* (Neumoegen) *45*
- *robiniae* (Hy. Edwards) *48*

Sesia
- *tibialis* (Harris) *51*
- *apiformis* (Clerck) *54*

Sannina
- *urocerifomis* Walker *56*

Synanthedon
- *exitiosa* (Say) *59*
- *pictipes* (Grote and Robinson) *62*
- *scitula* (Harris) *65*
- *acerni* (Clemens) *68*
- *acerrubri* Engelhardt *70*
- *resplendens* (Hy. Edwards) *72*
- *rhododendri* (Beutenmuller) *75*
- *pyri* (Harris) 78
- *kathyae* Duckworth and Eichlin *80*
- *decipiens* (Hy. Edwards) *83*
- *sapygaeformis* (Walker) *83*
- *geliformis* (Walker) *85*
- *rubrofascia* (Hy. Edwards) *87*
- *sigmoidea* (Beutenmuller) *89*
- *albicornis* (Hy. Edwards) *91*
- *proxima* (Hy. Edwards) *93*
- *bolteri* (Hy. Edwards) *93*
- *viburni* Engelhardt *94*
- *fatifera* Hodges *96*
- *mellinipennis* (Boisduval) *96*
- *culiciformis* (Linnaeus) *97*
- *castaneae* (Busck) *98*
- *tipuliformis* (Clerck) *99*

Pennisetia
- *marginata* (Harris) *101*

Vitacea
- *polistiformis* (Harris) *104*
- *scepsiformis* (Hy. Edwards) *106*

Carmenta
- *phoradendri* (Engelhardt) *108*
- *prosopis* (Hy. Edwards) *110*
- *querci* (Hy. Edwards) *110*

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

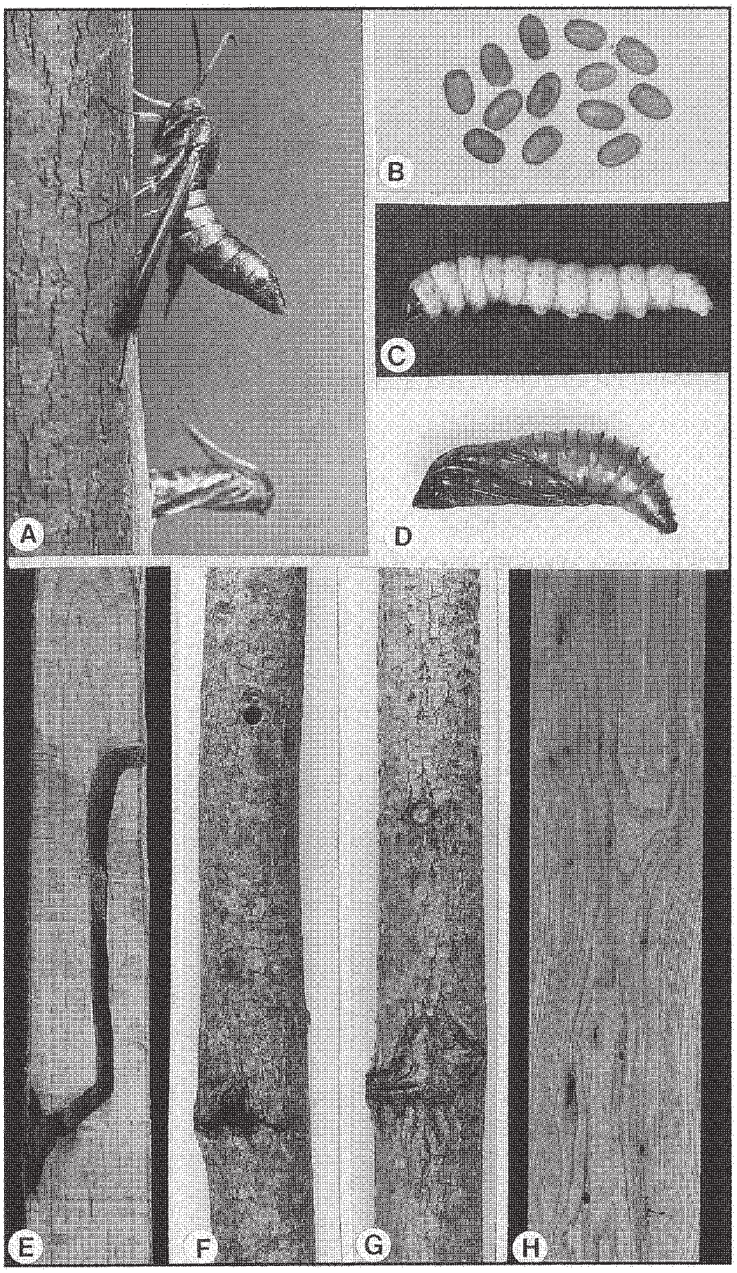

Figure 11—Podosesia syringae, *ash borer: A, newly emerged adult, pupal skin below; B, eggs; C, larva; D, pupa; E, completed gallery; F, entrance hole below, round exit hole above; G, bark scars of healed entrance and exit; H, wormhole defects in ash lumber.*

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 ± 2 crochets per row in *P. aureocincta* and 18 ± 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

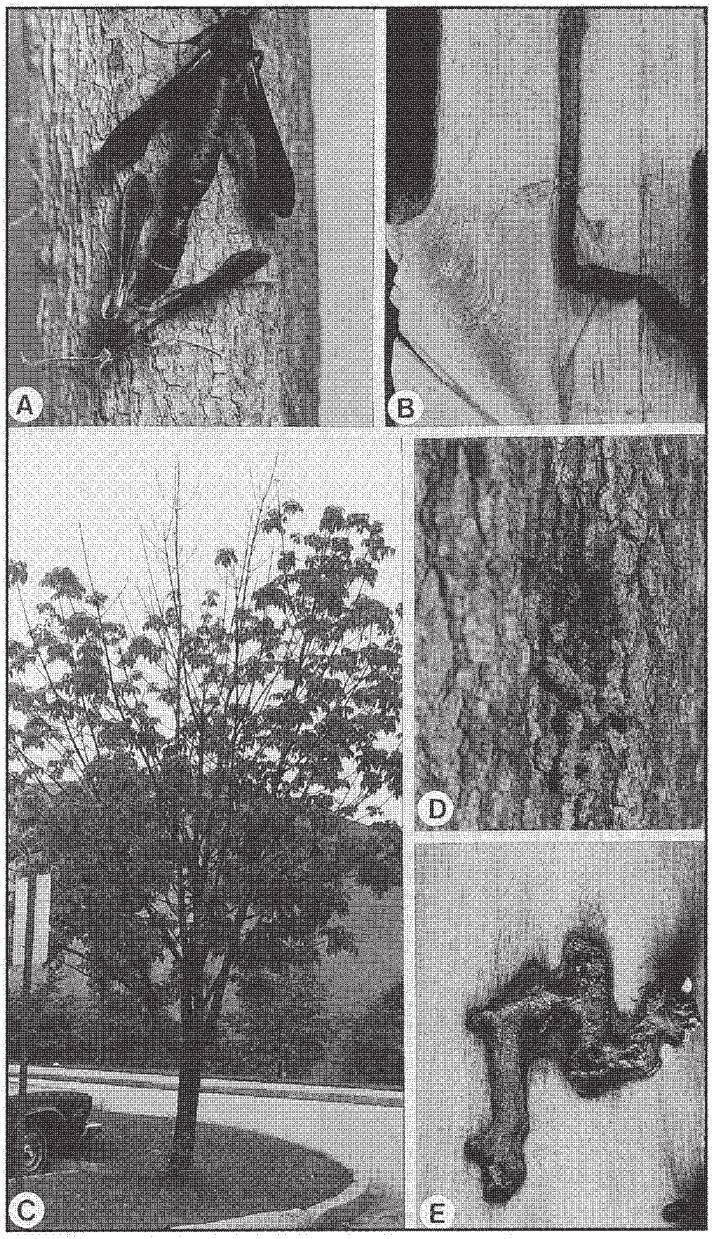

Figure 12—Podosesia aureocincta, *banded ash clearwing: A, mating adults; B, gallery with cambial cavity; C, tree under heavy attack with crown dieback and basal sprouts; D, active attack site with sapstained bark and frass; E, cambial burrow on surface of sapwood.*

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

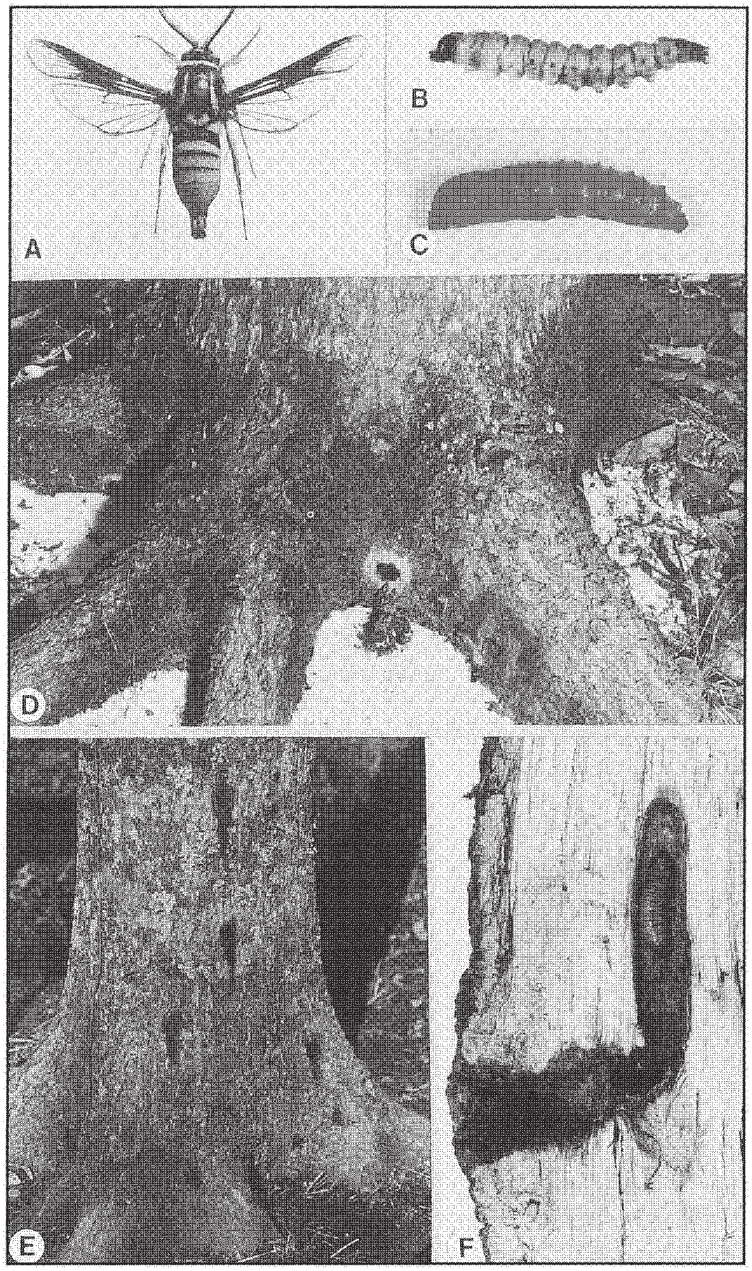

Figure 13—Paranthrene simulans, *[red oak clearwing borer]: A, adult; B, larva; C, pupa; D, entrance hole and frass pile between root flanges; E, sap spots indicating new attack sites; F, completed gallery.*

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

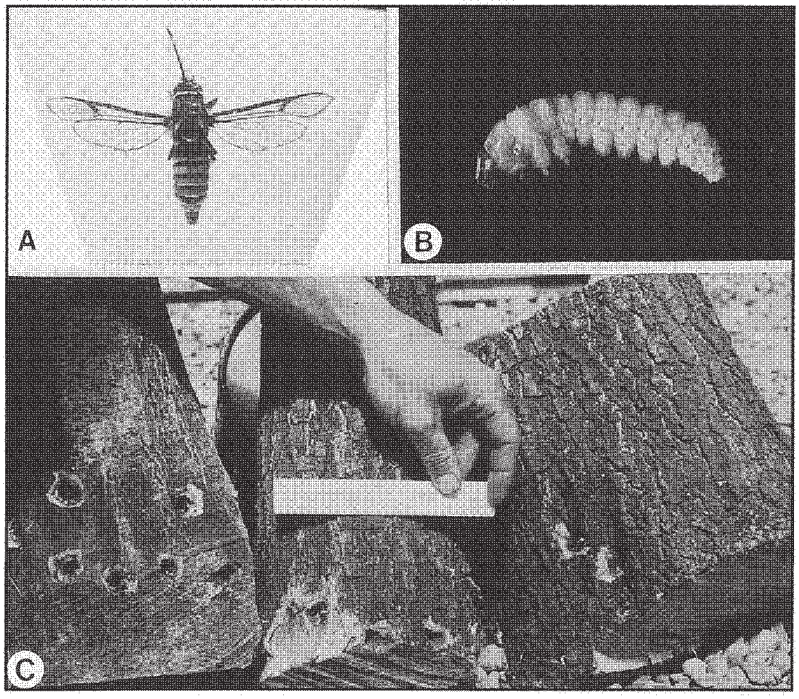

Figure 14—Paranthrene pellucida, *[pin oak clearwing]: A, adult; B, larva; C, entrance holes in oak trunk sections (courtesy F. Purrington).*

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

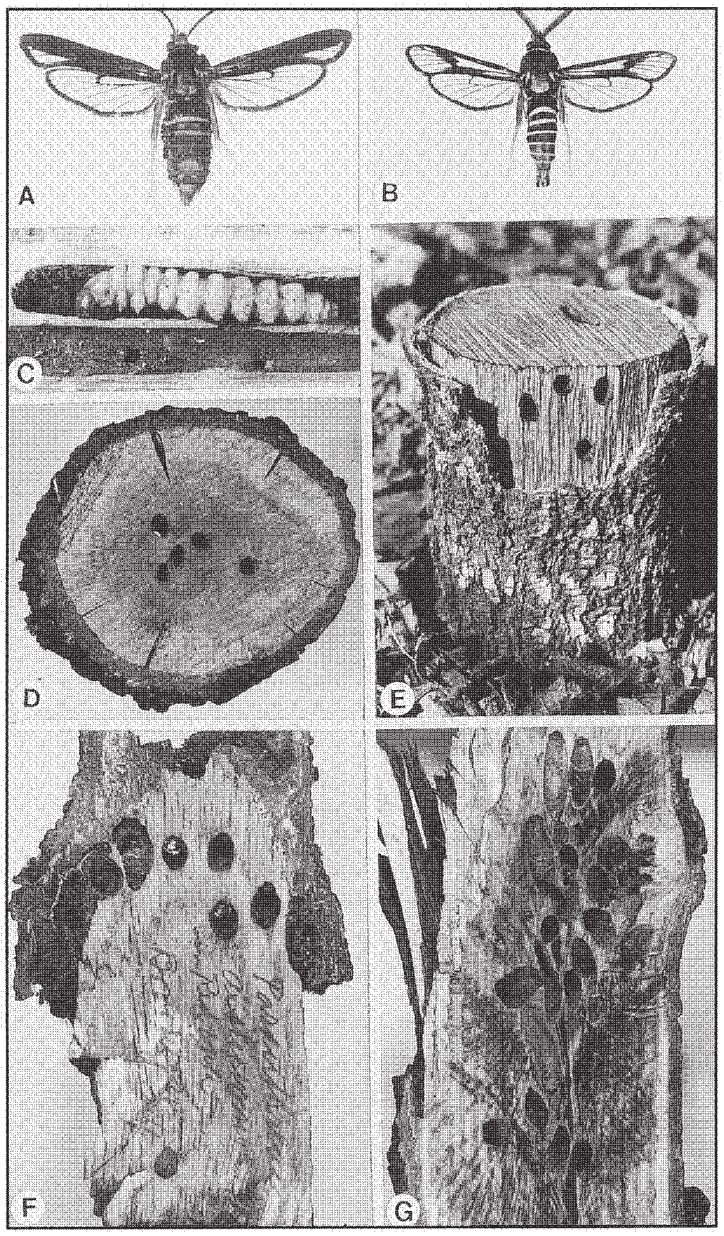

Figure 15—Paranthrene asilipennis, *oak clearwing moth: A, adult female; B, adult male; C, larva; D, cross section of galleries; E, entrance holes in stump; F, bark slab removed to expose holes; G, stump split to expose multiple galleries (A, B, F, & G, specimens courtesy R. Hodges).*

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

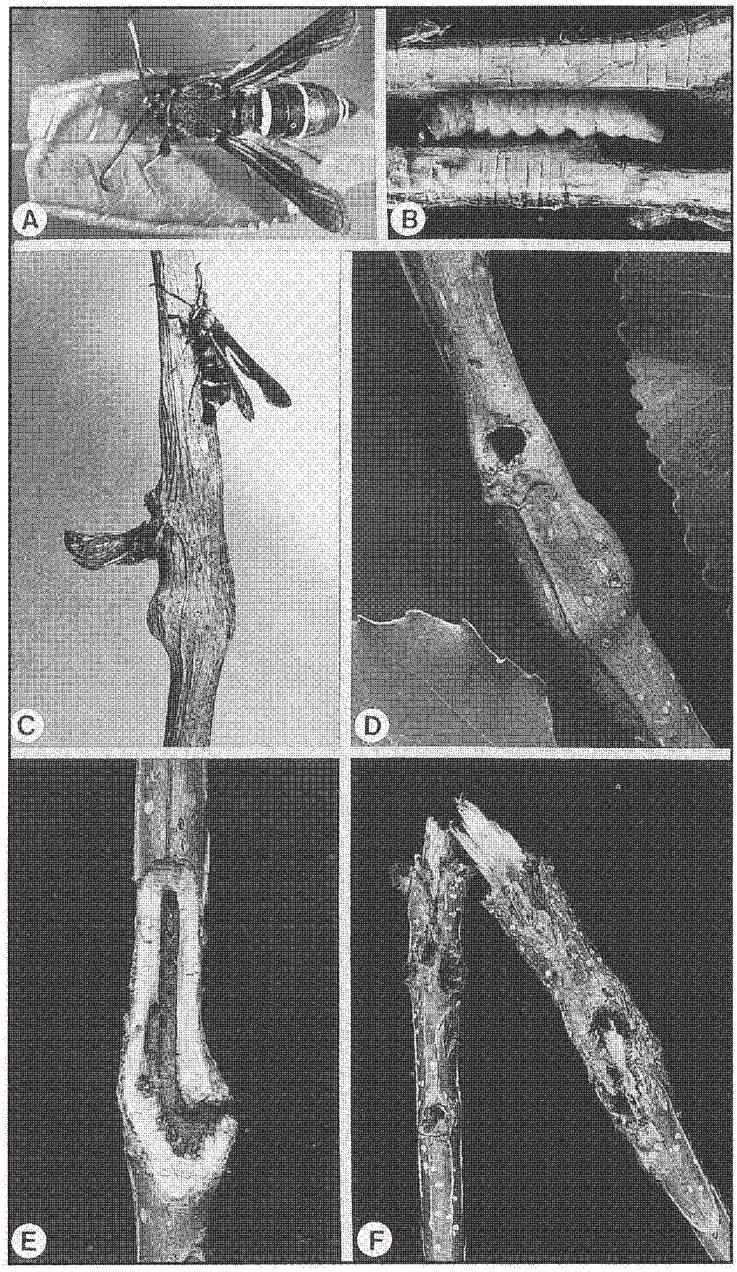

Figure 16—Paranthrene tabaniformis, *[dusky clearwing]: A, adult; B, larva; C, newly emerged adult, pupal skin below; D, swollen branch with exit hole; E, completed gallery; F, stem broken at site of attack.*

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.***

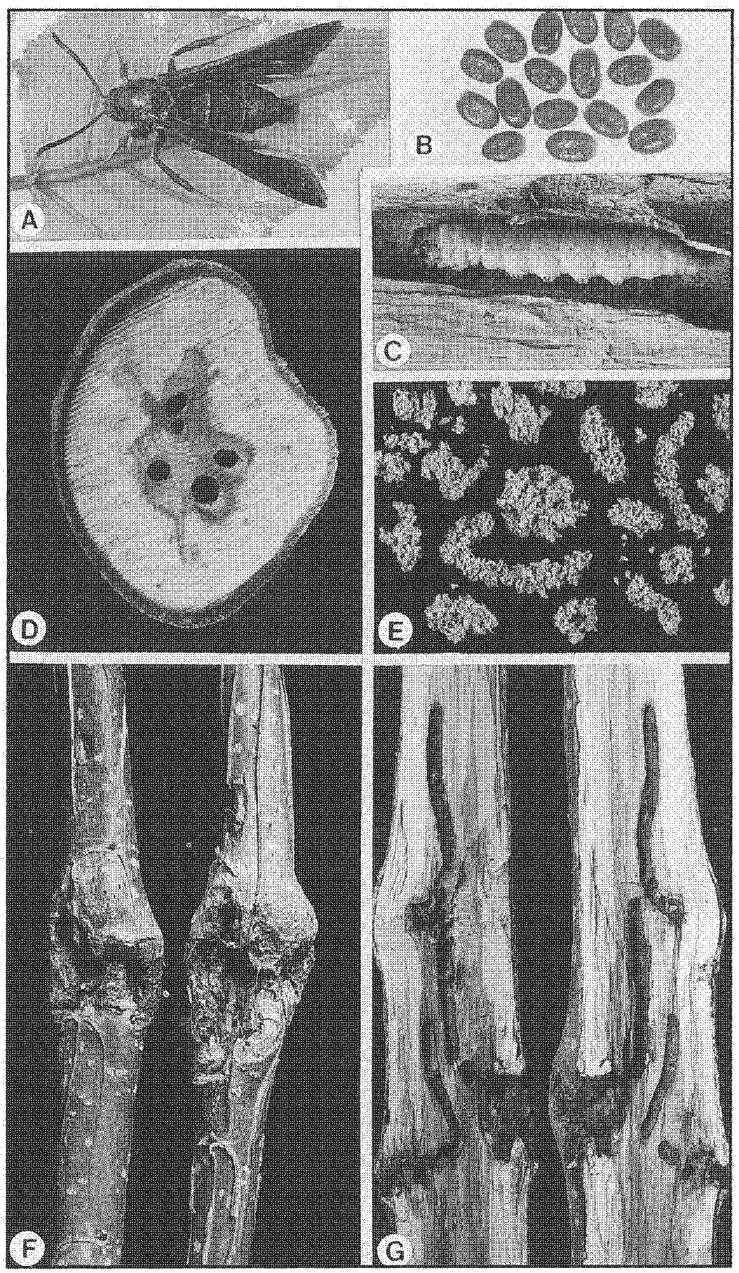

Figure 17—Paranthrene dollii, *[cottonwood clearwing borer]: A, adult; B, eggs; C, larva; D, cross section of galleries; E, frass clumps; F, active attack sites on nursery switches; G, stem split exposing galleries.*

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

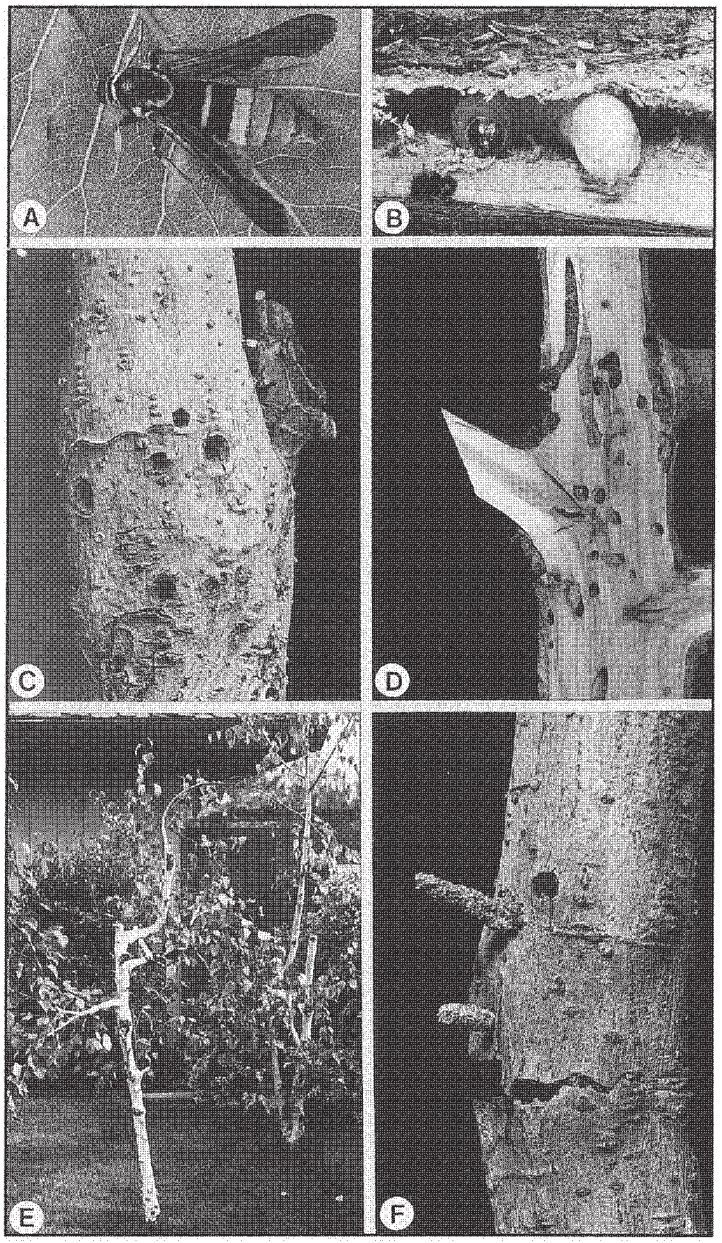

Figure 18—Paranthrene robiniae, *western poplar clearwing: A, adult; B, larva; C, exit holes in willow trunk; D, split to expose galleries; E, infested birch; F, frass tubes over exit holes (B, courtesy T. Eichlin; C & F, specimens courtesy J. Donahue; D, specimen courtesy R. Hodges; E, courtesy H. Kaya).*

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

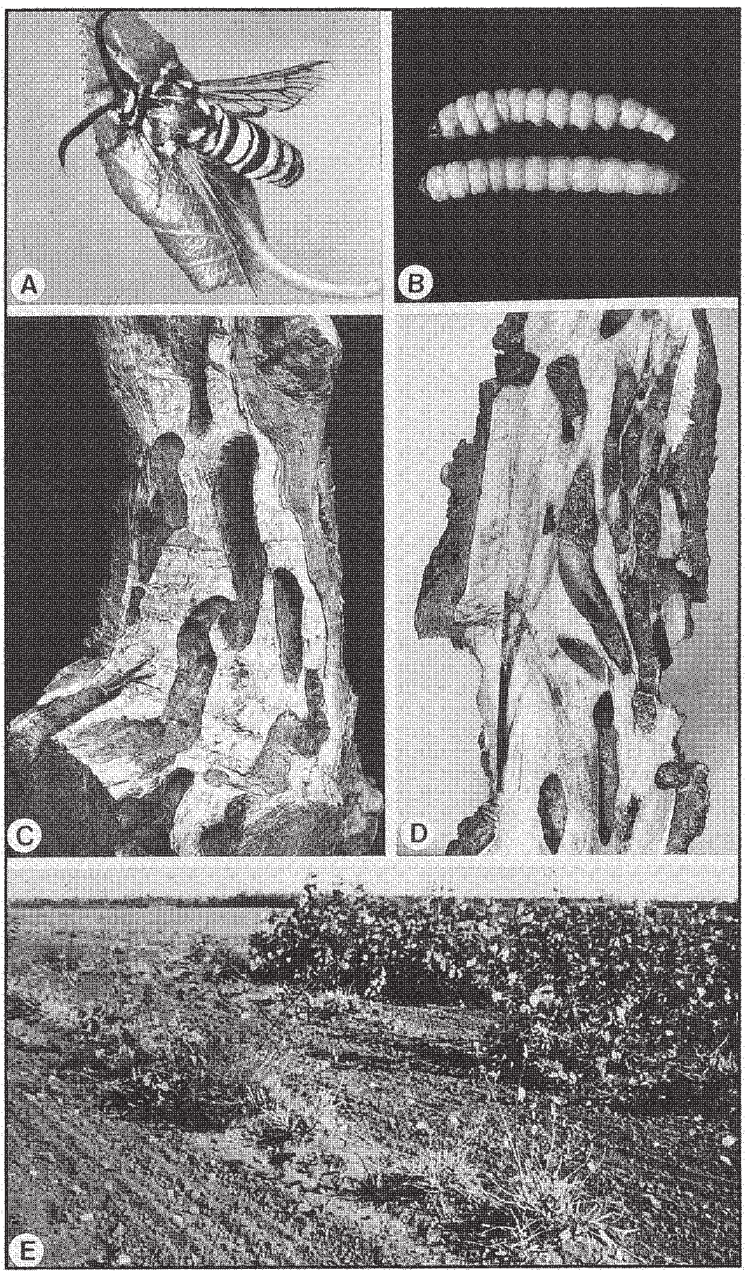

Figure 19—Sesia tibialis, *American hornet moth: A, adult; B, larvae; C, surface removed from poplar rootstock exposing galleries; D, split poplar rootstock showing heavy damage; E, poplar stocks in portion of nursery killed by borers (courtesy G. Neill).*

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

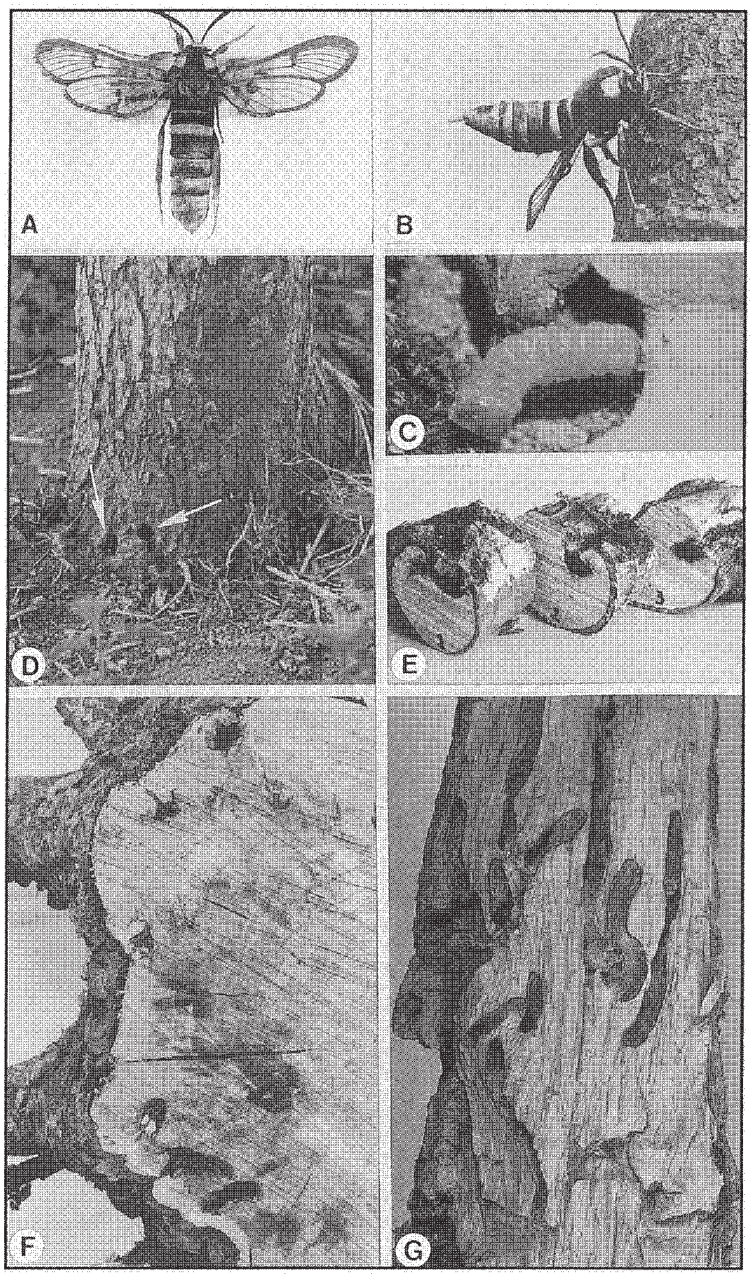

Figure 20—Sesia apiformis, *hornet moth: A, adult; B, calling female; C, larva; D, entrance holes and frass at root collar; E, gallery in root; F, stump cross section showing galleries; G, stem split to expose galleries (A & G, specimens courtesy R. Hodges; B, courtesy J. Burzynski; C & D, courtesy J.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

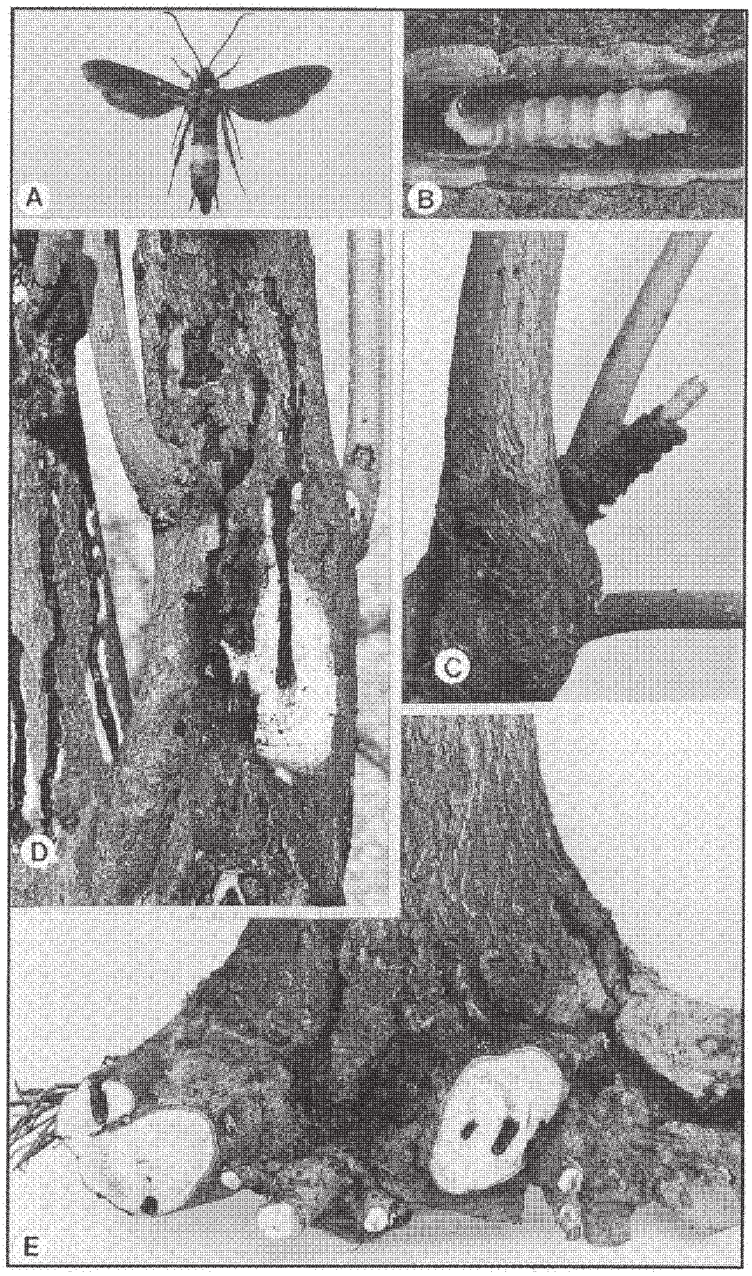

Figure 21—Sannina uroceriformis, *persimmon borer: A, adult; B, larva; C, frass tube with protruding pupal skin at base of tree; D, galleries in lower trunk; E, galleries at root collar and in roots.*

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

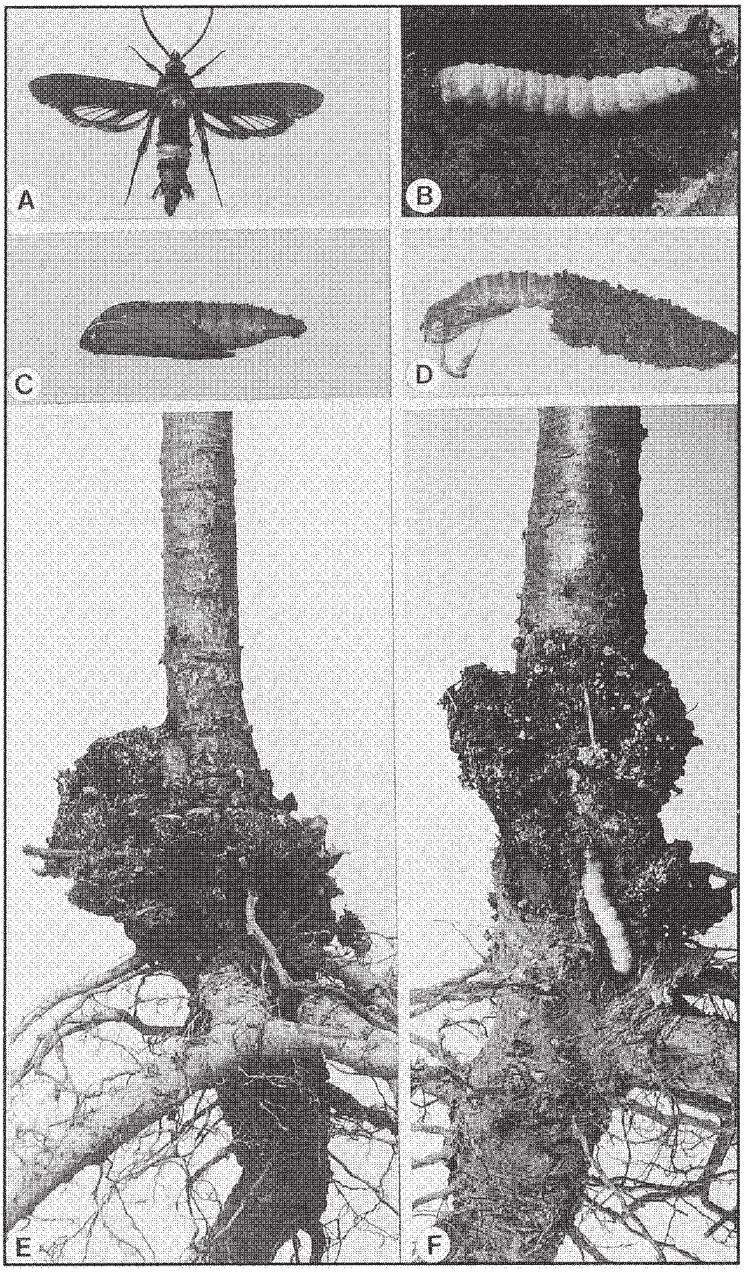

Figure 22—Synanthedon exitiosa, *peachtree borer: A, adult; B, larva; C, pupa; D, frass-covered cocoon with pupal skin protruding; E, young tree with large frass-jelly mass at root collar; F, frass-jelly mass pulled back to expose burrow and larva.*

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).

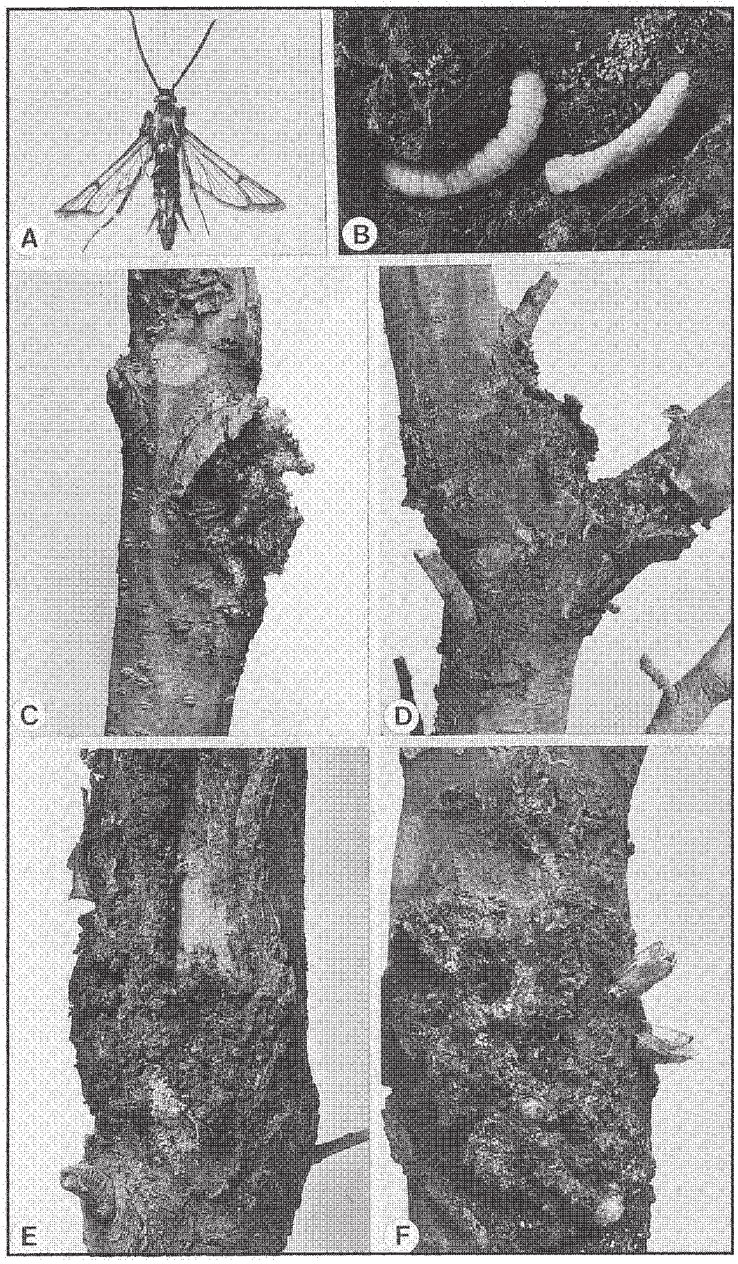

Figure 23—Synanthedon pictipes, *lesser peachtree borer: A, adult; B, larvae; C, frass adhering to bark; D, active attack site at branch crotch; E, attack sites with frass at cankered site; F, pupal skins protruding from infested bark.*

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

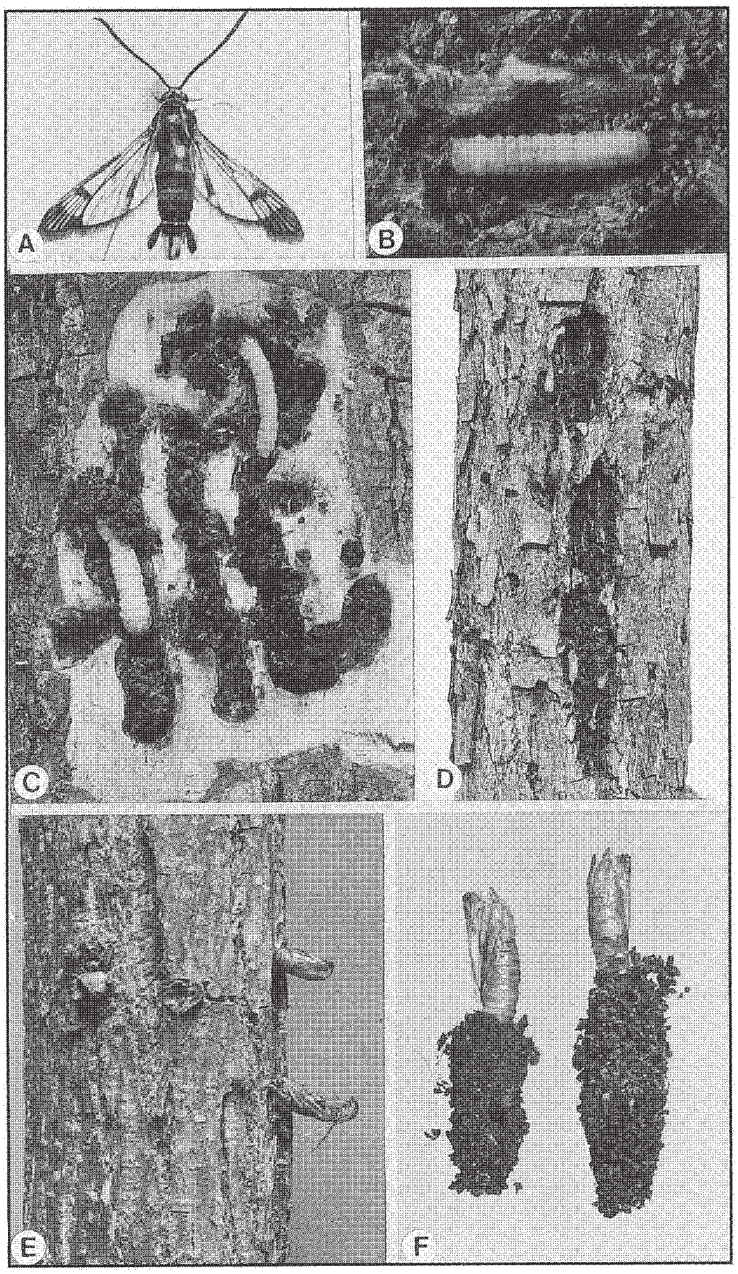

Figure 24—Synanthedon scitula, *dogwood borer: A, adult; B, larva; C, burrows under bark of pecan; D, sapstained bark and frass at site of attack; E, pupal skins protruding from bark; F, frass-covered cocoons with pupal skins.*

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

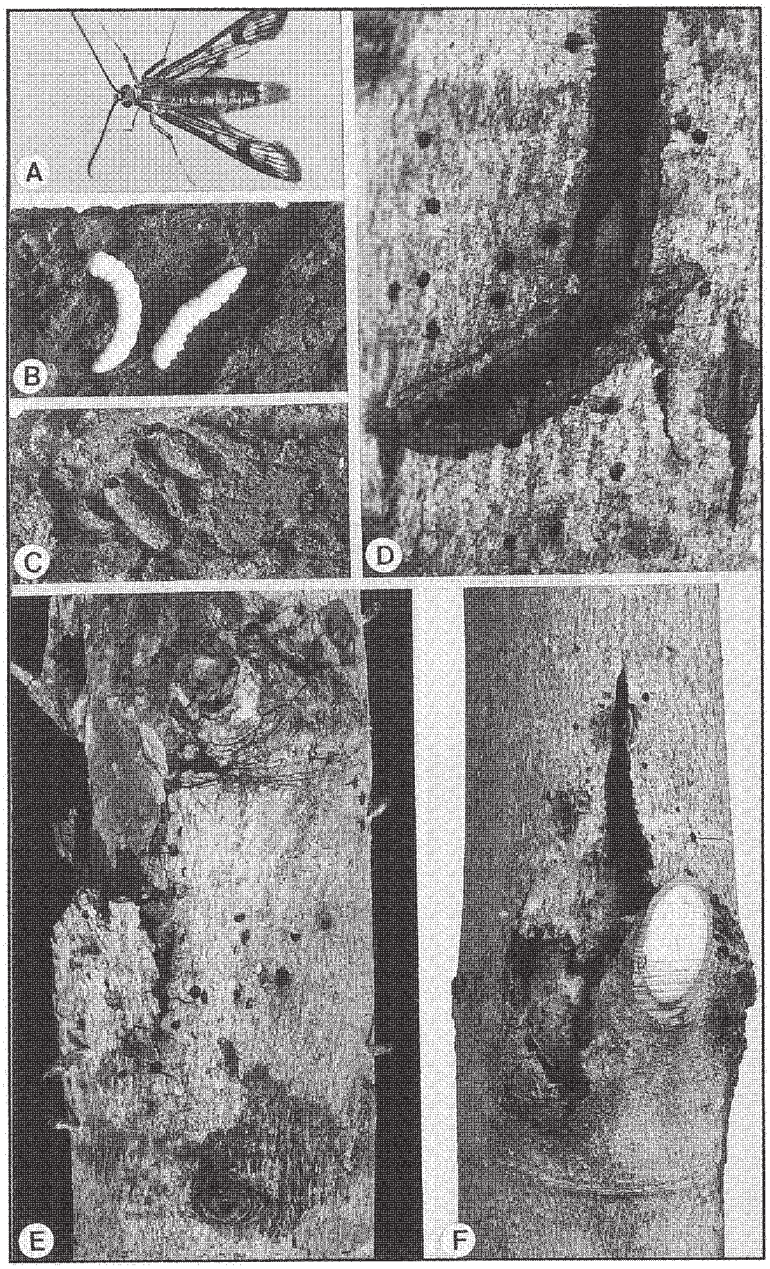

Figure 25—Synanthedon acerni, *maple callus borer: A, adult; B, larvae; C, frass-covered cocoons under bark; D, exit holes around ax wound; E, pupal skins protruding from bark; F, infested site with exit holes at branch crotch.*

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

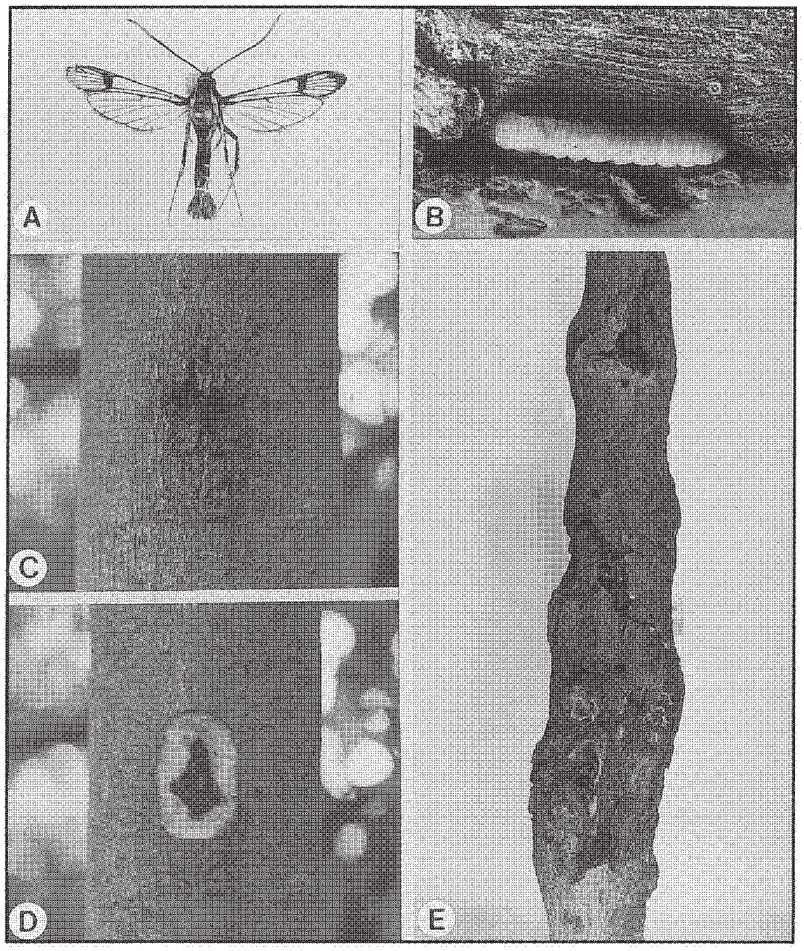

Figure 26—Synanthedon acerrubri, *[maple clearwing]: A, adult; B, larva; C, sapstained bark at site of attack; D, bark removed to expose burrow; E, gnarled, swollen stem from repeated attacks.*

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

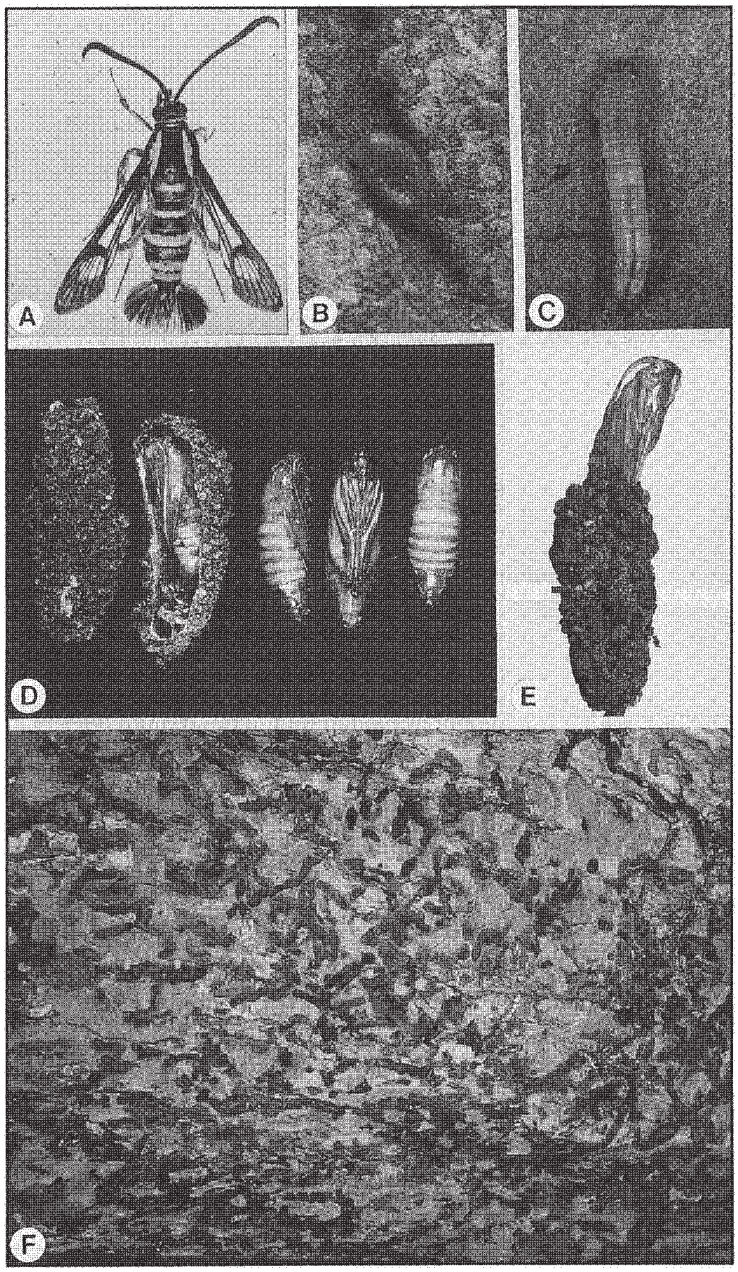

Figure 27—Synanthedon resplendens, *[sycamore borer]: A, adult; B, egg; C, larva; D, pupae and cocoons; E, cocoon with pupal skin protruding; F, outer bark removed exposing extensive tunneling (courtesy L. Brown).*

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

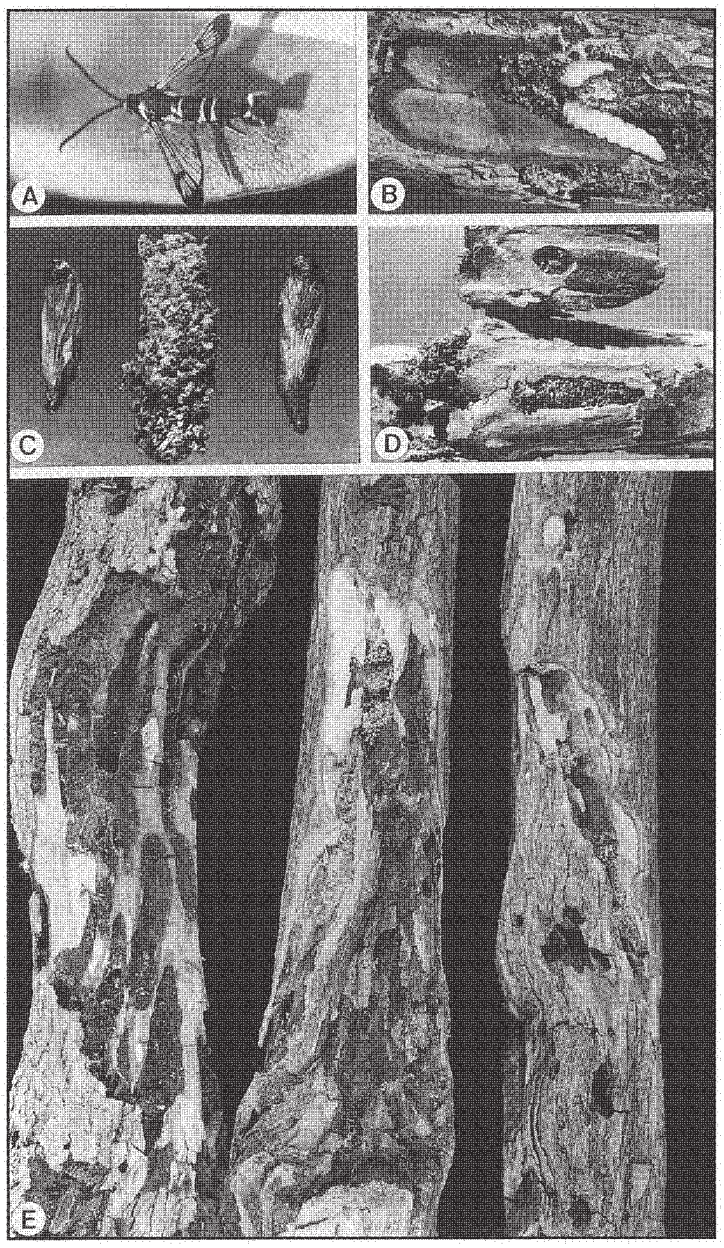

Figure 28—Synanthedon rhododendri, *rhododendron borer: A, adult; B, larva; C, pupae and frass-covered cocoon; D, bark removed exposing pupation chamber and cocoon; E, extensive larval burrows under bark of rhododendron stems (A, C, & D, courtesy J. Neal; B, courtesy D. Nielsen; E, courtesy C. Pless).*

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

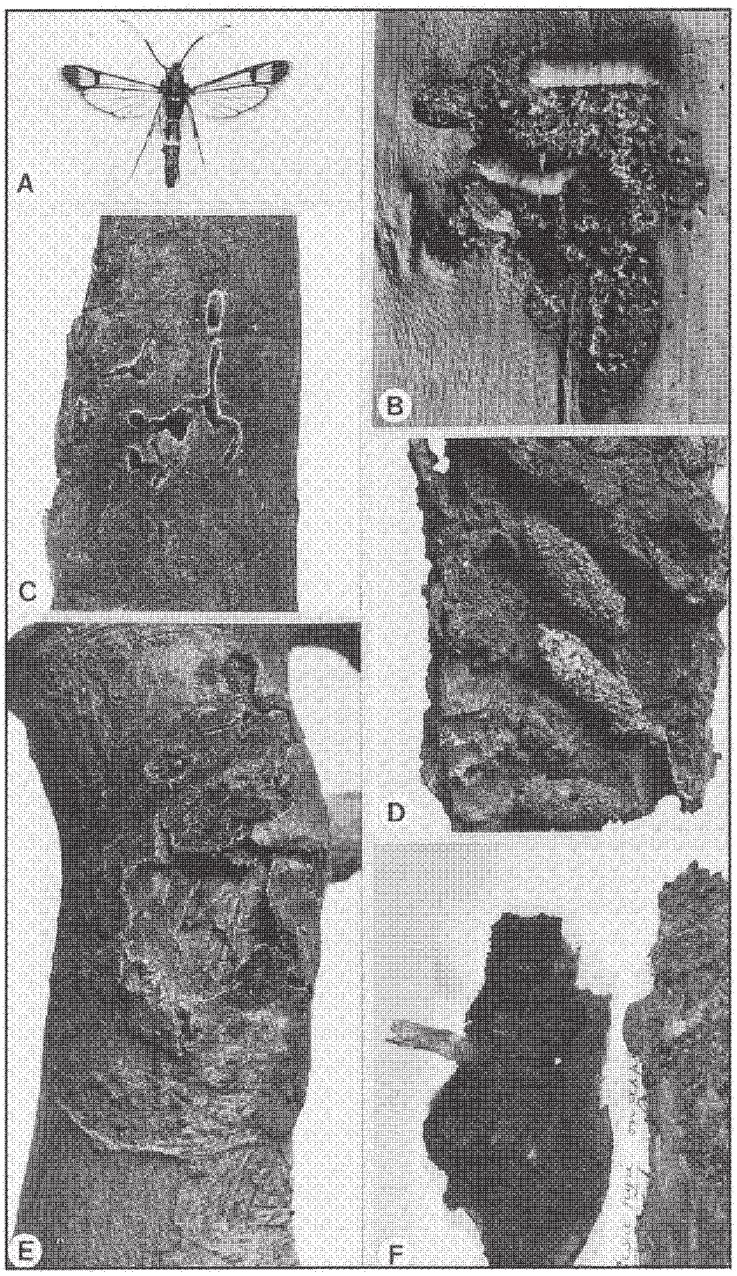

Figure 29—Synanthedon pyri, *apple bark borer: A, adult; B, larvae; C, active attack sites on trunk; D, cocoons under bark; E, bark scars over previous attacks; F, bark with pupal skin protruding (A & F, specimens courtesy R. Hodges).*

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

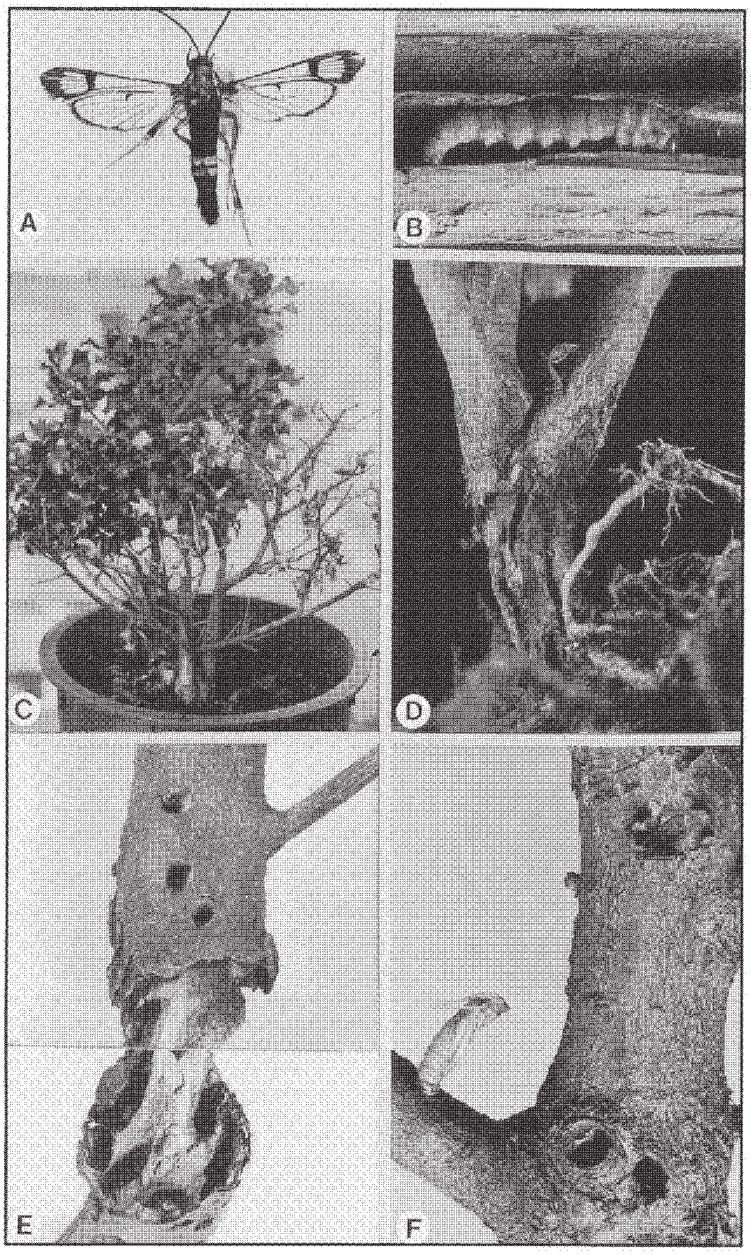

Figure 30—Synanthedon kathyae, *[holly clearwing borer]: A, adult; B, larva; C, potted holly with girdled stems dying; D, bark removed at root collar to expose galleries; E, multiple galleries and pupal exits; F, pupal skin protruding from stem. (specimens courtesy G. Ghidiu and L. Vasvary).*

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

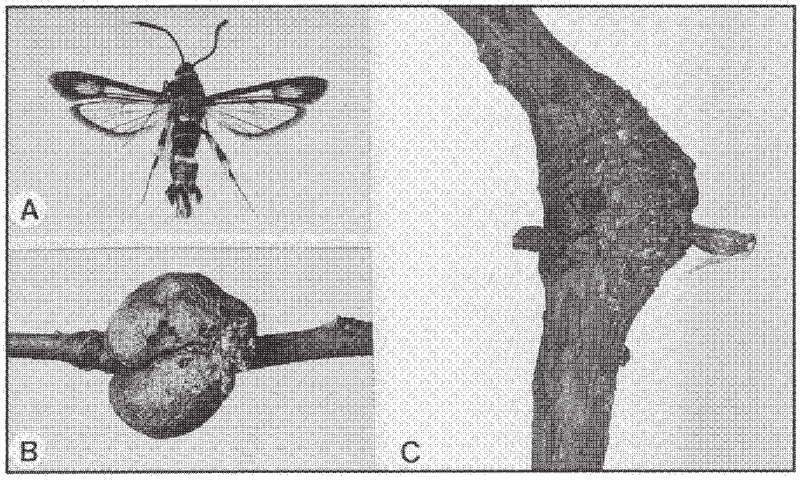

Figure 31—Synanthedon decipiens, *[oakgall clearwing]: A, adult; B, oak gall with entrance holes and frass; C, galled branch with pupal skin protruding (specimens courtesy R. Hodges).*

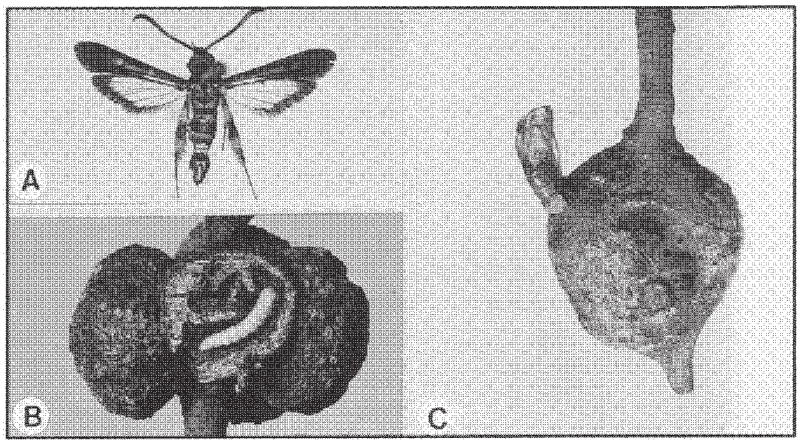

Figure 32—Synanthedon sapygaeformis, *[Florida oakgall clearwing]: A, adult; B, gall with burrows and larva; C, gall with pupal skin protruding (specimens courtesy R. Hodges).*

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.

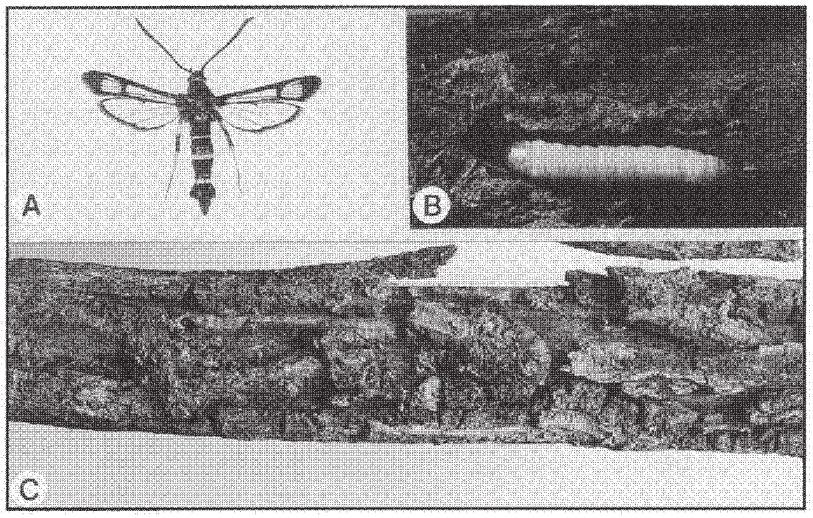

Figure 33—Synanthedon geliformis, *[pecan clearwing borer]: A, adult; B, larva; C, rough, loosened bark at attack site (A, specimen courtesy R. Hodges; B & C, specimens courtesy R. Mizell).*

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.

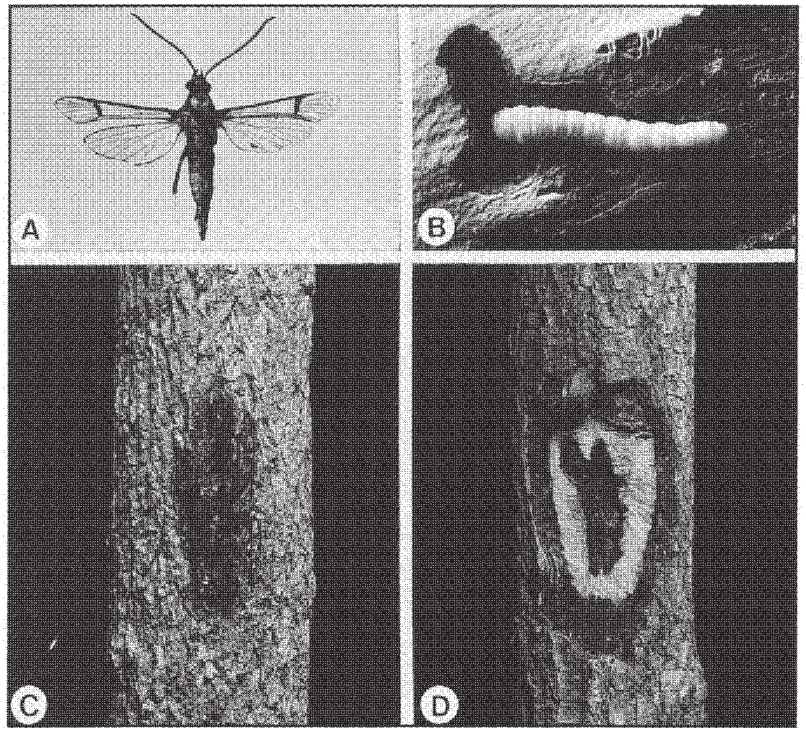

Figure 34—Synanthedon rubrofascia, *[tupelo clearwing borer]: A, adult; B, larva; C, sapspot at site of attack; D, bark removed to expose larval burrow (A, specimen courtesy W. Snow).*

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

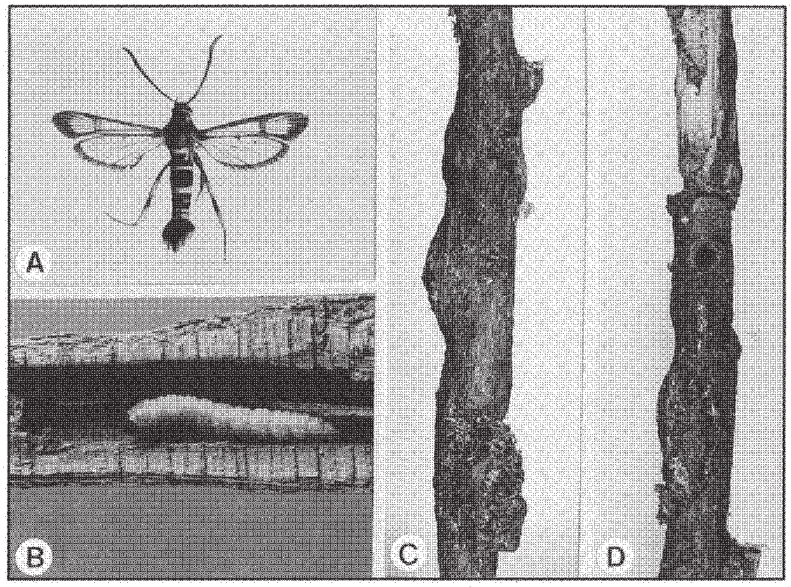

Figure 35—Synanthedon sigmoidea, *[willow clearwing]: A, adult; B, larva; C, openings, swellings, and frass on infested stem; D, round exit hole in bark (specimens courtesy R. Hodges).*

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

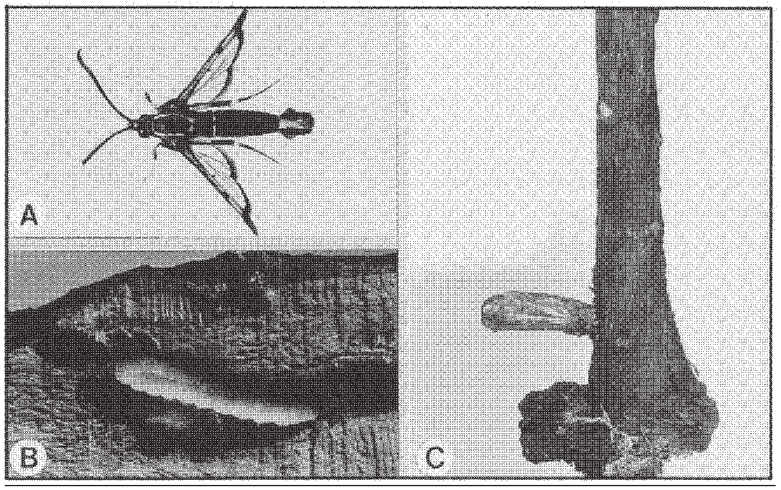

Figure 36—Synanthedon albicornis, *[western willow clearwing]: A, adult; B, larva; C, young willow with frass clump and protruding pupal skin.*

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

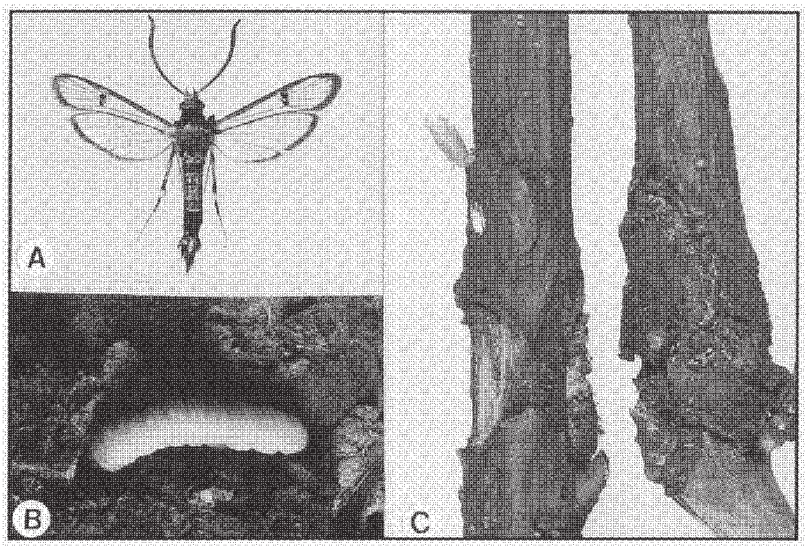

Figure 37—Synanthedon viburni, *[viburnum clearwing borer]: A, adult; B, larva; C, gnarled scarred stems with pupal skin protruding from bark (A & C, courtesy R. Hodges).*

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

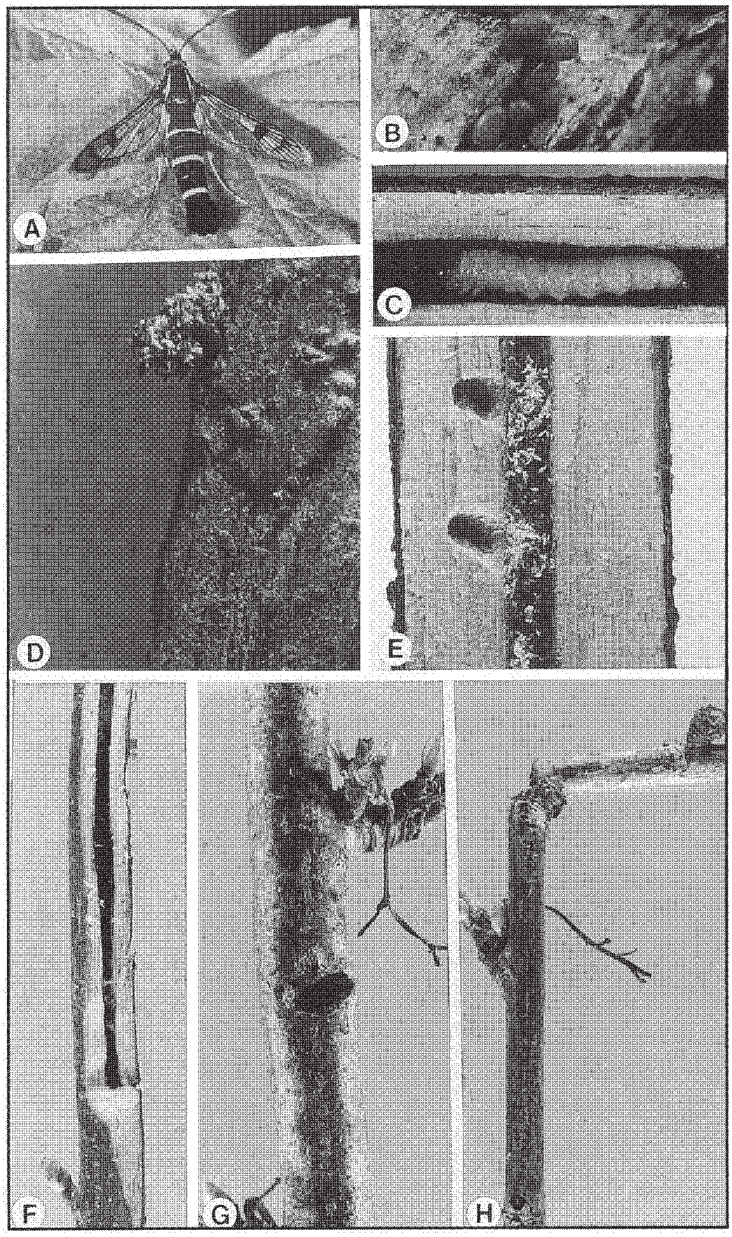

Figure 38—Synanthedon tipuliformis, *currant borer: A, adult; B, eggs; C, larva; D, frass clump on bark; E, larval burrows in wood; F, larval burrow in pith; G, entrance hole in cane; H, cane broken at entrance site (A-C, F-H, courtesy R. Bedding; D, courtesy A. Antonelli; E, courtesy R. Scott).*

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

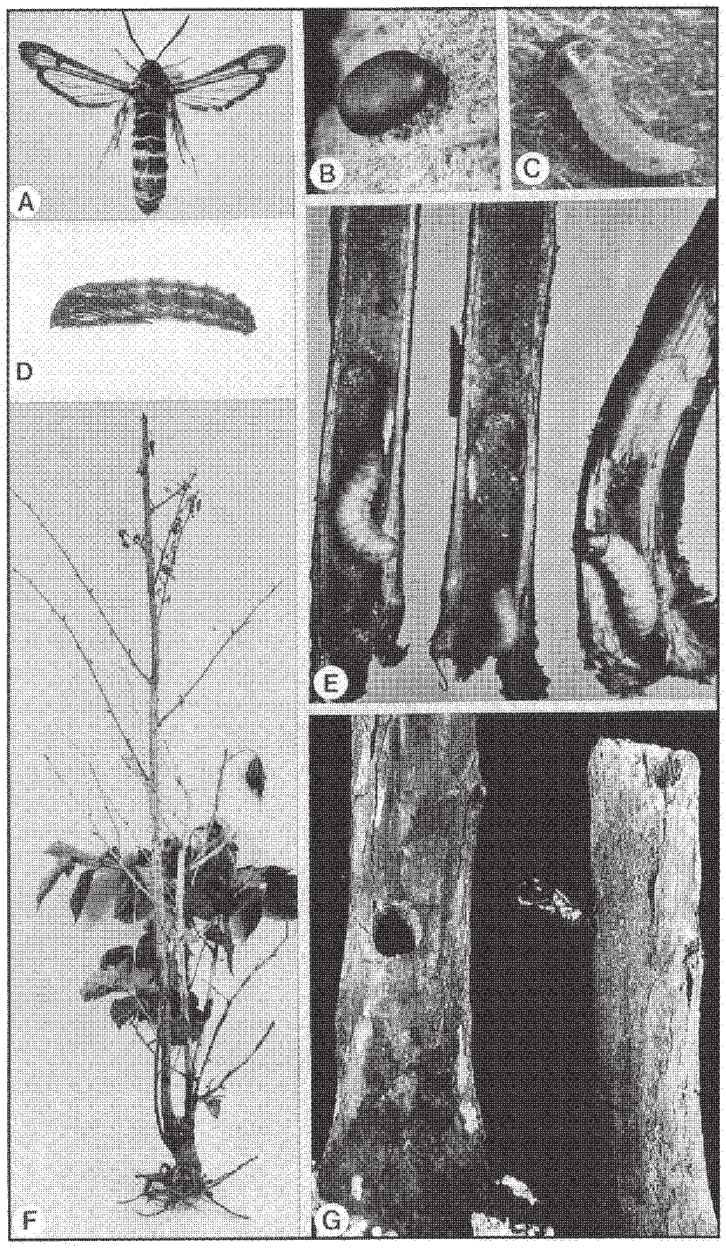

Figure 39—Pennisetia marginata, *raspberry crown borer: A, adult; B, egg; C, larva; D, pupa; E, tunneled canes; F, cane dieback with new shoots; G, exit hole and pupal skin protruding (A, specimen courtesy R. Hodges; B, C, courtesy R. Williams; D, E, G, courtesy A. Antonelli and E. Breakey).*

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

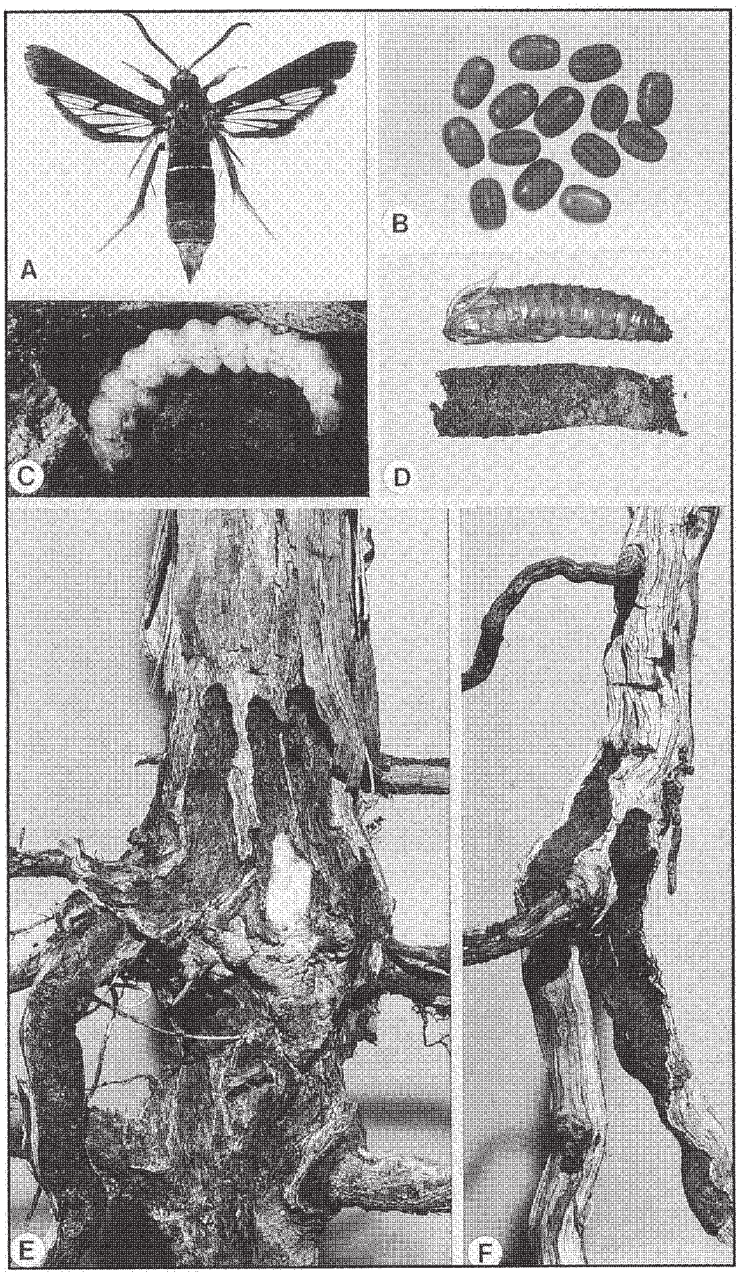

Figure 40—Vitacea polistiformis, *grape root borer: A, adult; B, eggs; C, larva; D, pupal skin and earthen cocoon; E, multiple galleries at root collar; F, burrows extending along main roots (B-D, courtesy D. Pollet).*

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

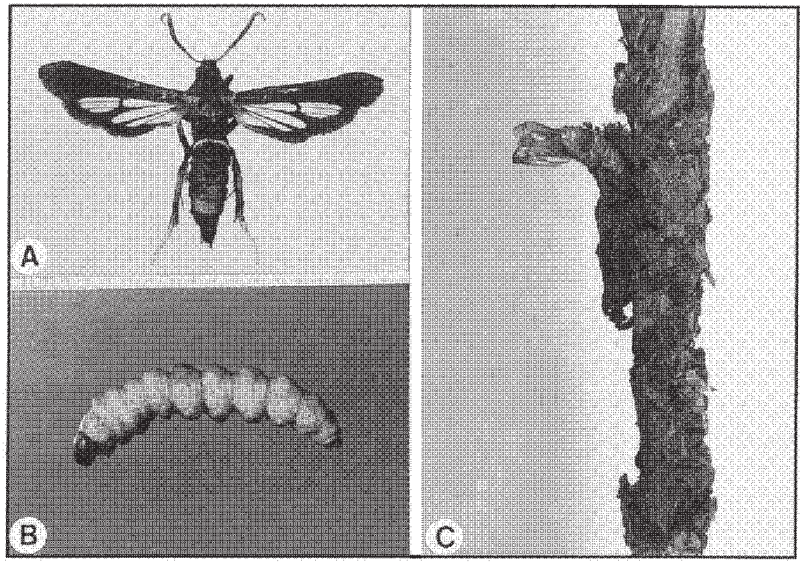

Figure 41—Vitacea scepsiformis, *[Virginia creeper clearwing]: A, adult; B, larva; C, damaged stem with pupal skin protruding from bark (specimens, courtesy R. Hodges).*

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

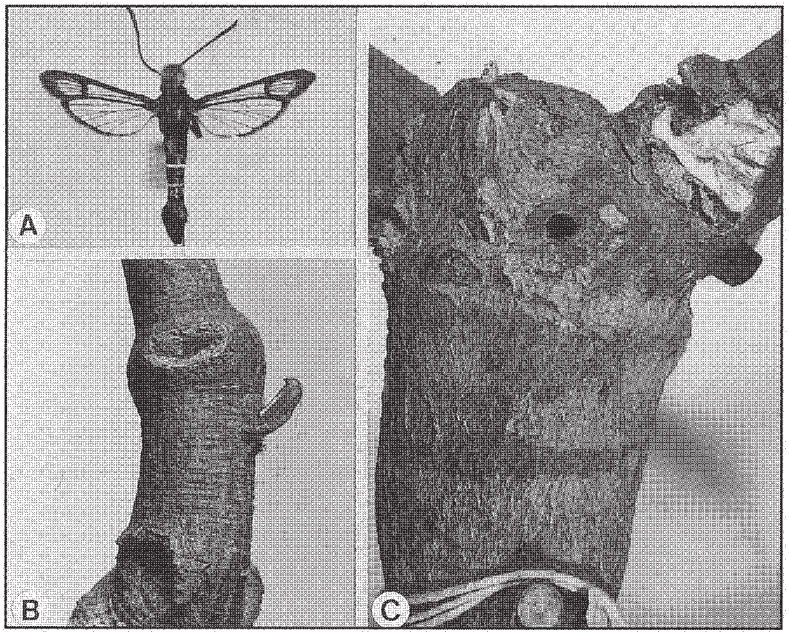

Figure 42—Carmenta phoradendri, *[mistletoe borer]: A, adult; B, pupal skin protruding from stem; C, feeding injury and exit hole (specimens courtesy R. Hodges).*

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) *112*
- *macmurtrei* (Guerin) *116*
- *piger* (Grote) *118*

Cossula
- *magnifica* (Strecker) *121*

Acossus
- *centerensis* (Lintner) *124*
- *populi* (Walker) *127*

Zeuzera
- *pyrina* (Linnaeus) *127*

Comadia
- *suaedivora* Brown and Allen *131*
- *bertholdi* Grote *133*

***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.

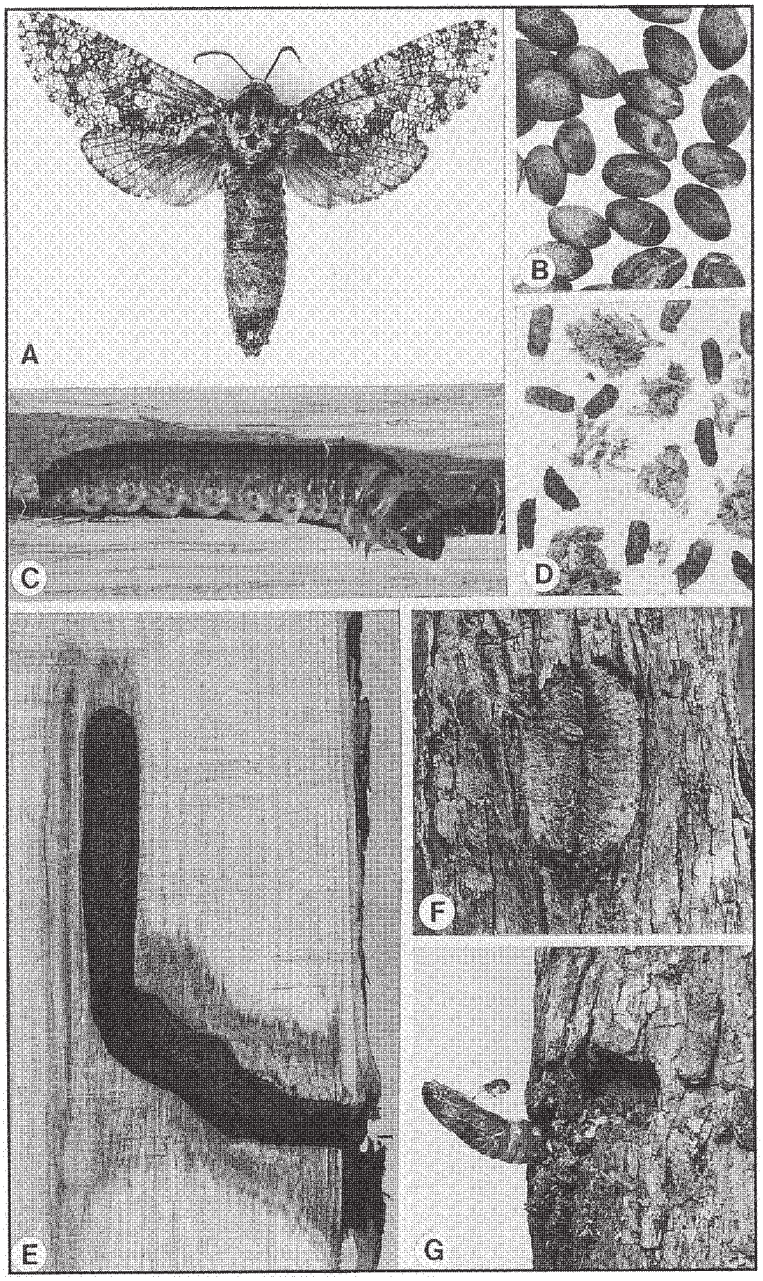

Figure 43—Prionoxystus robiniae, *carpenterworm: A, adult female; B, eggs; C, larva in gallery; D, frass of wood chips and excrement pellets; E, typical gallery; F, oval bark scar; G, pupal case protruding from exit hole.*

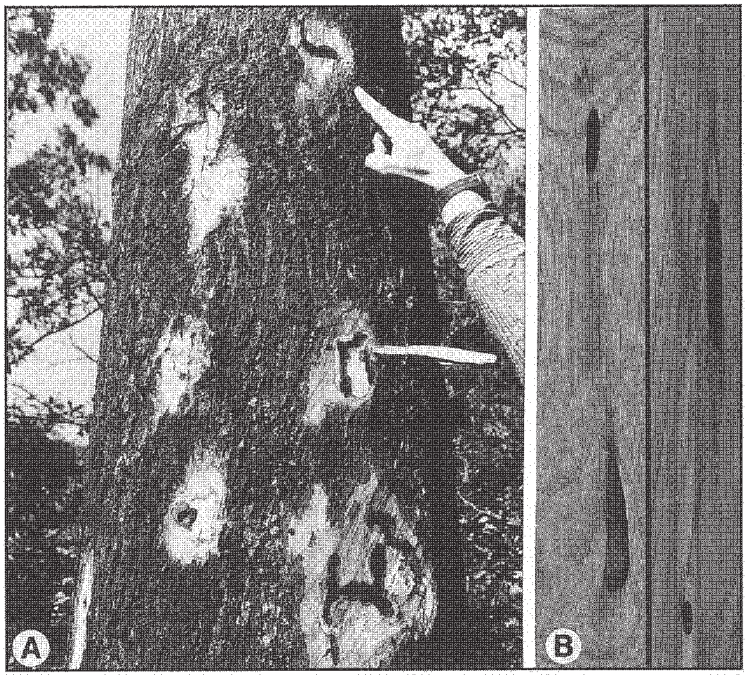

Figure 44—*Damage caused by* Prionoxystus robiniae, *carpenterworm: A, numerous attacks on bole of large red oak; B, wormhole defects in oak lumber.*

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-

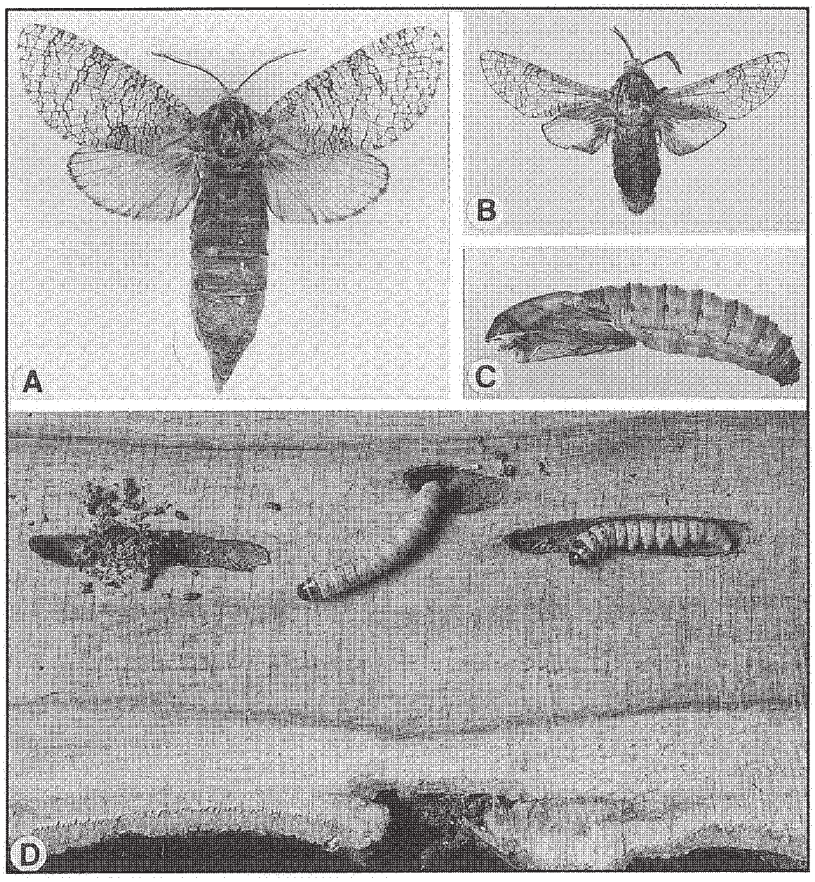

Figure 45—Prionoxystus macmurtrei, *little carpenterworm: A, adult female; B, adult male; C, pupal case; D, larvae with tunnels in red oak (specimens A & B, courtesy R. Hodges).*

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

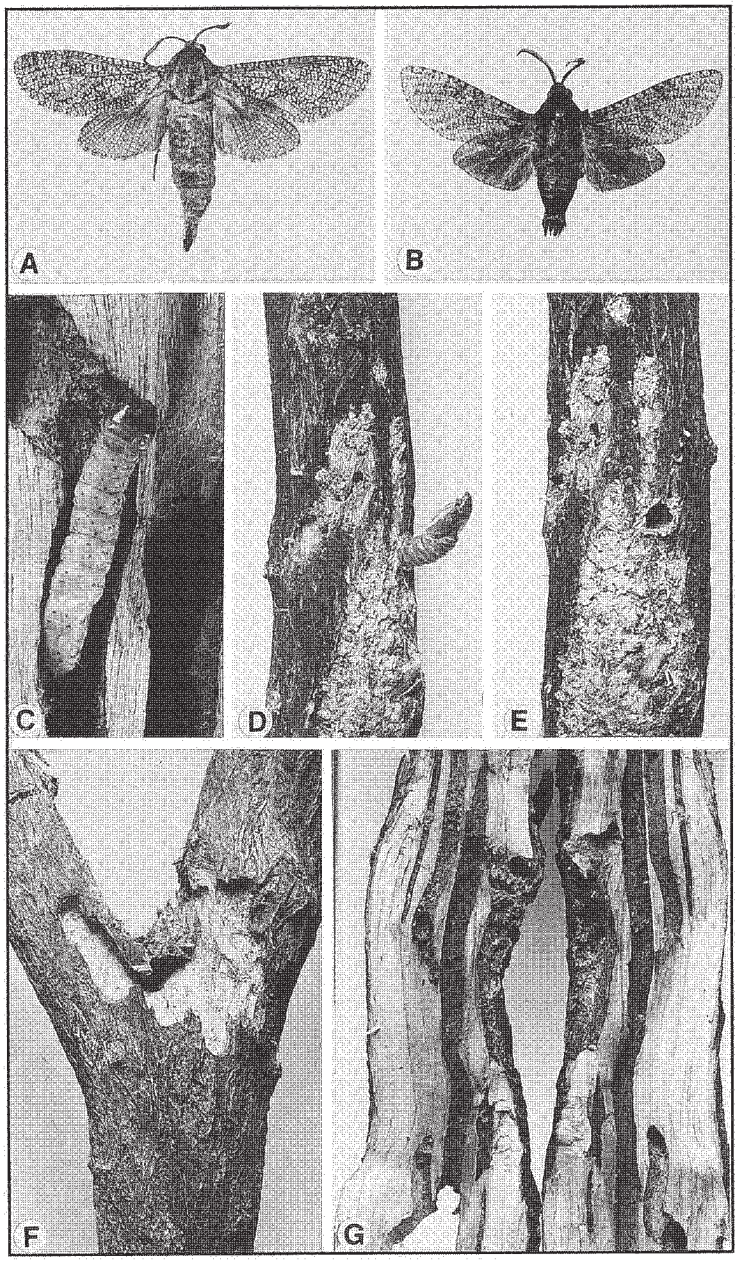

Figure 46—Prionoxystus piger, *[baccharis carpenterworm]: A, adult female; B, adult male; C, larva in gallery; D, pupal case in exit hole; E, entrance hole and frass; F, cambial burrow; G, larval galleries (specimens A & B, courtesy R. Hodges; specimens C-G, courtesy W. Palmer).*

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

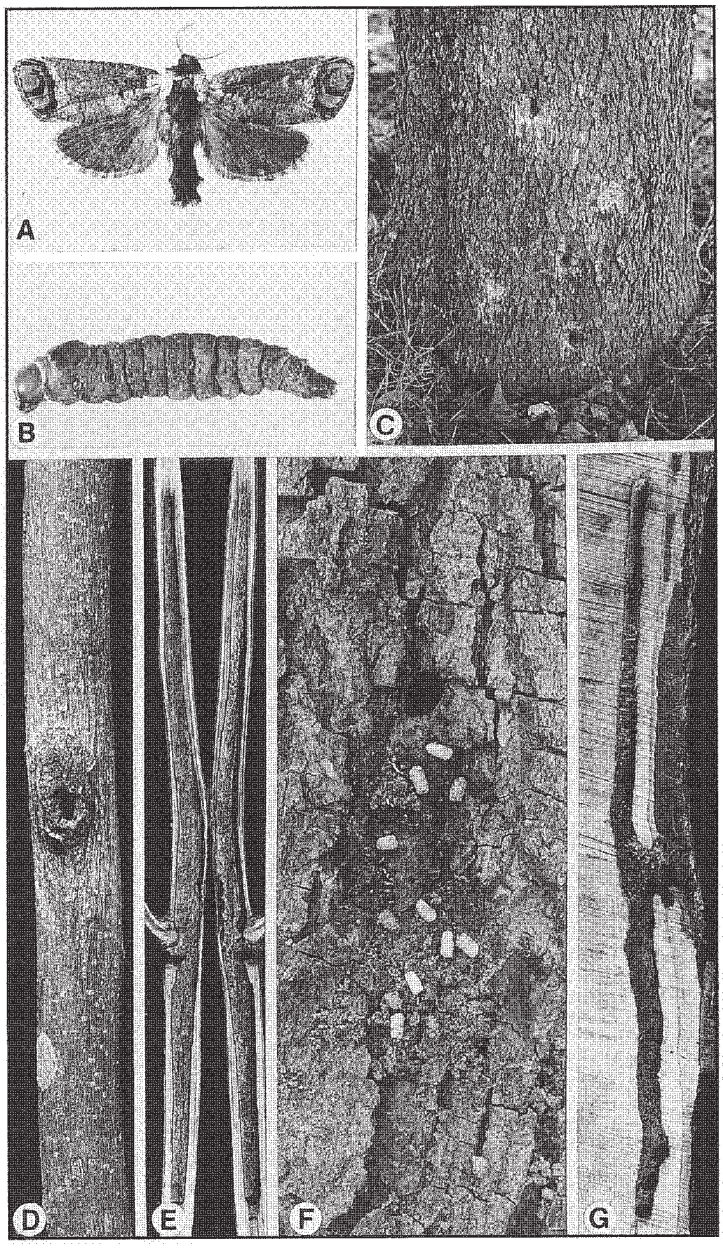

Figure 47—Cossula magnifica, *pecan carpenterworm: A, adult male; B, larva; C, holes and bark scars on trunk; D, entrance hole in branch; E, branch gallery; F, entrance hole, frass, and stained bark on trunk; G, completed gallery in trunk (specimens A & B, courtesy D. Habeck).*

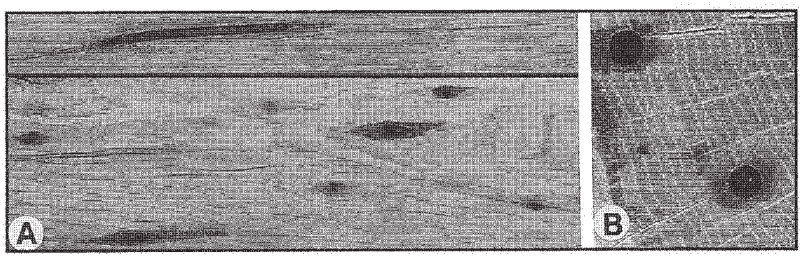

Figure 48—*Damage caused by* Cossula magnifica, *pecan carpenterworm: A, wormhole defects in lumber; B, round holes in log end.*

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-

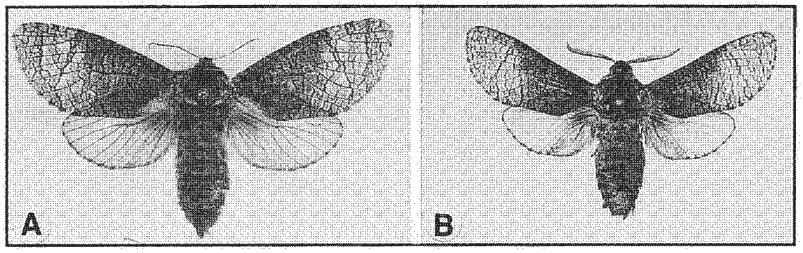

Figure 49—Acossus centerensis, *[poplar carpenterworm]: A, adult female; B, adult male (specimens courtesy R. Hodges).*

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

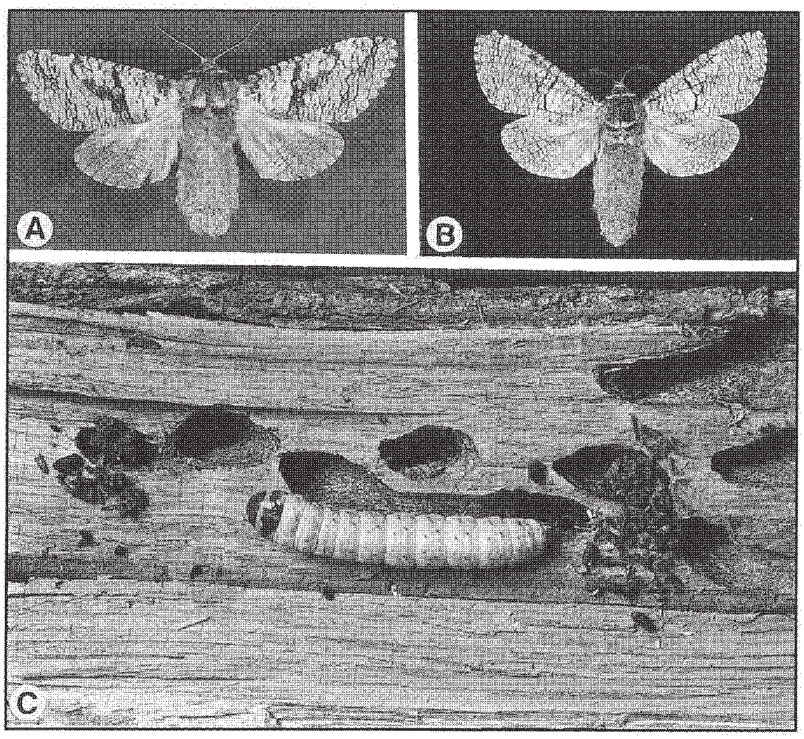

Figure 50—Acossus populi *[aspen carpenterworm]: A, adult female; B, adult male; C, larva and galleries in aspen (specimens courtesy R. Hodges).*

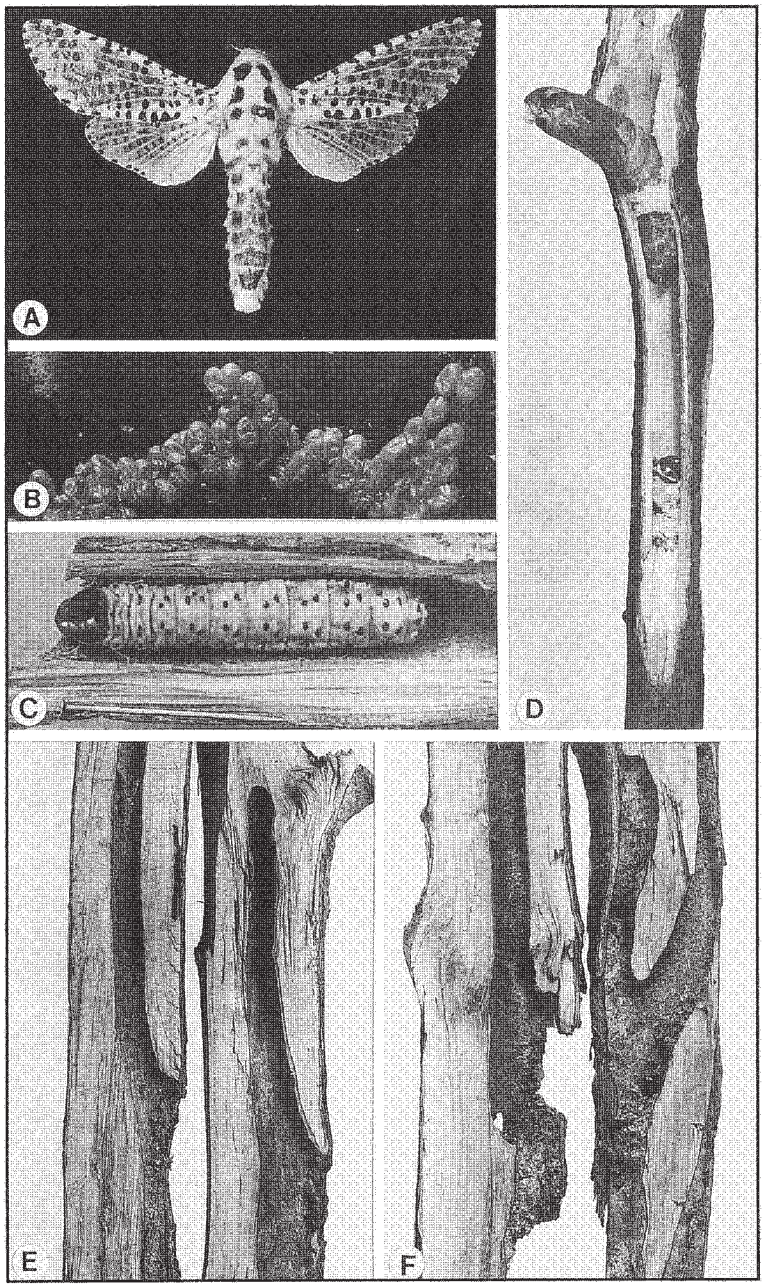

Figure 51—Zeuzera pyrina, *leopard moth: A, adult male; B, eggs; C, mature larva; D, tunneled twig with pupal skin protruding; E, single galleries in branches; F, multiple galleries in stem (B & C, courtesy of W. Johnson).*

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

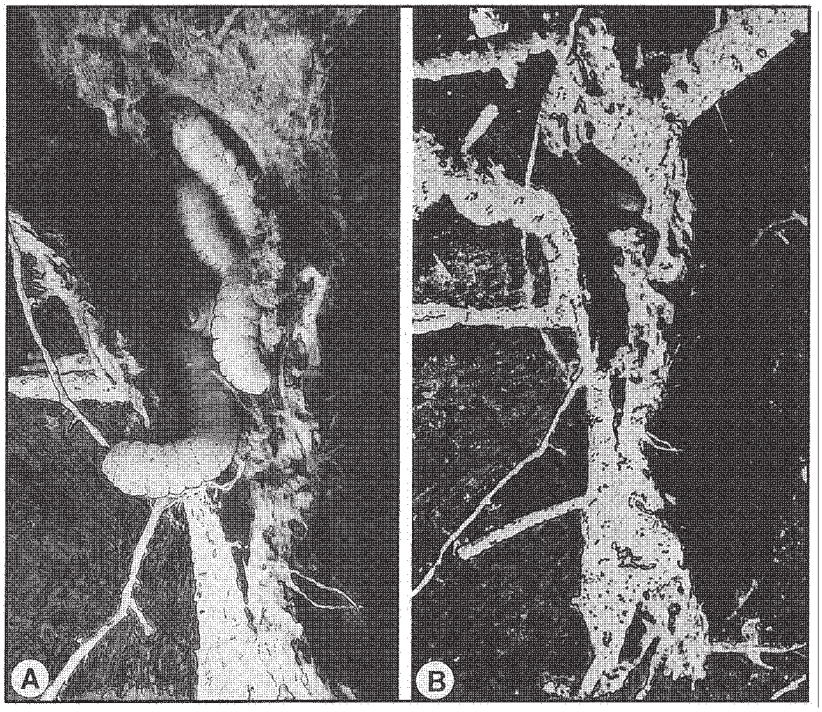

Figure 52—Comadia suaedivora, *[alkali blite borer]: A, cluster of larvae feeding in alkali blite; B, crown and root broken open to expose feeding cavity (courtesy R. M. Brown).*

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) *134*
Proteoteras
willingana (Kearfott) *137*
arizonae (Kearfott) *140*
crescentana Kearfott *142*
aesculana Riley *143*
moffatiana Fernald *145*
Zeiraphera
claypoleana (Riley) *147*
Spilonota
ocellana (Denis&Schiffermuller) *147*
Epinotia
solicitana (Walker) *149*
nisella (Clerck) *151*
Hendecaneura
shawiana (Kearfott) *152*
Hystricophora
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Gretchena
bolliana (Slingerland) *155*
Ecdytolopha
insiticiana Zeller *157*
Grapholita
molesta (Busck) *160*
packardi Zeller *162*
Cydia
gallaesaliciana (Riley) *163*
Episimus
tyrius Heinrich *164*

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

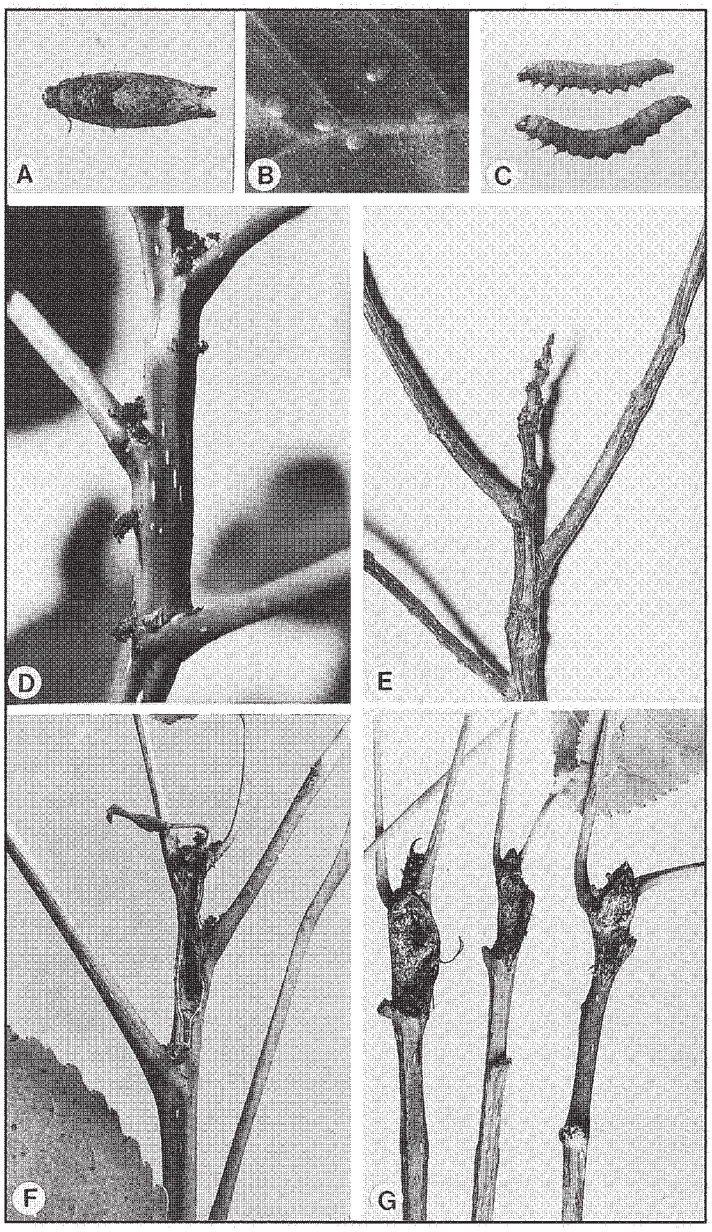

Figure 53—Gypsonoma haimbachiana, *cottonwood twig borer: A, adult; B, eggs; C, larvae; D, frass tubes at entrance holes; E, killed terminal; F, larval tunnel in terminal; G, Terminals flared open by potter wasp predation.*

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-

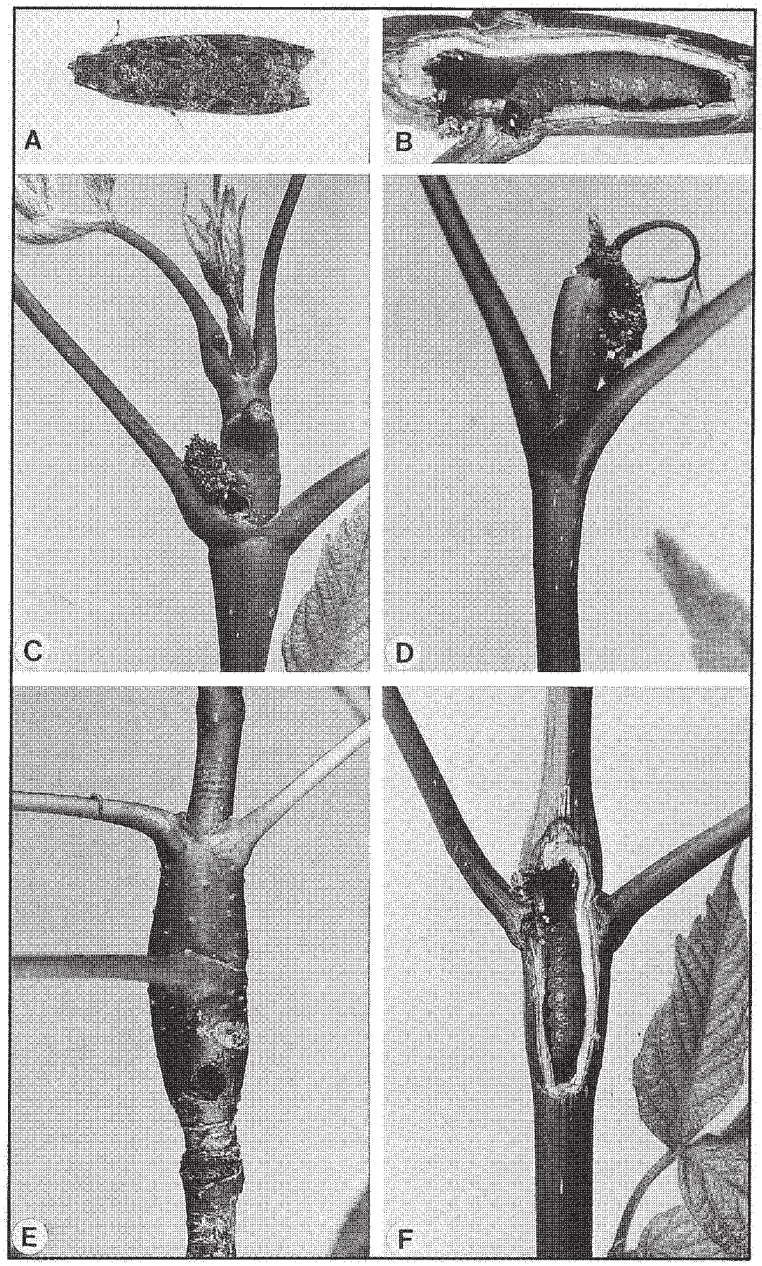

Figure 54—Proteoteras willingana, *boxelder twig borer: A, adult; B, larva; C, frass protruding from entrance at petiole juncture; D, dead terminal with frass at apex; E, gall-like swelling with entrance hole; F, gallery exposed.*

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

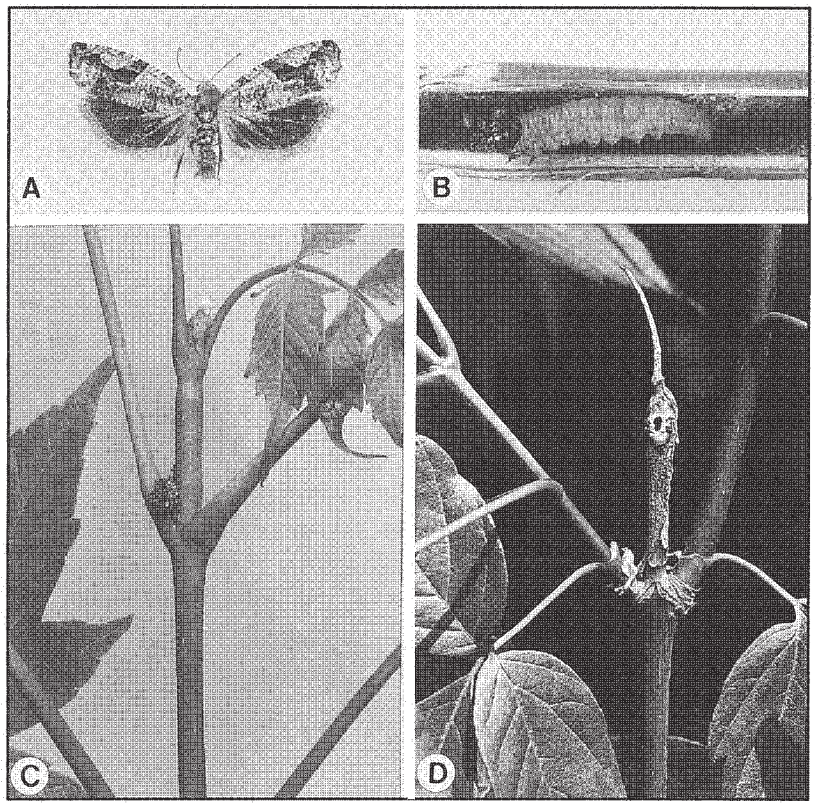

Figure 55—Proteoteras arizonae, *[California boxelder twig borer]: A, adult; B, larva; C, frass clump at larval entrance; D, dead terminal with entrance hole (A, specimen courtesy R. Hodges).*

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

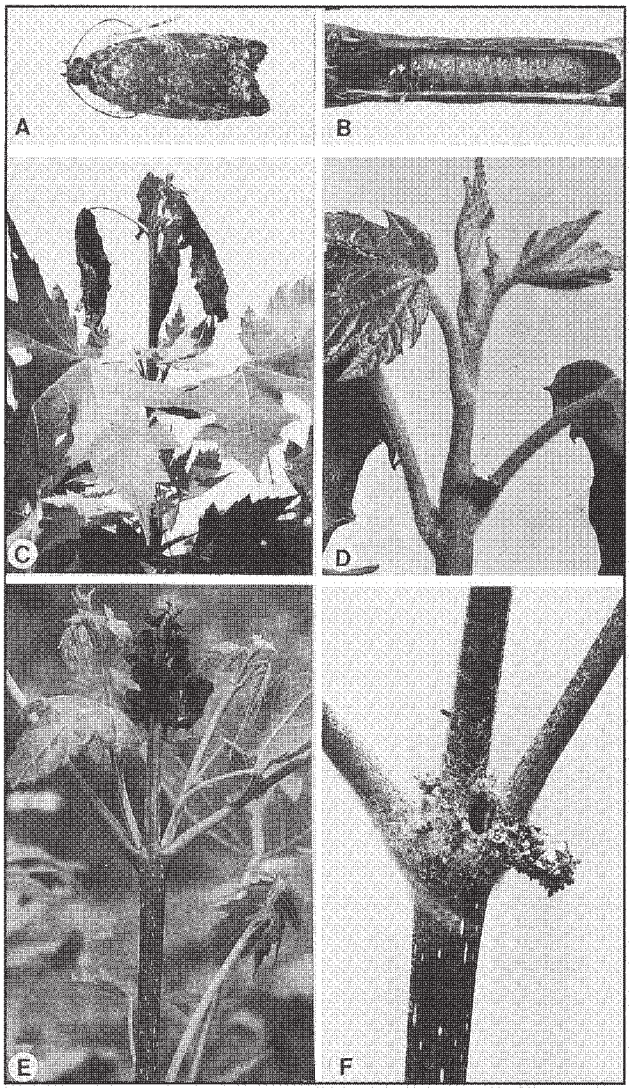

Figure 56—Proteoteras aesculana, *[maple twig borer]: A, adult; B, larva; C, dead terminal; D, frass at juncture of petiole; E, laterals elongating after terminal being killed; F, larval entrance hole.*

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

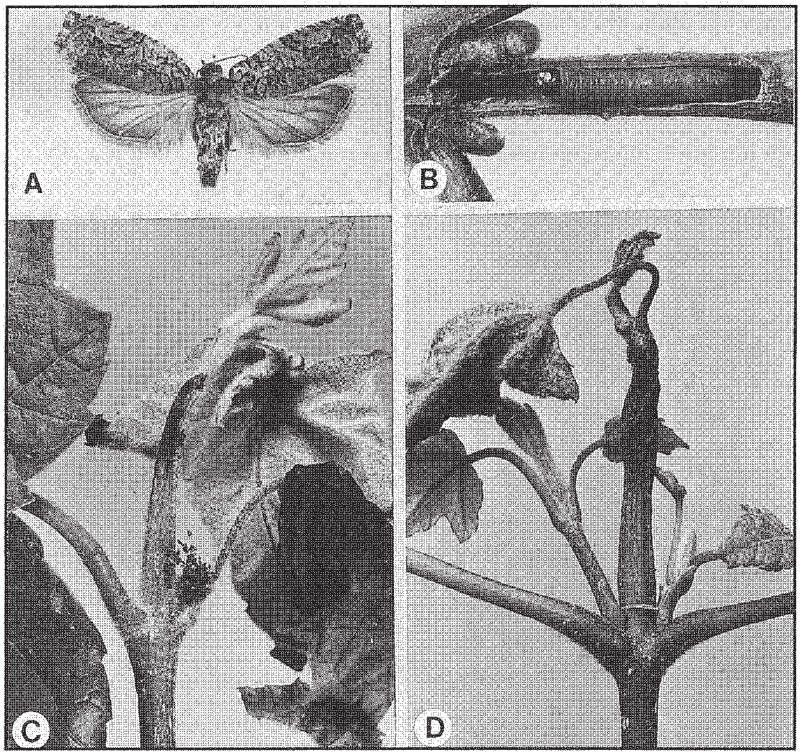

Figure 57—Proteoteras moffatiana, *[maple bud borer]: A, adult; B, larva; C, frass clump at base of dead petiole; D, terminal and one lateral dead allowing opposite lateral to elongate (A, specimen courtesy R. Hodges).*

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

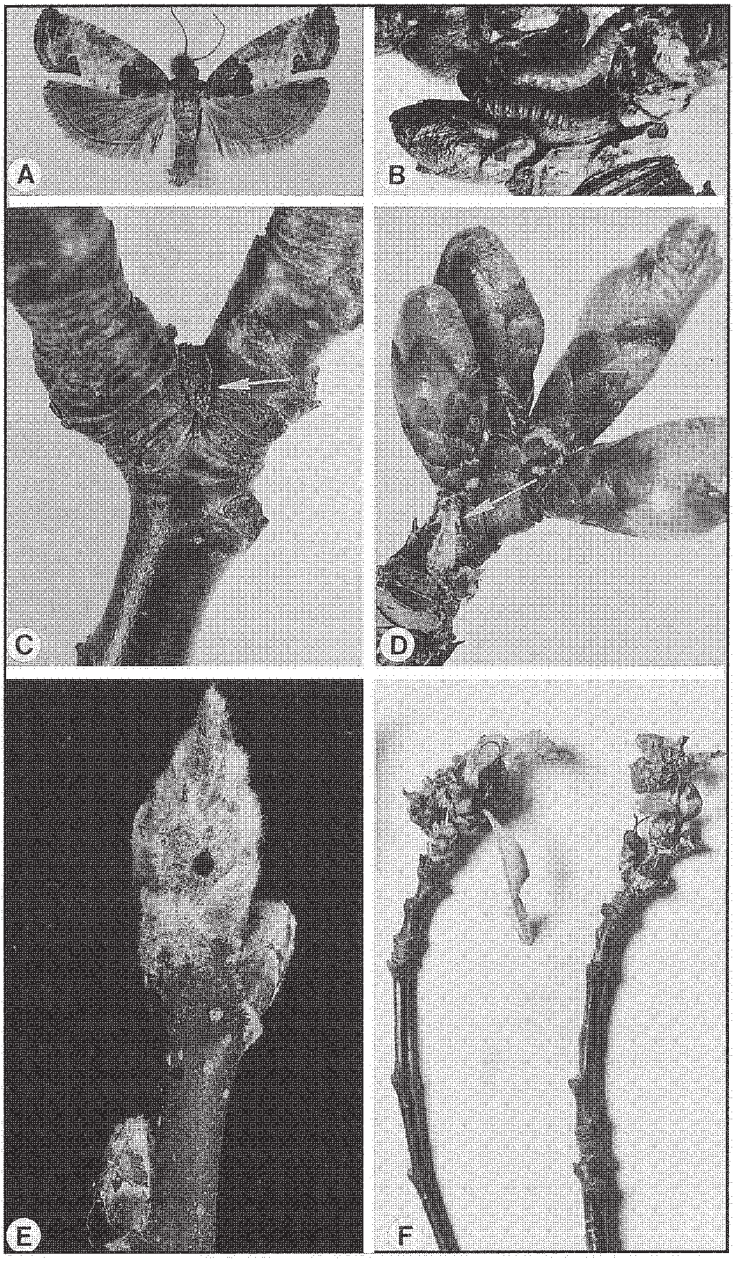

Figure 58—Spilonota ocellana, *eyespotted bud moth: A, adult; B, larvae; C, hibernaculum in twig crotch; D, hibernaculum opened to expose silken interior; E, larval entrance in bud; F, crumpled leaves at twig tip (B–F, courtesy E. Oatman).*

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

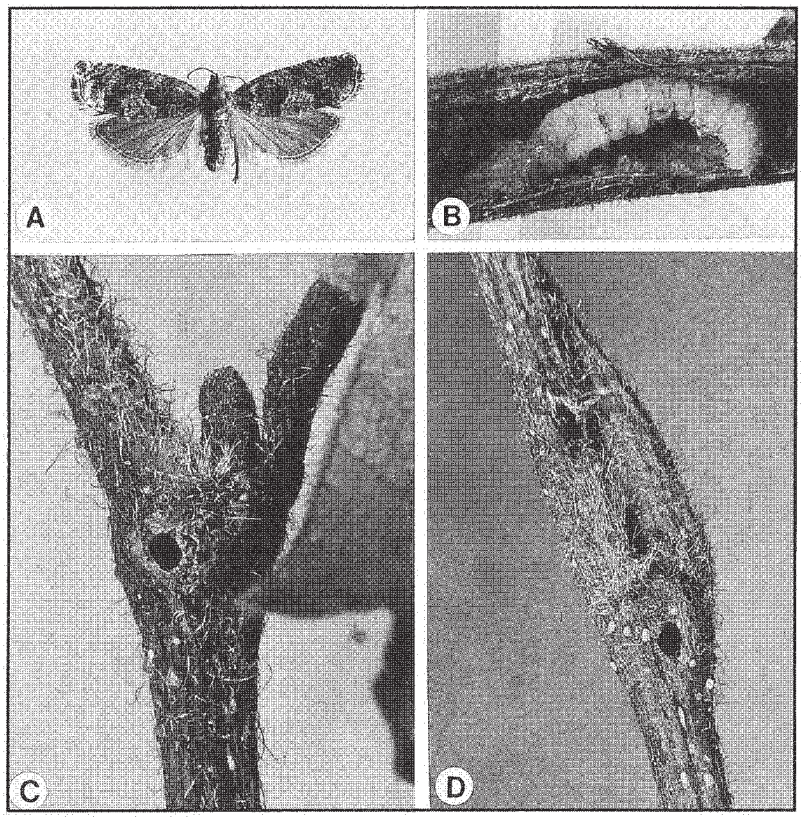

Figure 59—Epinotia solicitana, *[birch shoot borer]: A, adult; B, larva; C, infested swollen shoot; D, entrance hole near juncture of petiole and bud (A, specimen courtesy R. L. Brown).*

(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

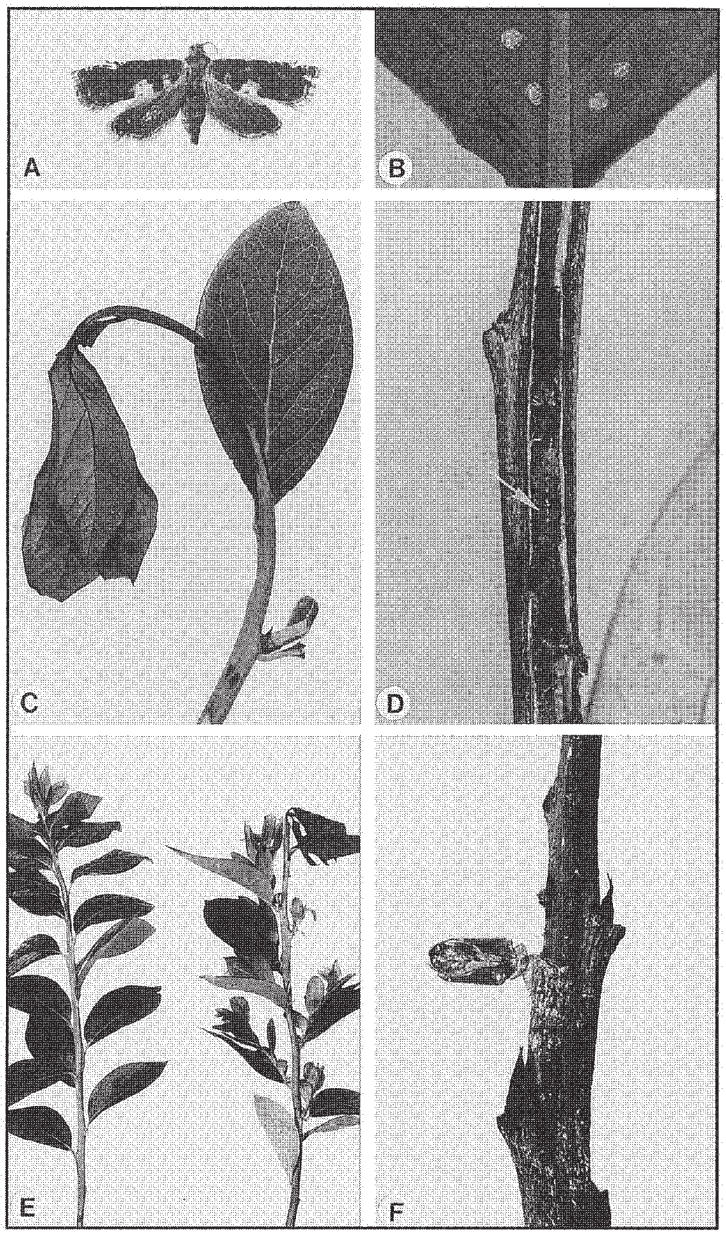

Figure 60—Hendecaneura shawiana, *[blueberry tip borer]: A, adult; B, eggs on underside of leaf; C, wilting shoot; D, burrow and larva; E, healthy shoot on left, infested shoot at right with dead tip and laterals beginning growth; F, pupal skin protruding from shoot (courtesy G. Schaefers).*

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).

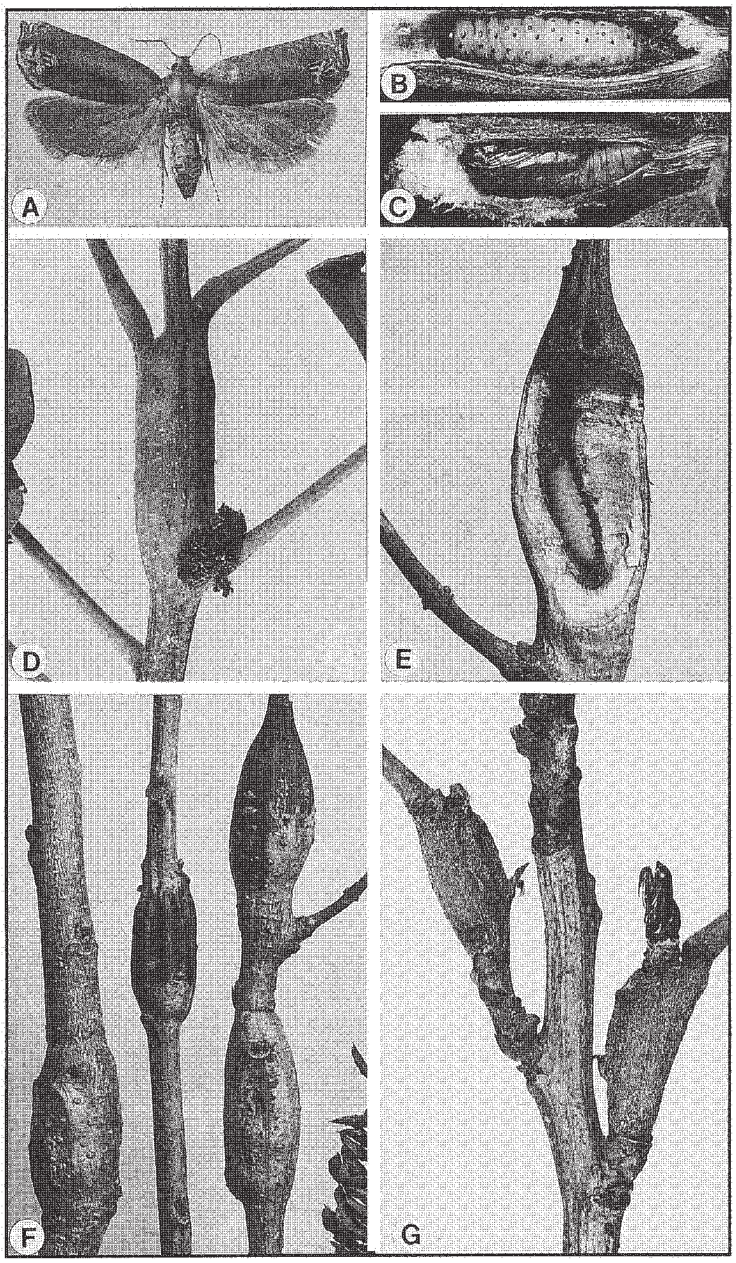

Figure 61—Hystricophora taleana, *[indigobush twig borer]: A, adult; B, larva; C, pupa; D, frass clump at base of petiole; E, larval burrow; F, gall-like swellings on stems; G, pupal skin protruding from enlarged stem.*

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

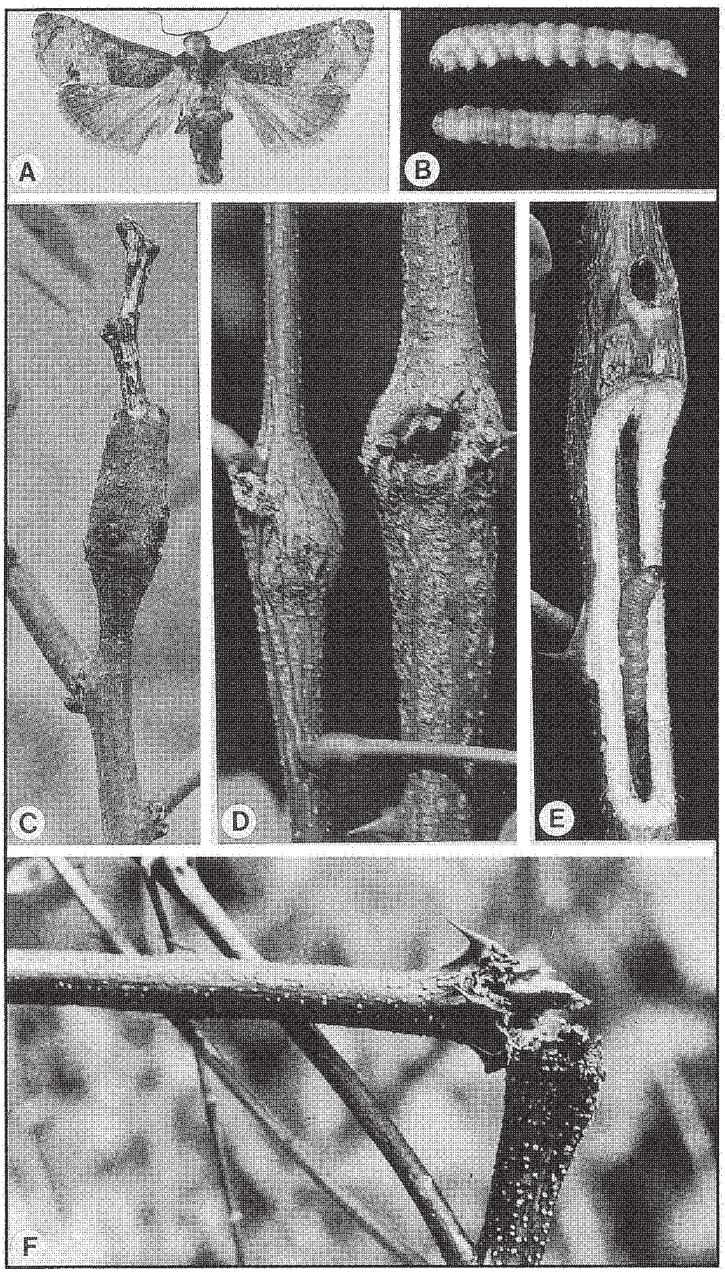

Figure 62—Ecdytolopha insiticiana, *locust twig borer: A, adult; B, larvae; C, gall-like swelling on terminal; D, swollen stems with entrance hole and frass; E, stem split to expose gallery; F, broken stem.*

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

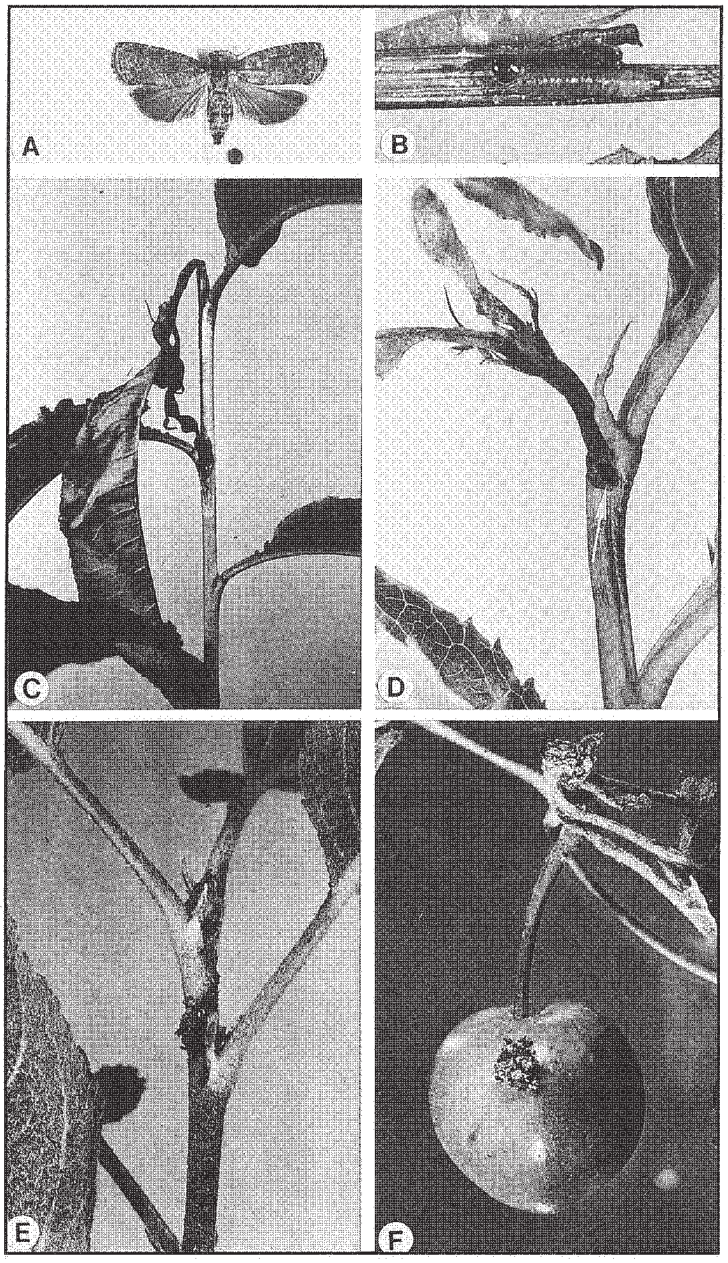

Figure 63—Grapholita molesta, *oriental fruit moth: A, adult; B, larva; C, wilting shoot tip; D, entrance hole in shoot; E, frass at entrance site; F, frass clump on infested fruit (A, specimen courtesy R. Hodges; B, E, & F, courtesy NY Agricultural Experiment Station).*

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.

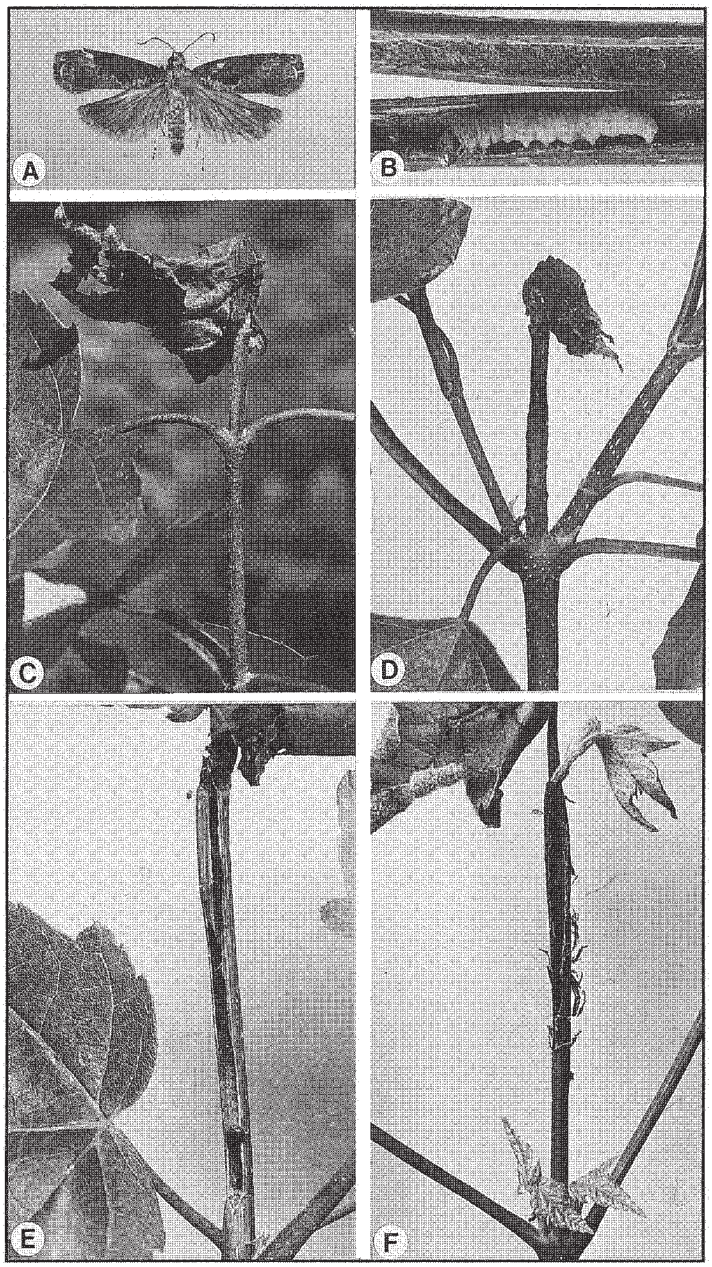

Figure 64—Episimus tyrius, *[maple tip borer]: A, adult; B, larva; C, withering shoot tip; D, silk-tied leaves around dead terminal; E, gallery exposed; F, stem shredded by predator, exposing gallery.*

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 *166*
- *semifuneralis* (Walker) *169*
- *magnolialis* Capps *172*

Acrobasis
- *demotella* Grote *175*
- *nuxvorella* Neunzig *177*
- *caryivorella* Ragonot *180*

Hypsipyla
- *grandella* (Zeller) *182*

Elasmopalpus
- *lignosellus* (Zeller) *184*

Nephopteryx
- *carneella* Hulst *187*

Meroptera
- *cviatella* Dyar *187*

Terastia
- *meticulosalis* Guenee *187*

Ostrinia
- *nubilalis* (Hübner) *189*

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).

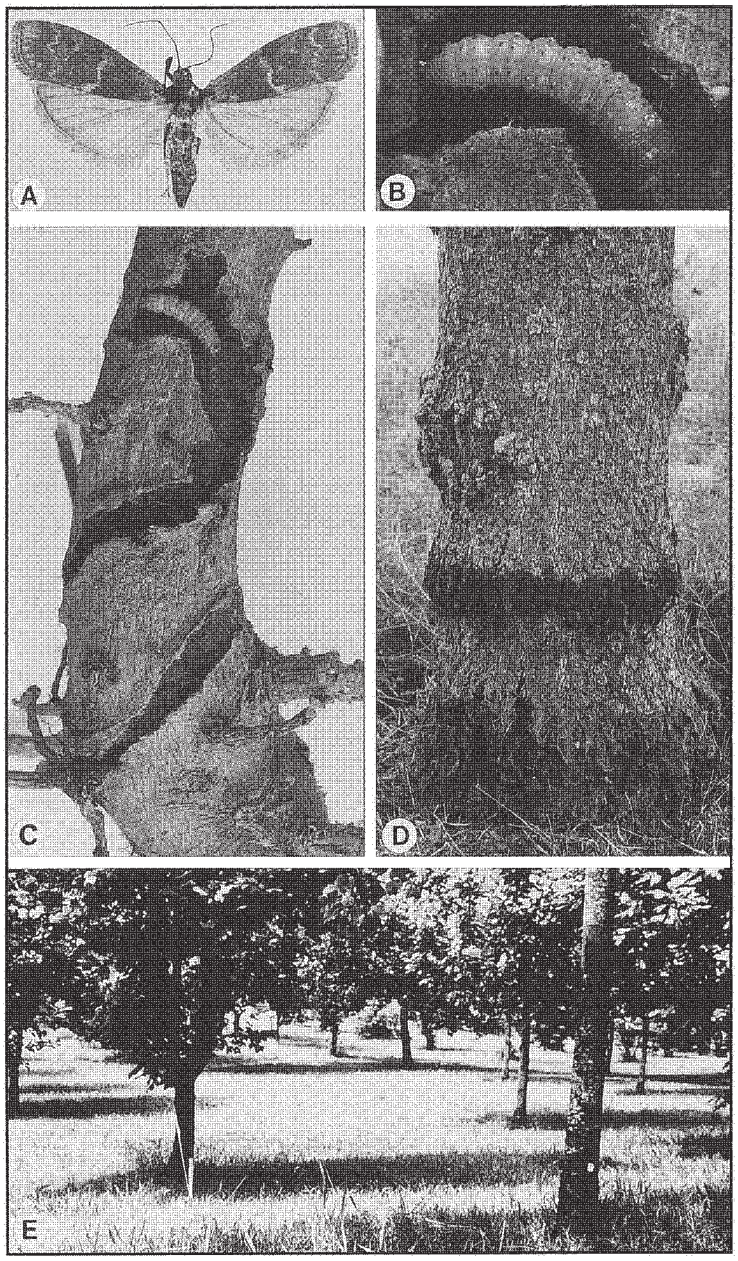

Figure 65—Euzophera ostricolorella, *[root collar borer]: A, adult; B, larva; C, spiral burrow in sapling; D, tree heavily infested at root collar; E, heavily infested yellow-poplar seed orchard (E, courtesy C. Pless).*

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)

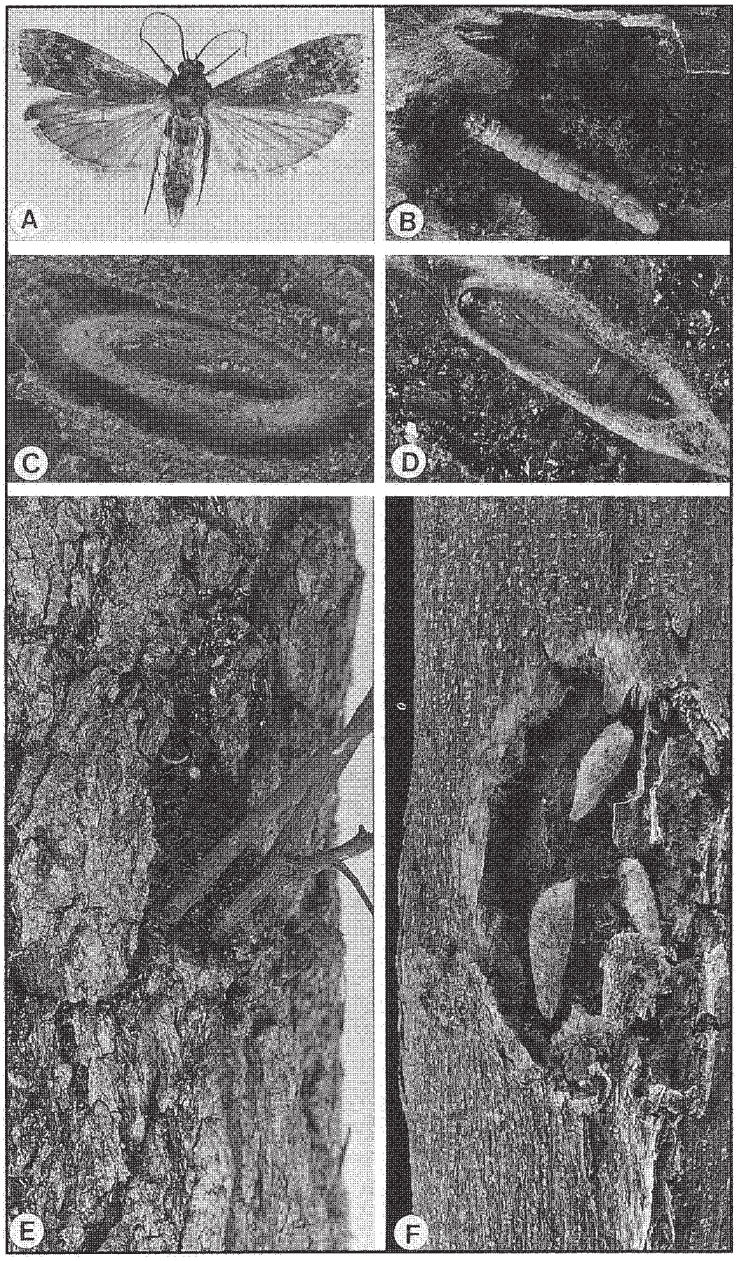

Figure 66—Euzophera semifuneralis, *American plum borer: A, adult; B, larva in burrow; C, cocoon with pupa inside; D, pupa; E, clump of dark frass on bark; F, white silken cocoons in burrows under bark.*

(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

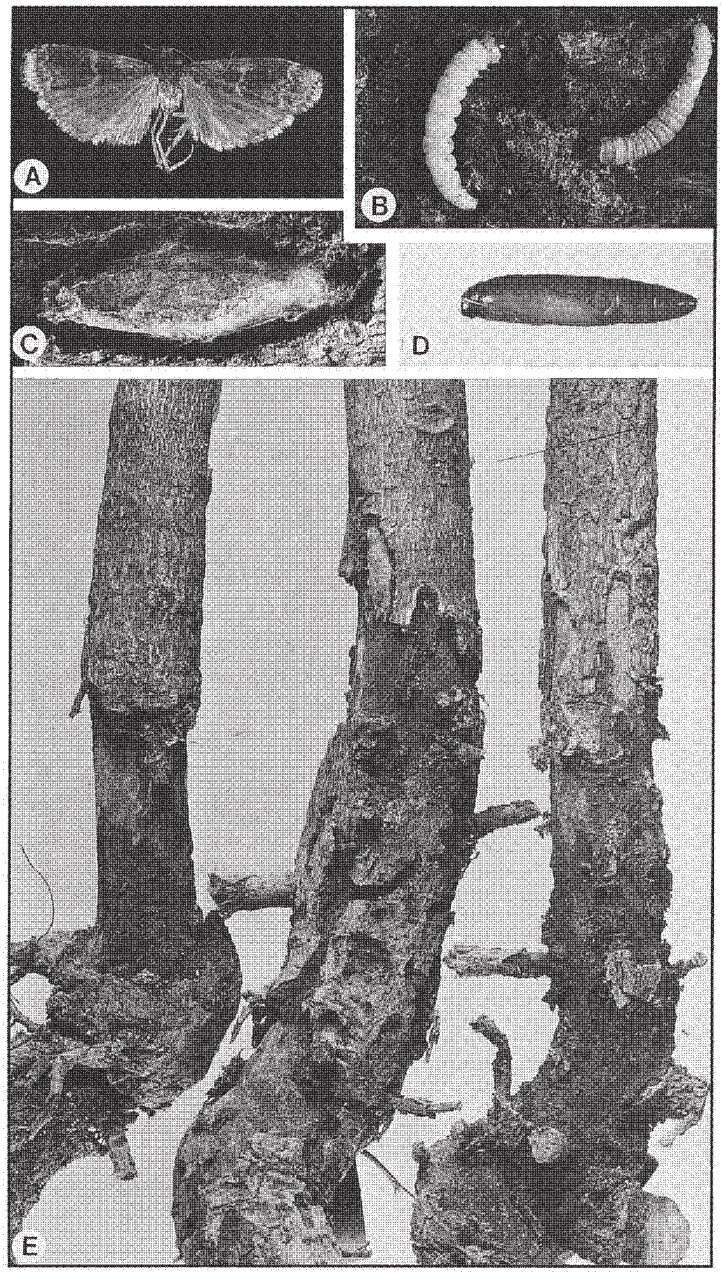

Figure 67—Euzophera magnolialis, *[magnolia borer]: A, adult; B, larvae in burrows; C, white silken cocoon in pupal cell; D, pupa; E, extensive injury at root collar of nursery-grown magnolias (A, specimen courtesy R. Hodges; B-E, specimens courtesy R. Mizell).*

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 leaf-drop 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

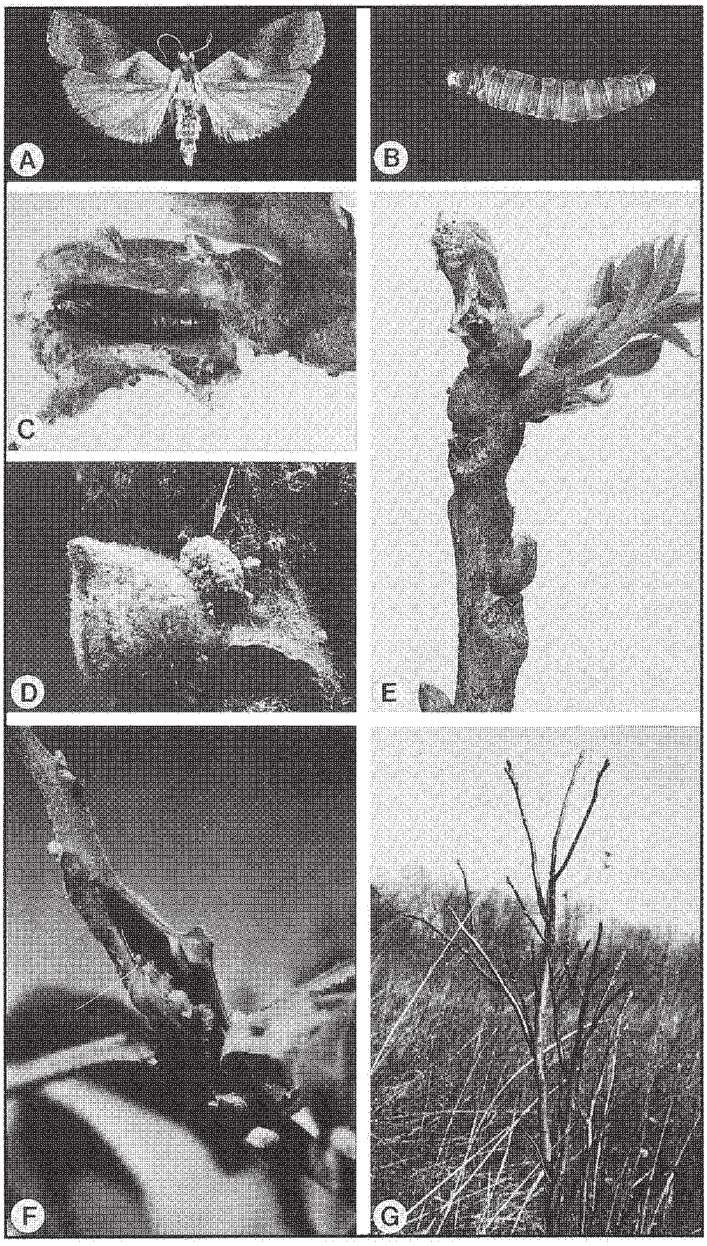

Figure 68—Acrobasis demotella, *walnut shoot moth: A, adult; B, larva; C, pupa inside shoot; D, hibernaculum in bud axil; E, infested terminal bud failing to elongate; F, hollowed shoot; G, young tree damaged by attacks (A, specimen courtesy R. Hodges; D & G, courtesy G. Simmons; F, courtesy B. Weber).*

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

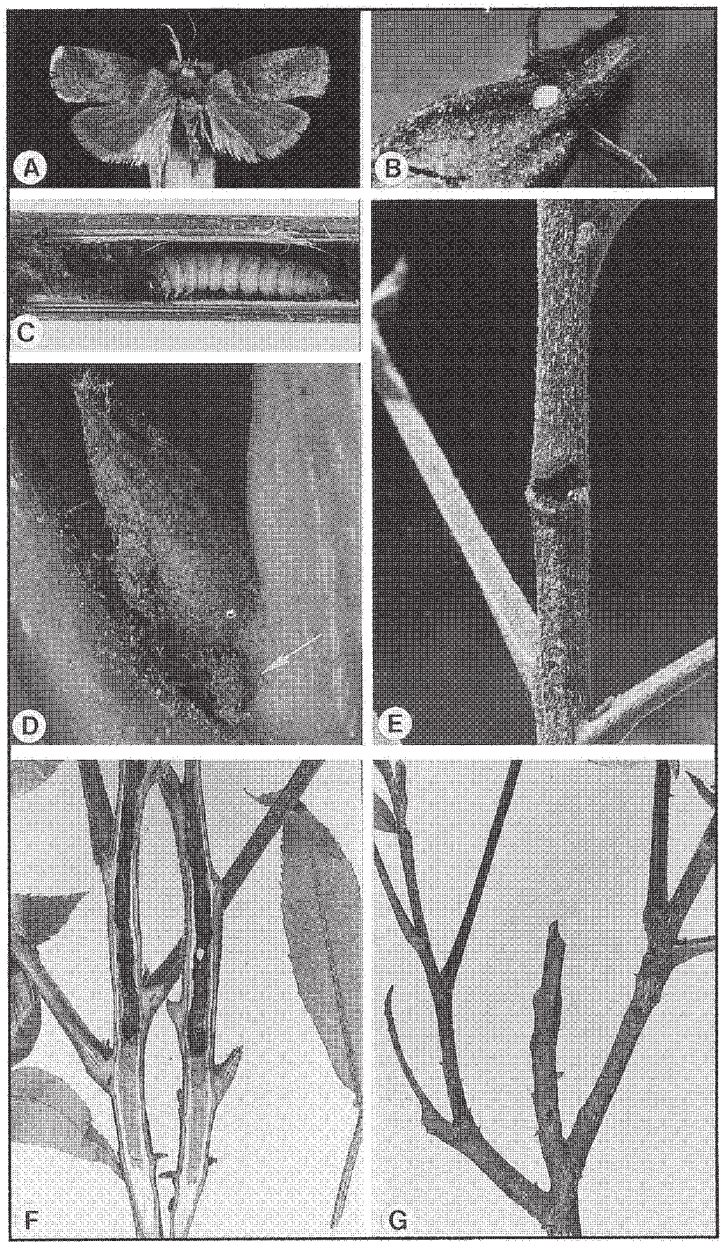

Figure 69—Acrobasis nuxvorella, *pecan nut casebearer: A, adult; B, egg on nutlet; C, larva; D, hibernaculum at base of lateral bud; E, entrance hole in shoot; F, hollowed shoot; G, terminal shoot killed (A, specimen courtesy R. Hodges; B & D, specimens courtesy V. Calcote; C, specimen courtesy E. Brown).*

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).

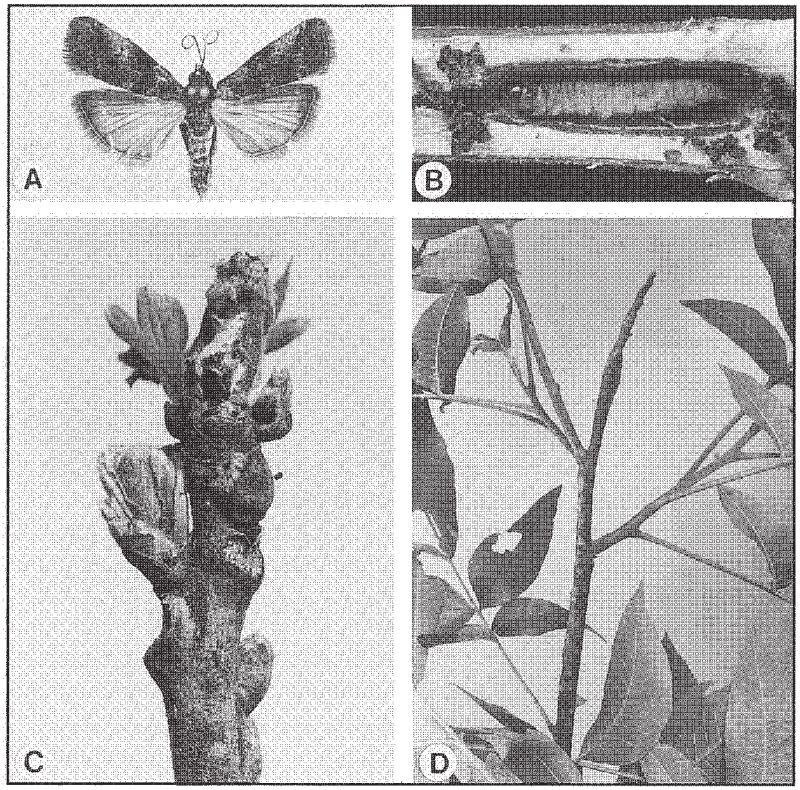

Figure 70—Acrobasis caryivorella, *[hickory shoot moth]: A, adult; B, larva; C, buds and shoot apex hollowed out; D, shoot mortality (A, specimen courtesy H. Neunzig).*

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

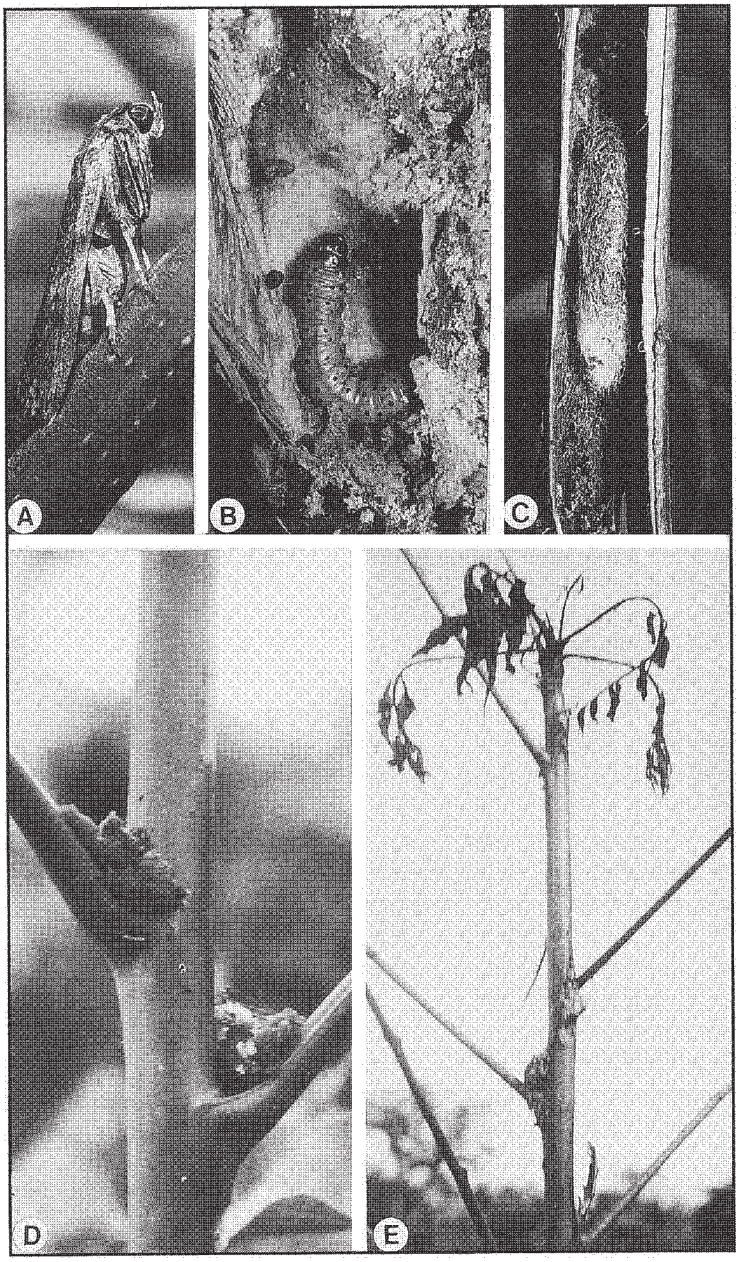

Figure 71—Hypsipyla grandella, *[mahogany shoot borer]: A, adult in resting position; B, larva in burrow; C, silken cocoon in shoot gallery; D, clumps of frass on infested shoot; E, dying shoot (A-C, courtesy E. Holsten; D-E, courtesy J. Whitmore).*

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

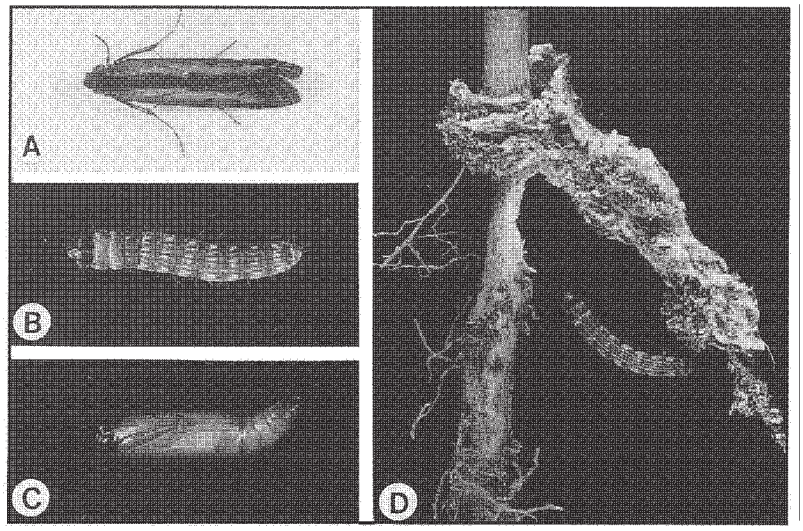

Figure 72—Elasmopaplus lignosellus, *lesser cornstalk borer: A, adult; B, larva; C, pupa; D, seedling injured at root collar with silken feeding tube (specimens courtesy J. Todd).*

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,

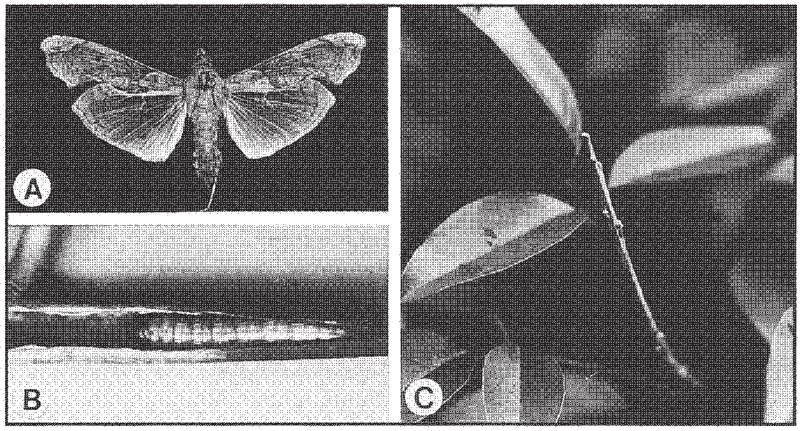

Figure 73—Terastia meticulosalis, *[bucare twig borer]: A, adult; B, larva in twig gallery; C, twig killed by larva (A, specimen courtesy R. Hodges; B & C, courtesy C. Chellman).*

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

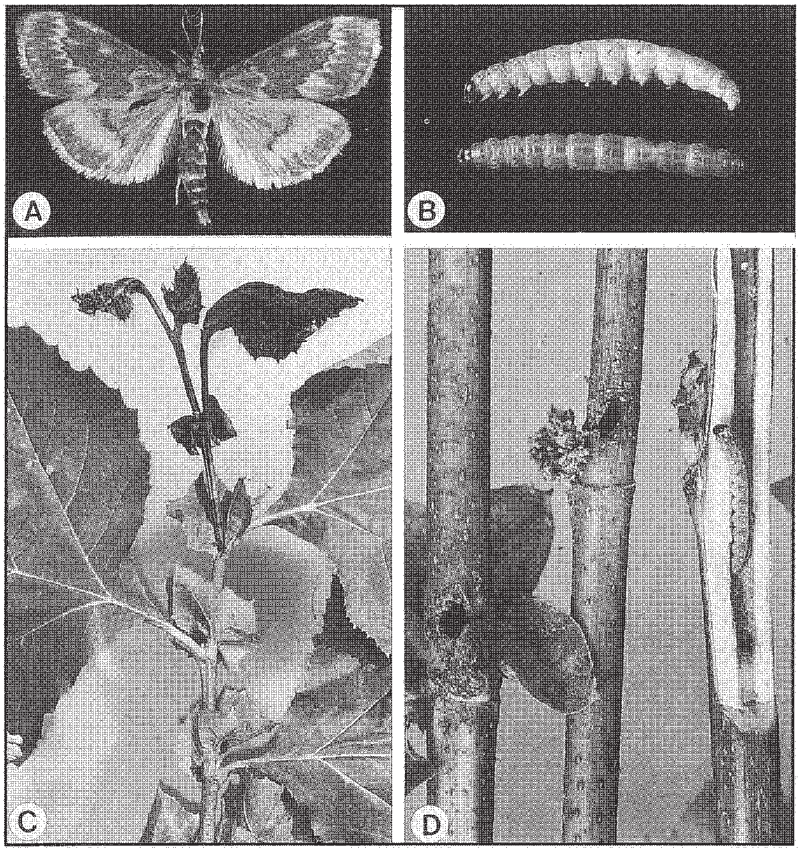

Figure 74—Ostrinia nubilalis, *European corn borer: A, adult; B, larvae; C, seedling terminal killed by larva; D, entrance holes, frass, and gallery in sycamore seedlings (A, specimen courtesy R. Hodges; B-D, specimens courtesy P. Marshall).*

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) *192*

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

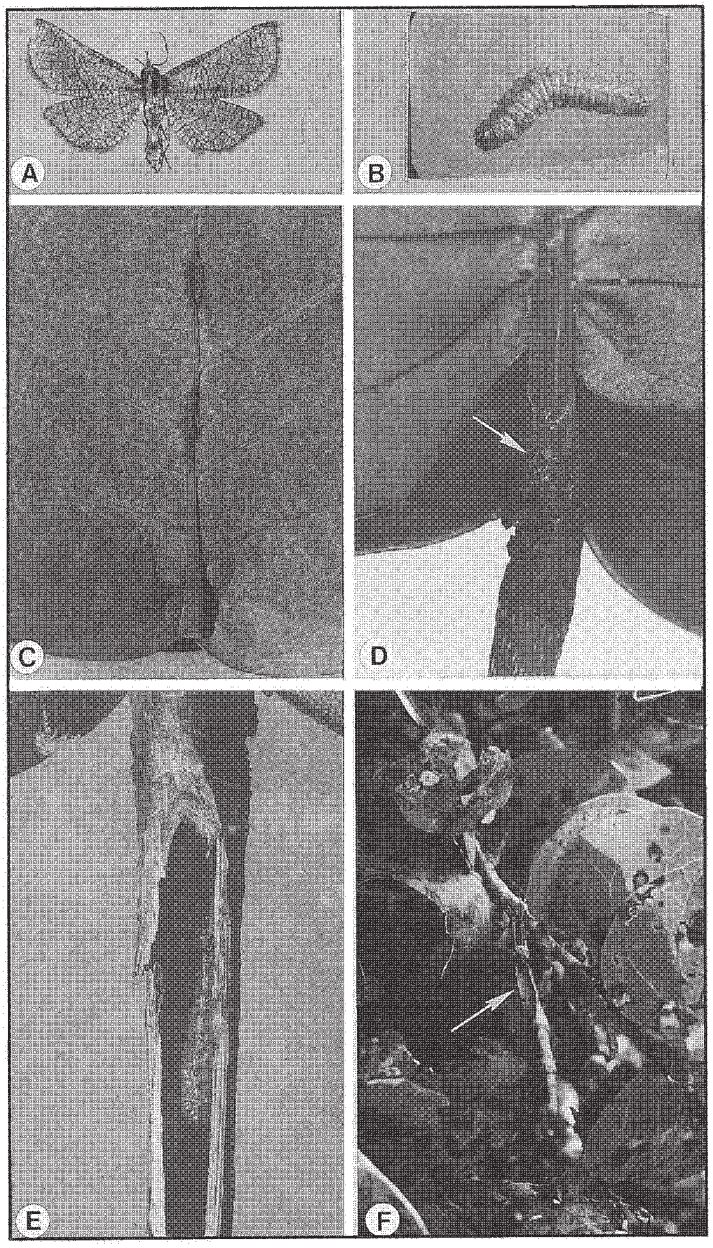

Figure 75—Hexeris enhydris, *[seagrape borer]: A, adult; B, larva; C, early injury to leaf midrib; D, entrance hole in infested shoot; E, closeup of gallery with larva; F, seagrape shoot hollowed out by larva (A, specimen courtesy R. Hodges; B-E, courtesy W. Johnson; F, courtesy C. Chellman).*

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) *195*
kellicottii (Fish) *197*
grandis (Fish) *199*

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

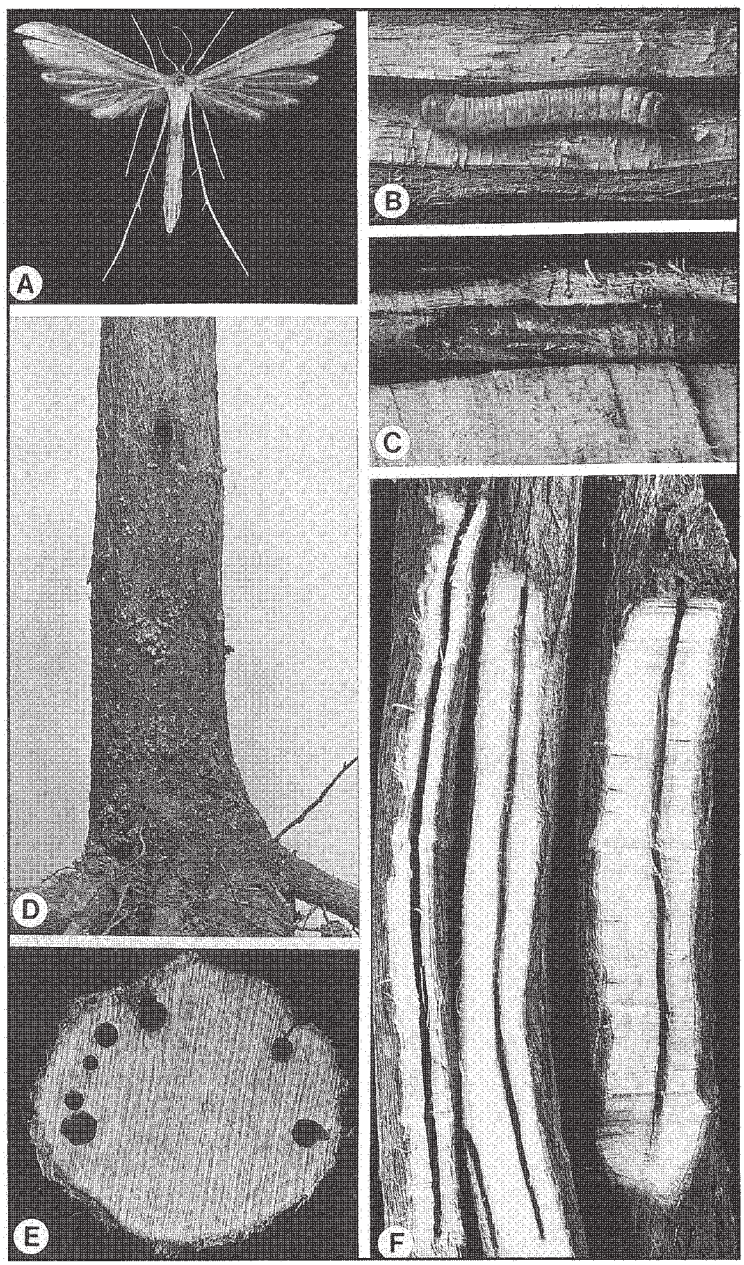

Figure 76—Oidaematophorus balanotes, *[baccharis borer]: A, adult; B, larva; C, pupa; D, entrance hole in baccharis stem; E, cross section of stem showing seven round galleries; F, long narrow galleries exposed.*

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

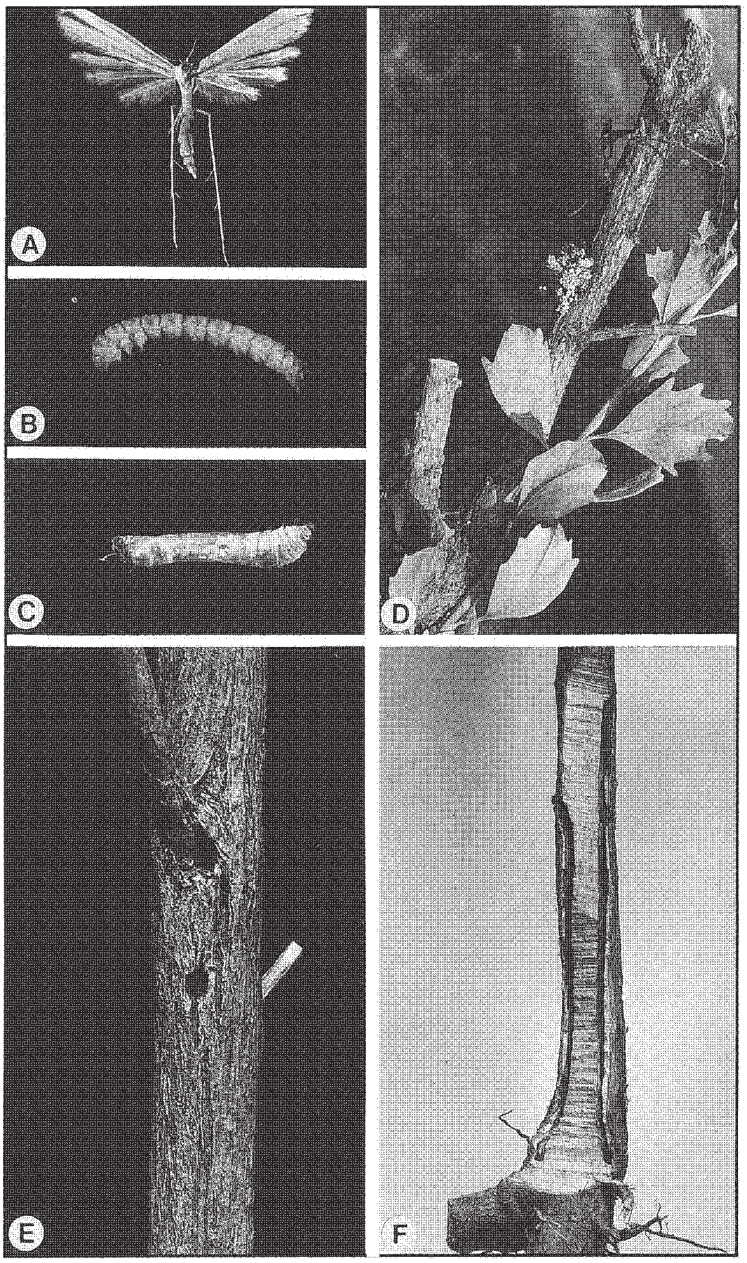

Figure 77—Oidaematophorus kellicottii, *[goldenrod borer]: A, adult; B, larva; C, pupa; D, clump of frass on baccharis stem; E, entrance hole on stem; F, stem sawn open to expose two galleries (A, specimen courtesy R. L. Brown).*

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.

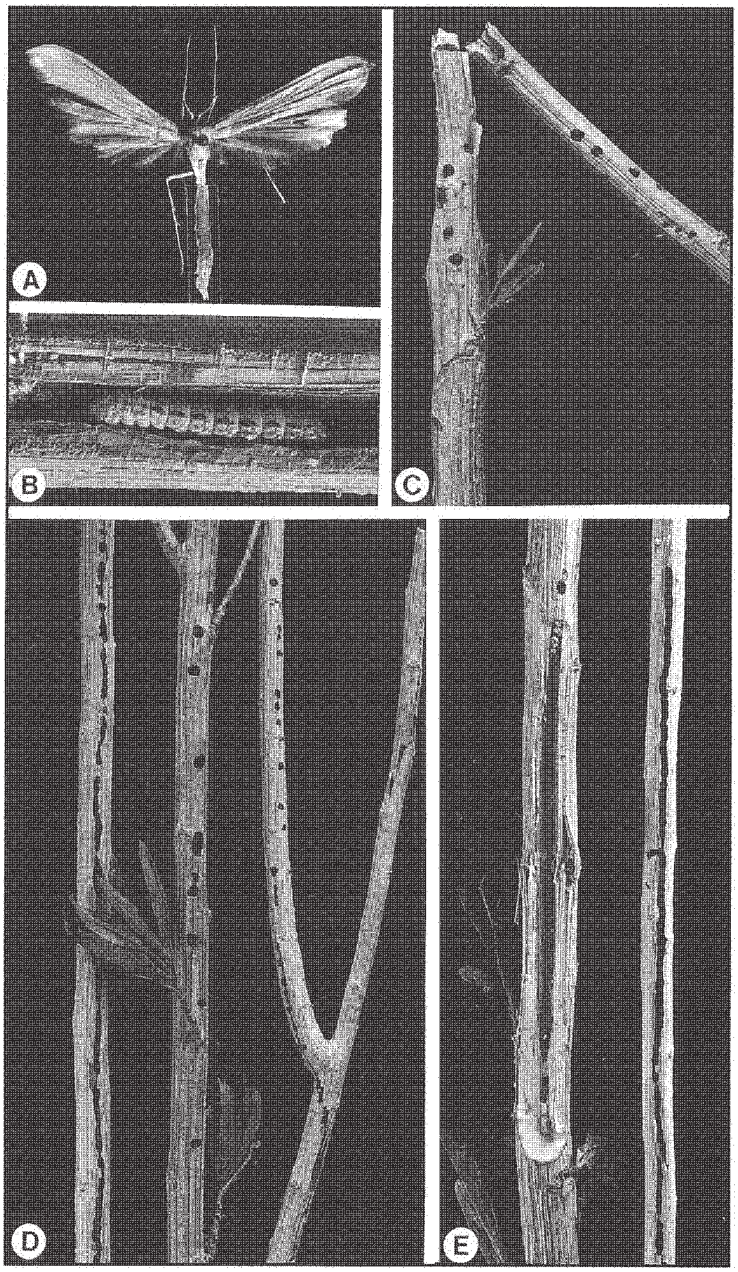

Figure 78—Oidaematophorus grandis, *[coyote brush borer]: A, adult; B, larva in gallery; C, stem broken at weakened site; D, series of holes in coyote brush; E, galleries exposed in stems (A, specimen courtesy R. Hodges).*

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) *202*
- *cataphracta* (Grote) *205*
- *furcata* (Smith) *207*

Achatodes
- *zeae* (Harris) *209*

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

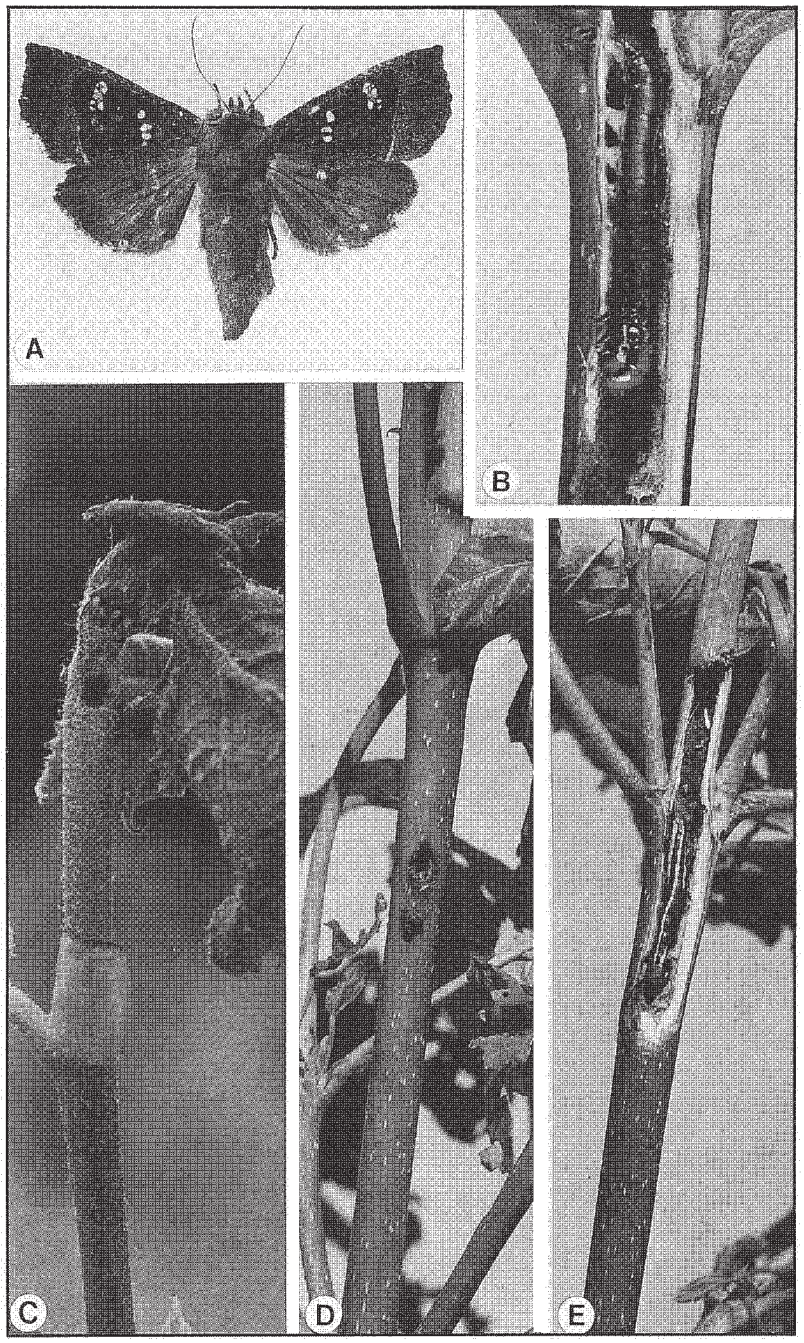

Figure 79—Papaipema nebris, *stalk borer: A, adult; B, larva in gallery; C, dying sycamore shoot with entrance hole; D, entrance hole with frass in silver maple; E, gallery exposed.*

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

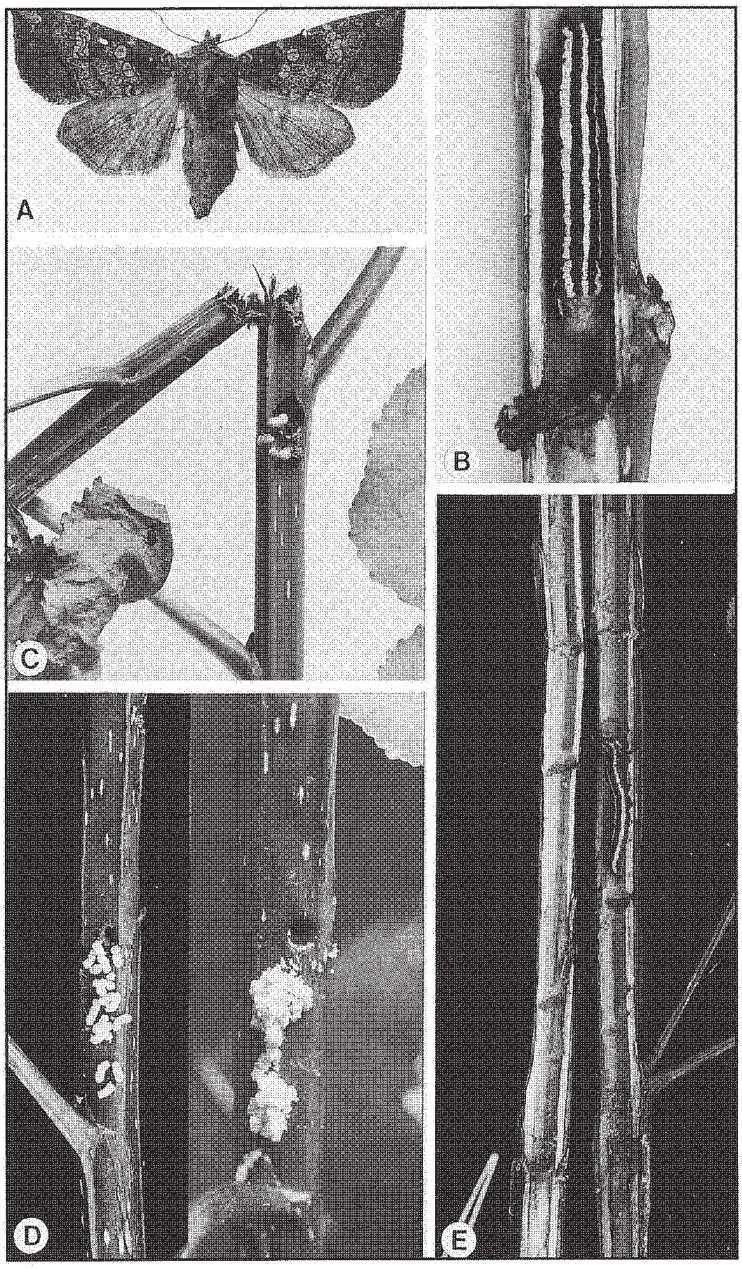

Figure 80—Papaipema cataphracta, *burdock borer: A, adult; B, larva in gallery; C, cottonwood shoot broken at weakened site; D, entrance holes with frass on infested shoots; E, stem split to expose tunnel and larva.*

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

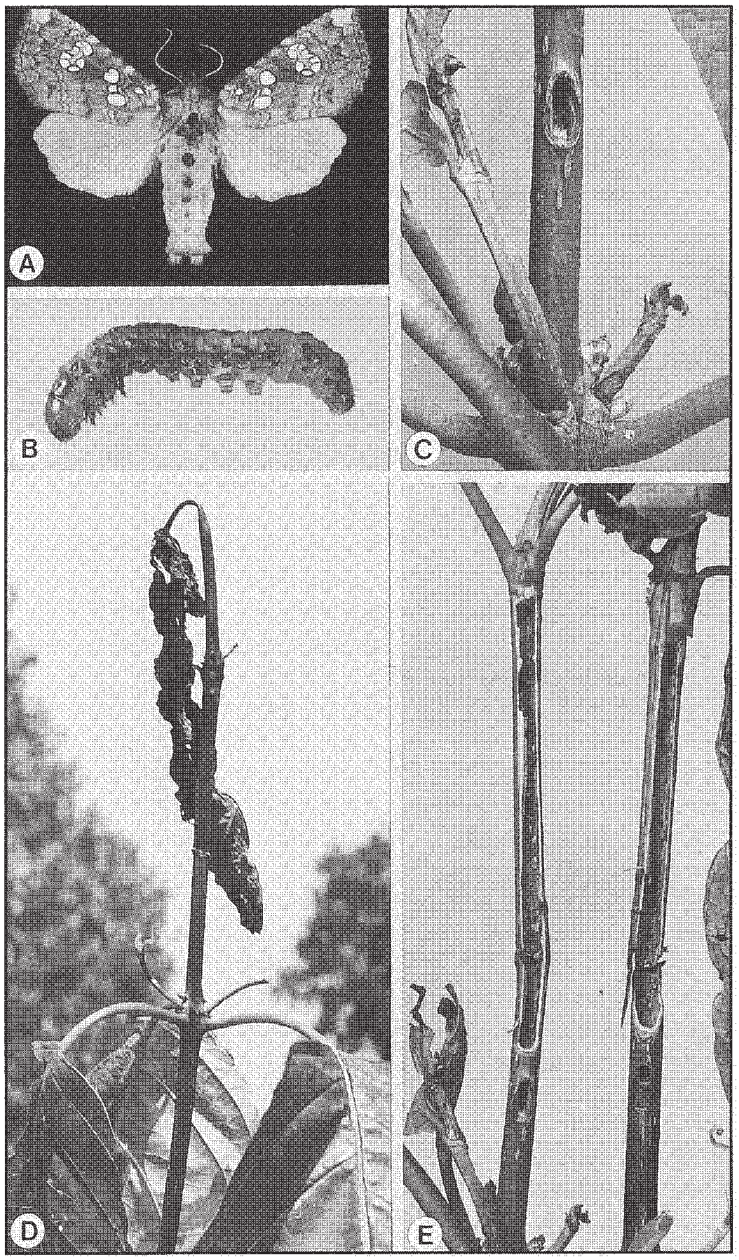

Figure 81—Papaipema furcata, *[ash shoot borer]: A, adult; B, larva; C, entrance hole in shoot; D, buttonbush shoot killed by larva; E, galleries exposed in shoots (A, specimen courtesy R. Hodges).*

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.

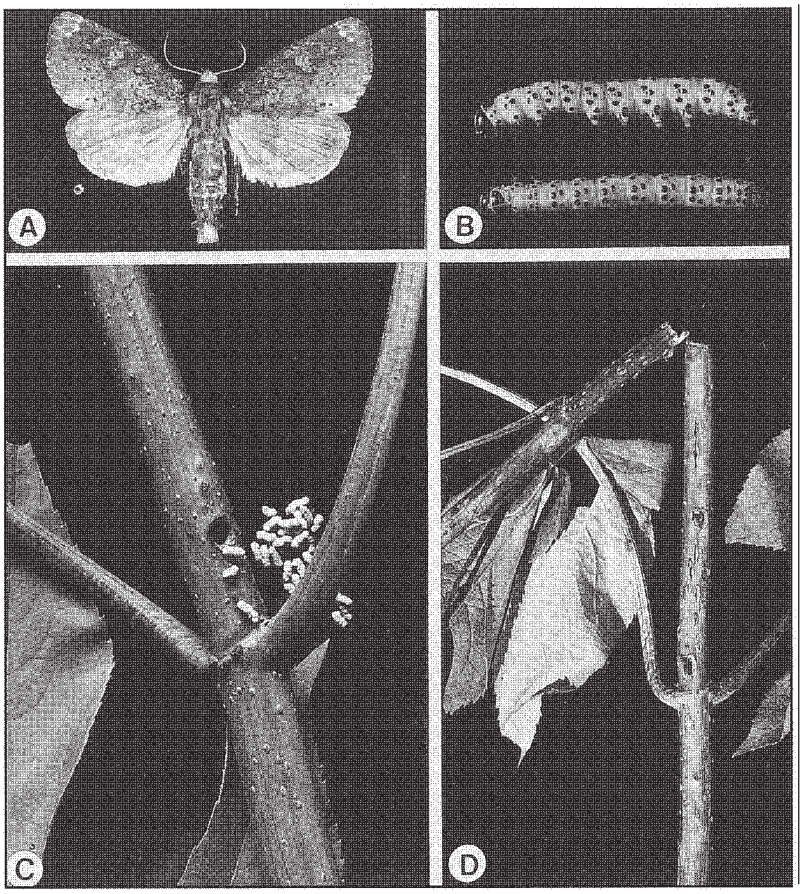

Figure 82—Achatodes zeae, *elder shoot borer: A, adult; B, larvae; C, entrance hole in elder shoot with white excrement pellets; D, stem broken at weakened site (A, specimen courtesy R. Hodges).*

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).

Order Coleoptera—Beetles

Beetles comprise the largest order of insects, including the largest group of borers, and can be distinguished by their hard leathery forewings (elytra) that meet in a straight line along the middle of the back (Borror and others 1981, Craighead 1950). The elytra cover the long membranous hindwings used for flying. Some beetles have their heads drawn out into more or less elongated snouts, with mouth parts at the end. Larvae vary considerably in form and habits, but most are white to yellowish with dark heads and light to amber thoracic shields, elongate, rounded to flattened bodies, and straight to crescent shapes. They feed in shoots, branches, trunks, and roots of healthy, weakened, dying, and dead trees, and in green logs and moist lumber. Some are very specific as to host part and condition. Economically, the beetles are the most important order of forest insects. They cause huge losses to standing timber through degrade, decline, and mortality; to shade and ornamental trees and shrubs through esthetic damage and mortality; and to seedlings in nurseries, plantations, seed orchards, and natural stands through growth loss, stem deformation, and mortality.

Family

Buprestidae *213*
Bostrichidae *284*
Lymexylidae *290*
Cerambycidae *294*
Brentidae *476*
Curculionidae *479*
Scolytidae *503*
Platypodidae *578*

Family Buprestidae—Flatheaded Borers

The buprestids are a large important family of borers. The adults are flattened and elliptical or oval and often beautifully marked with black, copper, green, or blue, often with a metallic luster (Craighead 1950, Furniss and Carolin 1977). Larvae are typically "flatheaded," a condition produced by the enlargement of the first and sometimes second and third thoracic segments that is so characteristic as to readily distinguish them from all other larvae found in trees. The adults are most active on sunny days and are commonly observed running rapidly over the bark, stopping frequently to oviposit. A few species attack healthy trees; most prefer weakened, injured, dying, or recently dead trees. A number of species mine in the cambium of branches, trunks, and roots, some bore extensively in the wood, and others feed in both sites. Larval galleries are flattened, oval in cross section, winding, and always packed tightly with frass. Some make spiral galleries around small stems. Emerging beetles leave characteristic oval, elliptical, D-shaped, or round holes in the bark. Some economically important species girdle and kill trees; several hasten the death of weakened trees; some cause degrade in wood products sawn from infested trees and logs; and others act as gallmakers or twig pruners.

Genus and Species

Agrilus
bilineatus (Weber) *214*
anxius Gory *217*

horni Kerremans *220*
granulatus granulatus (Say) *222*
granulatus liragus Barter and Brown *224*
granulatus populi Fisher *227*
criddlei Frost *227*
politus (Say) *229*
burkei Fisher *230*
pensus Horn *232*
acutipennis Mannerheim *234*
angelicus Horn *237*
arcuatus torquatus LeConte *239*
otiosus Say *242*
juglandis Knull *244*
cephalicus LeConte *244*
difficilis Gory *246*
champlaini Frost *249*
sayi Saunders *249*
masculinus Horn *252*
vittaticollis Randall *254*
sinuatus (Olivier) *256*
crataegi Frost *258*
fuscipennis Gory *260*
ruficollis (Fabricius) *262*
aurichalceus Redtenbacher *264*
Eupristocerus
cogitans Weber *265*
Chrysobothris
femorata (Olivier) *267*
mali Horn *270*
bacchari Van Dyke *272*
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merkelii Horn *273*
Descarpentriesina
cyanipes (Say) *274*
californica Chamberlin *276*
thureura (Say) 277
Dicerca
lepida LeConte *277*
pugionata (Germar) *279*
tenebrica (Kirby) *280*
Texania
campestris (Say) *280*
Ptosima
gibbicollis (Say) *282*

Agrilus bilineatus (Weber)

twolined chestnut borer (figure 83)

Hosts. Chestnut, oak, beech. American chestnut was the primary host before chestnut blight killed most of it during the early to middle years of this century (Chapman 1915). Since then, the oaks including white, scarlet, bur, northern red, black, chestnut, water, Nuttall, and live oaks are preferred hosts (Dunbar and Stephens 1976). A variety of *A. bilineatus* called "carpini" occasionally attacks American hornbeam, eastern hophornbeam, and honeylocust (Cote and Allen 1980, Fisher 1928).

Range. Indigenous to North America (Cote and Allen 1980). Occurs in southeastern Canada southward throughout the eastern and central United States and westward to Texas and the Rocky Mountains (Dunbar and Stephens 1976).

Description. ***Adult.*** Slightly flattened bluish black beetle, usually with light yellowish or whitish pubescent stripe on each elytron, 6 to 12 mm long (figure 83A) (Solomon and others 1987). ***Egg***. Oval, somewhat flattened, and about 1 mm long (Chapman 1915). ***Larva.*** White, slender, flattened, with brown anal forceps at rear end; grows to about 25 mm long (figure

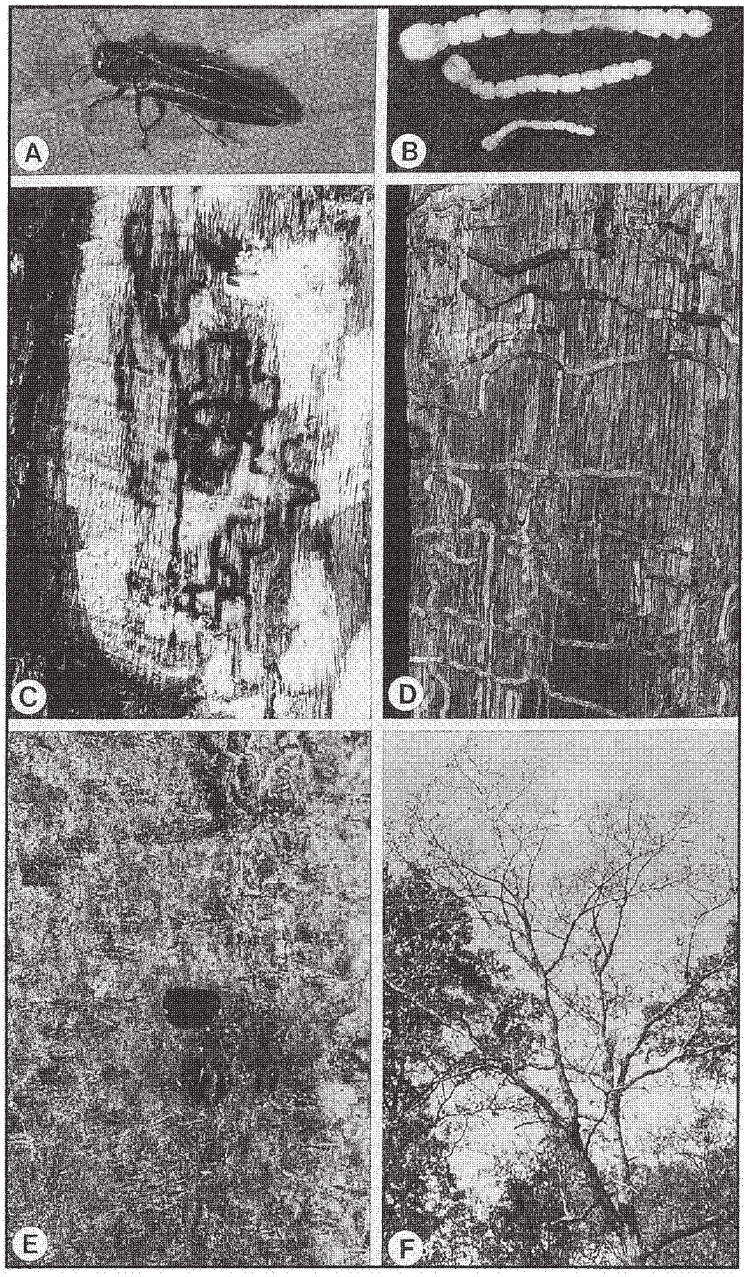

Figure 83—Agrilus bilineatus, *twolined chestnut borer: A, adult; B, larvae; C, galleries under bark of living tree; D, galleries beneath bark of dying tree; E, D-shaped exit hole in bark; F, oak tree dying from larval attacks (A, B, D, E, courtesy R. Haack).*

83B) (Solomon and others 1987).

Biology. Adults emerge May through August and live about 2 weeks (Dunbar and Stephens 1974, 1976). They feed on leaves of many trees but prefer those of their hosts. Females, attracted to host volatiles, oviposit in bark crevices, preferring the bottom of crevices in rough bark. From 1 to 10 eggs are usually laid in a cluster (Chapman 1915). Eggs hatch in 10 to 14 days, and the larvae burrow through the bark and begin feeding between the bark and wood (Solomon and others 1987). Feeding ceases in autumn, and larvae burrow outward in the bark. Larvae overwinter in pupal chambers constructed just beneath the outer surface of the bark. In spring, pupation begins, and the transformed adults emerge through characteristic D-shaped holes. Usually, there is one generation per year; however, 2 years may be required in its northern range. Complex associations with other organisms sometimes exist. Along with defoliation caused by the gypsy moth, interaction between the borer and the shoestring fungus—*Armillaria mellea* (Vahl. ex Fr.) Karst—may be partially responsible for death of oaks (Wargo 1977). Other borer–fungus interactions include the fungi *Endothia parasitica* (Murrill) and *Ceratocystis fagacearum* (Bretz) (Dunbar and Stephens 1976) and at least six species of secondary borers (Cote and Allen 1980).

Injury and damage. Attacks usually begin in the upper branches of the crown and progress downward as the tree weakens (Solomon and others 1987). Feeding larvae excavate zigzag or meandering mines in the inner bark and on the surface of the main trunk (figure 83C and D) and larger branches (Dunbar and Stephens 1976). Principal injury results from larvae feeding in phloem and cambium. When translocation is interrupted as a result of larval feeding in the cambium, sudden wilting and browning of foliage in the tree tops occur. D-shaped emergence holes in the bark of weakened and dying trees provide good evidence of infestation (figure 83E). Weakened trees usually die (figure 83F) during the season of initial attack, but most healthy trees that are infested take 1 to 3 years to die (Dunbar and Stephens 1974). Population densities up to 73 larvae per square meter in dying trees have been measured. Red and white oaks throughout the eastern United States are the principal economically important trees attacked. Trees stressed by drought, insect defoliation, or other factors are most susceptible (Dunn and others 1987). Feeding larvae destroy cambium and girdle the tree, causing extensive mortality in weakened stands (Solomon and others 1987). The insect can increase in numbers rapidly and bring about large-scale mortality. In some areas, as many as 75% of the infested trees may be killed. When weakened trees are scarce and the beetles numerous, healthy trees may be severely damaged.

Control. Insect parasites affecting populations include *Atanycolus simplex* Cresson, *Spathius simillimus* Ashmead, and *Trichogramma* sp. (Dunbar and Stephens 1976); *Phasgonophora sulcata* Westwood and *Wroughtonia ligator* (Say) (Cote and Allen 1980); and *Doryctes anatolikus* Marsh

(Marsh 1979). Predaceous insects reported are *Adelocera oculatus* LeConte and *Tenebrioides bimaculatus* (Melsheimer) (Dunbar and Stephens 1976), *Phyllobaenus* sp., *P. verticalis* (Say), and *T. corticalis* (Melsheimer) (Cote and Allen 1980). Birds prey on larvae, pupae, and adults. Large numbers of adults were recovered from the stomach of a wood thrush (Dunbar and Stephens 1976). The northern downy woodpecker and the eastern hairy woodpecker prey on prepupae and pupae, sometimes consuming up to three-fourths of local populations (Cote and Allen 1980). Host condition is a major factor regulating populations. Larvae in trees that die and dry too quickly may be unable to complete development, whereas those boring in vigorous hosts may be engulfed in new growth or phloem exudate (Dunbar and Stephens 1976). Good sanitation—cutting and using or burning infested and dying trees—helps to alleviate the problem. Fell-and-leave before mid-July will ensure high larval mortality (Haack and Benjamin 1980a). From mid-July through August, larvae can be killed by debarking felled trees. Afterwards, infested bark must be chipped, burned, or sprayed to kill larvae. Insecticides sometimes may be useful in managing populations (Haack and Benjamin 1980b).

Agrilus anxius Gory

bronze birch borer (figure 84)

Hosts. Birch. Principal hosts are paper and water birches but other species of birch, including yellow, gray, western paper, sweet, and horticultural cut-leaf weeping birches are also attacked (Carlson and Knight 1969, MacAloney 1968). Reported on beech and aspen, but the species attacking aspen is the related borer *A. granulatus liragus* Barter and Brown.

Range. Throughout the range of birches in Canada from Newfoundland to British Columbia and in the United States from Maine westward to Idaho and Washington and south to Missouri (Carlson and Knight 1969, MacAloney 1968).

Description. ***Adult.*** Slighty flattened, olive-black beetle, sometimes with faint coppery reflections (figure 84A). Females 7.7 to 11.3 mm long; males 6.5 to 9.8 mm. Males with greenish frons, females with copper bronze. ***Egg.*** Oval, flattened on two sides, and 1.3 to 1.5 mm long and 0.8 to 1.0 mm wide (figure 84B). Initially creamy white, but becomes yellowish before hatching (Barter 1957). ***Larva.*** All larval instars originally whitish, acquiring creamy or yellowish brown tint when feeding on discolored cambium. Ranges from 2.5 mm long when newly hatched to 38 mm at maturity. Larvae (figure 84C) with moderately wide second thoracic segment and flat ribbonlike abdominal segments (Barter 1957). ***Pupa.*** Creamy white, darkens during development (figure 84D) (MacAloney 1968).

Biology. Adults emerge late May to August, depending on seasonal temperatures and location. After feeding on foliage, adults may live 3 weeks (MacAloney 1968). Oviposition begins about 1 week after adults emerge. Females prefer to oviposit in bark crevices beneath loose pieces of outer bark. They lay eggs singly or in clusters of up to 14, and the eggs hatch in about 2 weeks

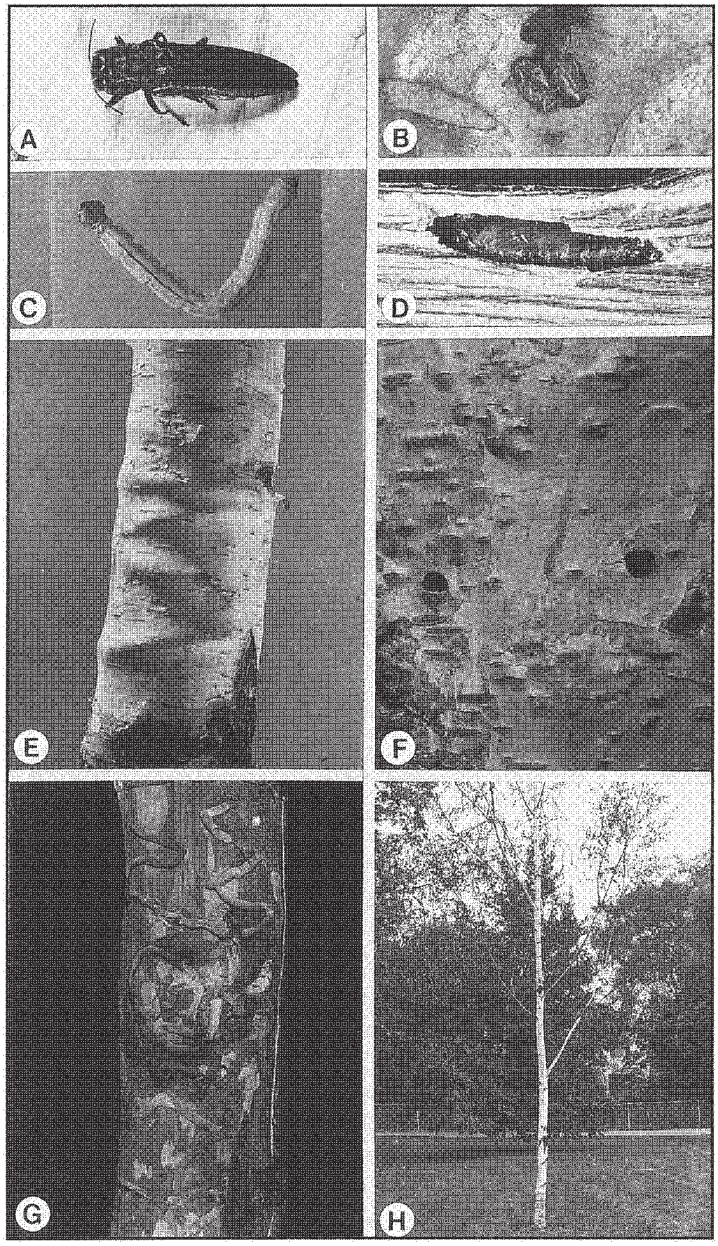

Figure 84—Agrilus anxius, *bronze birch borer: A, adult; B, eggs; C, larva; D, pupa in pupal chamber; E, swellings on bark; F, D-shaped emergence holes; G, galleries beneath bark; H, birch tree dying from borer attacks (A, B, D, courtesy D. Nielsen; C, E-H, courtesy W. Johnson).*

(Barter 1957). Newly hatched larvae begin chewing through the bark to the cambium, leaving the chorions of the eggs packed with fine frass. Larvae tunnel between the bark and wood, except for very short trips into the xylem. Larvae hibernate when the weather cools and, because of the long emergence, all larval stages may be present during hibernation (Barter 1957). The life cycle can be 1 or 2 years, depending on emergence date, host quality, climate, and geographic location. Pupation usually occurs during spring, but some occurs in summer (MacAloney 1968).

Injury and damage. Initially, this buprestid beetle typically attacks the crown, especially branches about 18 mm in diameter. Wilting and dying of the crown are often the first indications of attack. In subsequent years, attacks occur further downward into the bole (MacAloney 1968). Examination of infested limbs and branches may reveal ridges (figure 84E), bumps, and D-shaped adult emergence holes (figure 84F) in the bark. These holes may be surrounded by red-stained bark. Removal of the bark where ridges are abundant exposes the sawdust-packed galleries (figure 84G) (Heller 1979). Although repeated attacks often severely injure or kill trees (figure 84H), many survive, especially when growing conditions are good. In surviving trees, callus grows over the larval feeding tunnels. Healing results in many visible ridgelike swellings on the bark of previously infested trees (Barter 1957). Shade, ornamental, and forest trees are attacked. Damage results from girdling the cambium of branches and trunks and reduced translocation of food. The extent of damage is determined by number of borers and their distribution in the tree (Barter 1957). It is often considered a secondary insect pest, one that occurs after previous injury to trees (Anderson 1944), but apparently healthy trees can be attacked and killed (Balch and Prebble 1940, MacAloney 1968). Beginning in the early 1930's, widespread birch dieback occurred in Canada and the northeastern United States; trees that would have provided at least 1 million cords of wood were killed in Canada during 1939 alone (Brown 1940). Serious outbreaks of the bronze birch borer developed along with the dieback (MacAloney 1968).

Control. Nineteen species of insect parasites, including 6 species of egg parasites and 13 species of larval parasites, have been reported (Loerch and Cameron 1983). Egg parasitism has been the highest and most consistent cause of mortality, averaging 55% in New Brunswick (Barter 1957) but only 7% in Pennsylvania (Loerch and Cameron 1983). Larval parasitism generally averages under 20% (Barter 1957, Loerch and Cameron 1983). The importance of woodpeckers varies, but predation of 27 to 89% of the mature larvae and pupae has been reported (Barter 1957, Loerch and Cameron 1983). Cultural control practices include cutting of overmature and defective trees, preventing injuries to young trees, pruning infested parts of trees, and watering during dry periods (Mac-Aloney 1968). Insecticides can be used to protect valuable trees (Akers and Nielsen 1984, Barter 1957).

Agrilus horni Kerremans

[aspen root girdler] (figure 85)

Hosts. Poplar. Trembling aspen is the major host, but bigtooth aspen and balsam poplar are also commonly attacked (Carlson and Knight 1969). Aspen hybrids and the Eurasian species *Populus alba* L. and *P. tremula* L. are also readily infested (Carlson and Knight 1969, Nord and others 1965).

Range. Recorded from Massachusetts and New York in the Northeast; Wisconsin, Michigan, South Dakota, and Iowa in the Midwest; Arizona in the Southwest; and southern Ontario and Aweme, Manitoba, to the north (Carlson and Knight 1969, Nord and others 1965).

Description. ***Adult.*** Slightly flattened, black beetle, 6.5 to 11.5 mm long, with green reflections giving it bronze or coppery appearance (figure 85A). Females slightly larger than males. Taxonomically similar to *A. anxius* Gory and *A. granulatus liragus* Barter and Brown, but can be reliably distinguished by shorter male genitalia and shorter ovipositors (Carlson and Knight 1969). Also, beetles with more dense pubescence on lateral abdominal sclerites, more uniform pubescence on elytra, and front of head more convex than similar species. ***Egg.*** Creamy white, flattened and oval in outline, 1.2 mm long and 0.8 mm wide. Egg chorions darken as embryos develop, a characteristic not noted in *A. anxius* and *A. granulatus liragus* (Carlson and Knight 1969). ***Larva.*** White except for black mandibles, brownish anal forceps, and 25 mm long at maturity (figure 85B). ***Pupa.*** Creamy white and darkens with age within pupal chamber (figure 85C).

Biology. Adults are present in May and June, and emergence varies with weather. Beetles feed on leaves about 3 weeks before oviposition begins. Eggs are deposited over several weeks at the base of host plants, usually within 3 cm of the ground. Eggs are laid singly or in small groups on the smooth bark surface of small stems especially in aspen sucker stands. They hatch after 2 weeks, and the larvae tunnel into the cortex of the lower stem and then straight down into a large lateral root where they burrow outward in a generally straight line for 20 to 50 cm. They move to the cambium-xylem interface, turn and tunnel back toward the main stem, encircling the root with a tight spiral gallery. This part of the gallery is flattened in cross section and filled with tightly packed fine granular frass. On reaching the stem, the larvae continue the tightly spiraled gallery for 5 to 25 cm above ground. They then bore to the center of the stem and form pupal chambers. When the chambers are complete, larvae bore exit tunnels to the outer layers of bark and then return to the pupal chambers, where they overwinter. Although the duration of development is unknown, the total gallery lengths and extended oviposition periods suggest a 2-year life cycle (Nord and others 1965).

Injury and damage. Young trees in aspen sucker stands with stem diameters of less than 18 mm appear most susceptible to attack (Nord and others 1965). Most trees attacked are 12 mm or less in diameter. Attacks occur in the lower stem

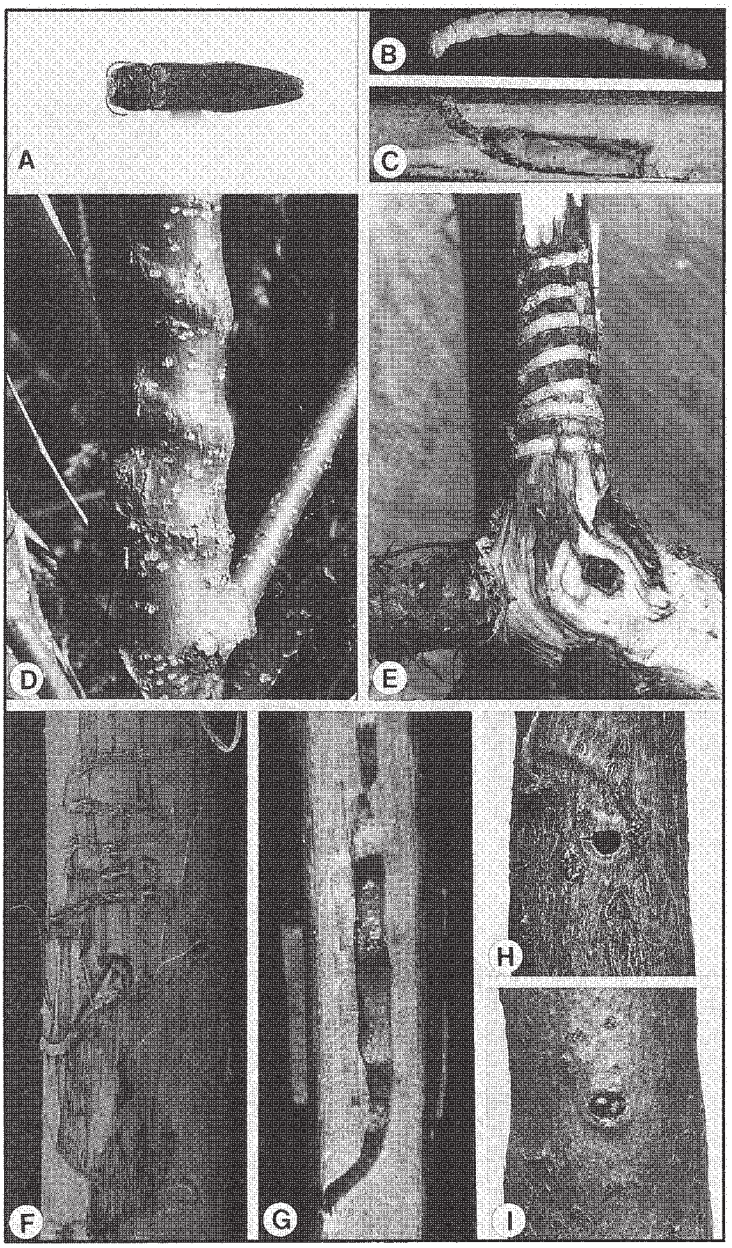

Figure 85—Agrilus horni, *[aspen root girdler]: A, adult; B, larva; C, pupa; D, spiral swellings on bark; E, spiral galleries; F, sinuate galleries on large stem; G, pupation chamber with larva; H, D-shaped exit hole; I, bark scar over exit hole (A, F-I, courtesy E. Hart; B, C, E, courtesy J. Nord; D, courtesy M. Ostry).*

and roots. Weakened, dying, and dead sprouts and young planted stock may be the most noticeable signs of infestation. Examination of affected plants reveals swellings that typically spiral around the lower stems (figure 85D). Removing bark exposes the flattened, spiral, frass-packed galleries on the surface of the wood (figure 85E). Some galleries meander back and forth besides spiraling around the stems and roots (figure 85F). Enlarged pupal chambers can be found in the stem centers by splitting infested stems (figure 85G). D-shaped emergence holes (figure 85H) are present in the bark and heal to form slightly oval bark scars (figure 85I). Roots and stems of young, apparently healthy aspen suckers are often heavily attacked. Suckers may be killed, but rates of mortality vary depending on the extent of infestation. The insect can survive in weakened or vigorous suckers. A damage survey in 4-year-old quaking aspen stands showed that 4% of the aspen suckers in the sampled areas had been killed by the borer. Damage is generally insignificant, maybe even helpful, in dense natural stands. However, this insect can be economically damaging in sparsely stocked natural stands, in test plantings, and in commercial plantations on dry sandy sites with few trees per hectare (Nord and others 1965).

Control. Natural egg mortality is high (Nord and others 1965). Some eggs darken, indicative of parasitism, but no egg parasites have been reared. Other eggs simply shrivel and disappear, possibly because of infertility or ant predation. Seven species of insect parasites have been recovered from mature larvae—including *Cenocolius sanguineiventrus* (Ashmead), *Mastrus smithii* (Packard), *Metastenus* sp., *Tetrastichus nordi* Burks, *Xylophrurus agrili* (Viereck), *X. bicolor maurus* Townes, and *X. fasciatus fasciatus* (Ashmead) (Burks 1979, Carlson 1979, Marsh 1979, Nord and others 1965). In a study of 140 infested aspen suckers collected at each of 2 locations, *T. nordi* parasitized 26 and 33% of the larvae, and *Xylophrurus* spp. parasitized 11 and 5%.

Agrilus granulatus granulatus (Say)

[granulate poplar borer] (figure 86)

Hosts. Poplar. Reared from Lombardy poplar, eastern cottonwood, and black cottonwood (Fisher 1928, Mutchler and Weiss 1922).

Range. The Great Plains eastward to New York, south to North Carolina and Louisiana, and west to Colorado and Montana (Carlson and Knight 1969, Fisher 1928). In Canada, common in both native and planted poplars, particularly in the grassland and southern regions of Alberta (Brown and Stevenson 1965).

Description. ***Adult.*** Slightly flattened, olive brown beetle, moderately shining, narrow, and 7 to 11 mm long (figure 86A) (Fisher 1928). Males slightly shorter and more slender than females. Body covered with short, recumbent, whitish pubescence. Each elytron ornamented with three spots of more dense whitish to golden hairs, one in basal depression, one in front of middle, and other near apical fourth. In living beetles, these spots distinguish this species

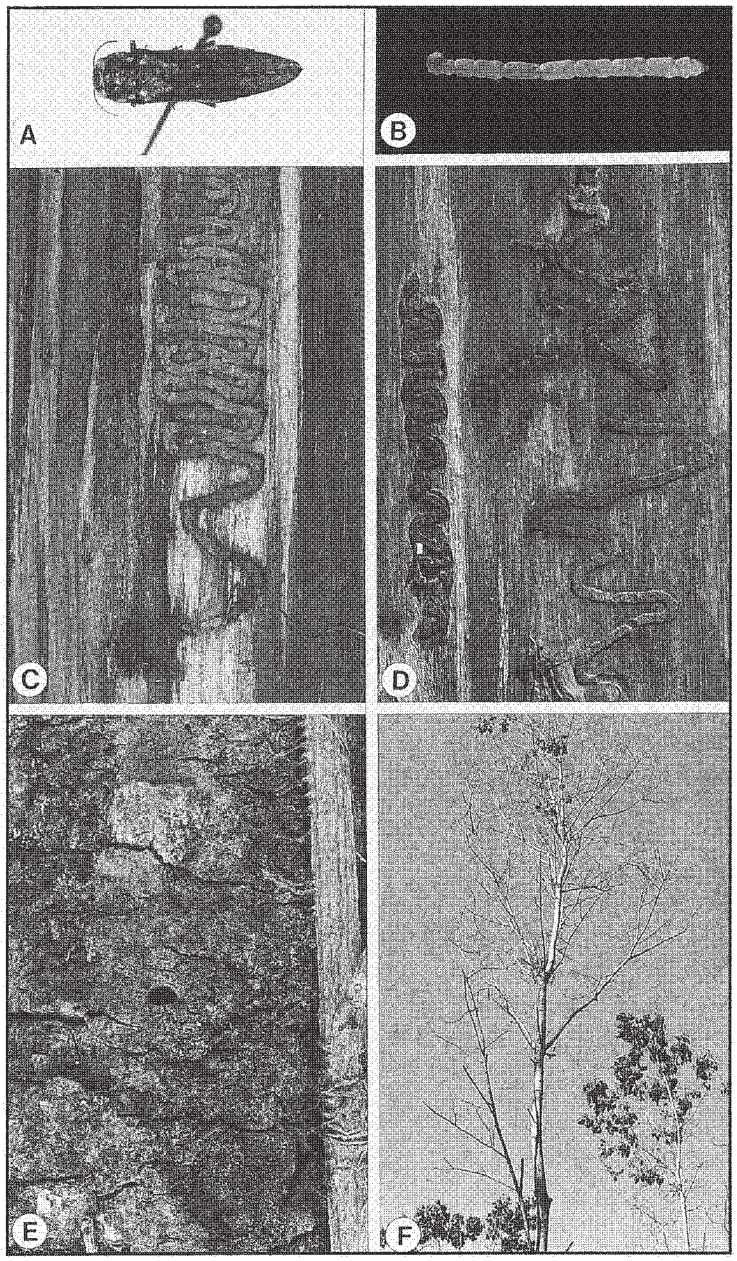

Figure 86—Agrilus granulatus granulatus, *[granulate poplar borer]: A, adult; B, larva; C, single gallery with tight loops; D, multiple meandering galleries; E, D-shaped emergence hole; F, tree dying from larval girdling (A, specimen courtesy D. Whitehead).*

from *A. g. liragus* Barter and Brown (Carlson and Knight 1969, Fisher 1928). ***Larva.*** Elongate, very narrow, and 27 to 40 mm long (figure 86B). Body flattened with widened prothorax, white except for brown mouthparts and anal forceps.

Biology. Adults emerge during June and July (Mutchler and Weiss 1922, Packard 1890) and feed on the foliage of host trees. Females deposit eggs in crevices of rough bark on branches and trunks of susceptible trees. They prefer trees severely weakened by drought, disease, and poor site conditions (Ives and Wong 1988). In the beetle's southern range, populations are most prevalent in river bottoms at lower altitudes. Larvae usually feed and develop beneath the bark but occasionally tunnel into the wood briefly, then back to the cambium. In October, larvae bore obliquely into the wood 2.5 to 5 cm, a few centimeters up or down, then curving back to within 3 to 8 mm of the wood surface. Here, they enlarge the galleries and overwinter in a folded or bent position. Pupation begins in May and lasts about 2 weeks. The life history is little known, but it appears to have a 1- or 2-year generation similar to that of *A. g. liragus*.

Injury and damage. Thin crowns and dying branches are early symptoms of attack. Trees from sapling to sawlog size may be attacked. Although sap spots occasionally appear on the bark, little other surface damage indicates early infestation. Extensive galleries can be exposed by removing bark. Galleries in the cambium vary from very tight zigzag loops extending vertically (figure 86C) to those that meander without much pattern (figure 86D) (Mutchler and Weiss 1922). Small D-shaped holes are left in the bark by emerging beetles (figure 86E). Infested trees may succumb suddenly or slowly over several years, depending on other stresses (figure 86F). The deaths of many trees previously attributed to drought are now charged to this borer (Brown and Stevenson 1965, Packard 1890).

Control. Woodpeckers have been observed feeding on the larvae, but their effectiveness has not been evaluated. Good cultural practices that promote high tree vigor and reduce the incidence of disease help to minimize infestations and losses.

Agrilus granulatus liragus Barter and Brown

bronze poplar borer (figure 87)

Hosts. Poplar. Five species of poplars—including quaking aspen, bigtooth aspen, balsam poplar, black cottonwood, and eastern cottonwood—are reported as hosts (Barter 1965).

Range. Newfoundland west to British Columbia; also found in the United States southward to Pennsylvania and westward to northern California and Oregon (Barter and Brown 1949, Nelson and Westcott 1976).

Description. ***Adult.*** Beetle that is structurally similar to *A. g. granulatus* but described as distinct subspecies based on color, morphology of male genitalia, and preferred host plants (Barter and Brown 1949, Carlson and Knight 1969). Slightly flattened beetle blackish with green reflections (figure 87A). Male head greenish. As

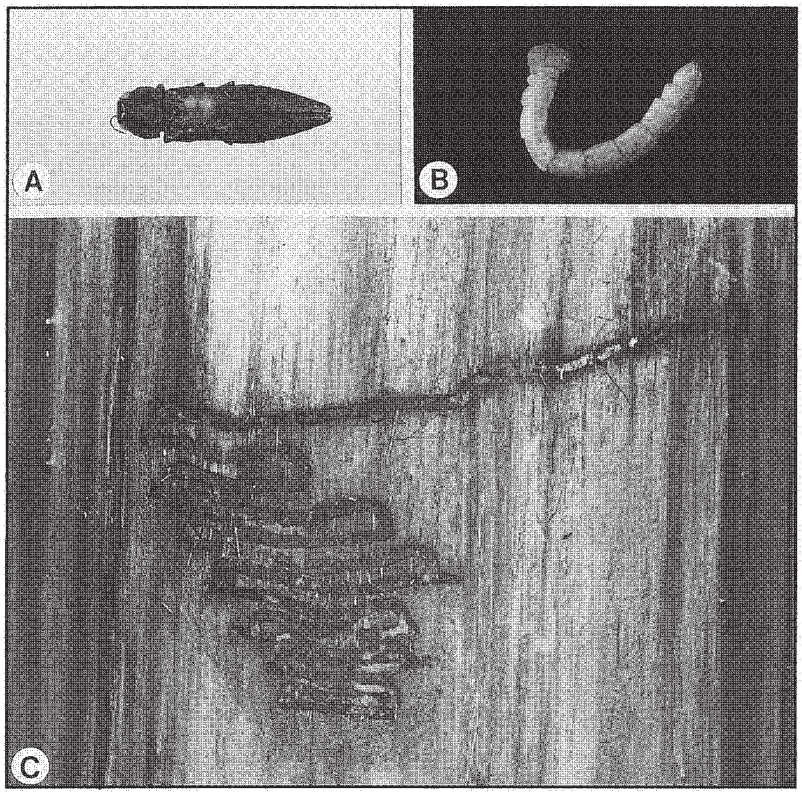

Figure 87—Agrilus granulatus liragus, *bronze poplar borer: A, adult; B, larva; C, single gallery beneath bark (A, specimen courtesy R. L. Brown).*

compared to *A. anxius*, coppery reflections nearly always lacking and never distinct. Male adults 7.2 to 10.3 mm long; females 6.8 to 11.5 mm long. ***Egg.*** Creamy white, flattened, oval, and about 1.2 by 0.8 mm (Carlson and Knight 1969). ***Larva.*** Long and slender—measuring 30 to 40 mm long and 2 to 3.5 mm wide (figure 87B). Prothorax wider than rest of body with median I-shaped line (Benoit 1965). Body white except for dark mandibles and prominent brown anal forceps.

Biology. In Canada, adults emerge from early June to late August (Barter 1965, Ives and Wong 1988). Emergence may begin earlier or later, with a corresponding change in its end, depending on prevailing environmental conditions. Adults feed on foliage of hosts for about 1 week before laying eggs. They deposit eggs in bark crevices in groups of five to eight. Each female deposits several groups of eggs, most frequently on the sunny side of trees when the temperature is about 27 °C (Barter 1965). Hatching from eggs in about 2 weeks, larvae bore directly through the bark to the cambium for most of their feeding, moving occasionally into the phloem and cortex. First-instar larvae travel about 8 to 16 cm before molting. Later instars travel much farther. Generally, larvae bore into the xylem to molt; a completed tunnel shows four such departures from the regular feeding tunnel, suggesting five larval instars. Mature larvae make pupal cells, and pupation occurs either in the outer xylem or in thick bark in spring. Borers in severely weakened trees usually complete a generation in 1 year, particularly in their southern range; those in more vigorous hosts require 2 years to complete development, especially in their northern range (Carlson and Knight 1969).

Injury and damage. Foliage discolors and leaves drop in portions of the crown after the initial attack (Barter 1965). Branch mortality soon becomes noticeable. Successful infestations in weakened trees typically move downward on the bole and often girdle and kill the tree. Removing the bark from affected branches or trunks reveals the larval feeding galleries in the cambium. Flattened galleries packed with frass range from 30 to 60 cm long and 0.6 to 3.0 mm wide (figure 87C). Gallery characteristics vary with condition of the host (Carlson and Knight 1969). In severely weakened trees, galleries usually meander without any distinct pattern. In vigorous hosts, a zigzag or sinuate gallery is the rule. Galleries weave back and forth across the grain with successive loops closer together in the most vigorous hosts. Emerging beetles leave D-shaped emergence holes in the bark (Ives and Wong 1988). Attacks on the branches and trunks of trees cause deterioration and frequently death of the hosts. Larval feeding damages the phloem and cambium, interfering with the movement of plant food (Barter 1965). The insect is most likely to become established in overmature or injured trees and in young trees released from the dominance of other trees. Felled, topped, and girdled trees and those damaged by the poplar borer (*Saperda calcarata* Say) and hypoxylon canker are particularly suscepti-

ble (USDA FS 1985). Evidence exists that infestation by this borer increases the incidence of hypoxylon canker (Barter 1965).

Control. Both egg and larval parasites have been reared. In one study, two egg parasites—*Coccidencyrtus* sp. and *Thysanus* sp. in the family Encyrtidae—destroyed about half the eggs. Five species of insect parasites—*Atanycolus charus* (Riley), *Doryctes* sp., *Ephialtes* sp., *Phasgonophora sulcata* Westwood, and *Testrastichus* sp. (probably *rugglesi* Rohwer)—were reared from the larvae. Range of from 2 to 20% parasitism by *P. sulcata* was most common (Barter 1965). Larvae and pupae are frequently prey of woodpeckers. In one study of standing trees, when larvae were pupating and transforming to adults in late spring, woodpeckers took up to 40% of full-grown larvae, pupae, and teneral adults from individual trees (Barter 1965). Maintenance of high tree vigor helps to reduce the incidence of attack. Because susceptibility to the borer is enhanced by injuries caused by other insects, wind, animals, and fungi, measures that prevent such injuries can reduce attacks and their severity (Barter 1965).

Agrilus granulatus populi Fisher

[western poplar agrilus]

Hosts. Poplar. Although black cottonwood is the main host (Fisher 1928), adults have been collected on Lombardy poplar, and other *Populus* species may also serve as hosts.

Range. Occurs from California and Oregon east to Montana and Wyoming and north to British Columbia (Barr 1971, Fisher 1928).

Description. ***Adult.*** Moderately robust, strongly shining, and slightly flattened beetle (Fisher 1928). Head green becoming slightly coppery toward neck. Pronotum bronzy green, sometimes with brownish copper tinge. Elytra vary from golden green to reddish copper, sometimes with distinct violet tinge. Each elytron ornamented with three small pubescent spots. Color beneath bronzy green. Beetles 7.5 to 9.8 mm long and 1.8 to 2.5 mm wide.

Biology. Adults are active May to July (Fisher 1928). Larvae bore beneath the bark where they burrow, feed, and develop. This species, similar in habits to the closely related subspecies *A. g. granulatus*, is found mostly in river bottomlands at lower altitudes (Carlson and Knight 1969).

Injury and damage. Weakened and dying trees should be examined for infestation. Removing the bark reveals the frass-packed meandering mines and larvae. Damage has been negligible, except in the Reno, Nevada, area. Little else is known of this insect's importance.

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

Agrilus criddlei Frost

[willow gall agrilus] (figure 88)

Hosts. Willow. Willows are the only known hosts (Stein and Kennedy 1972).

Range. A northern species recorded from the northern Great Plains as well as

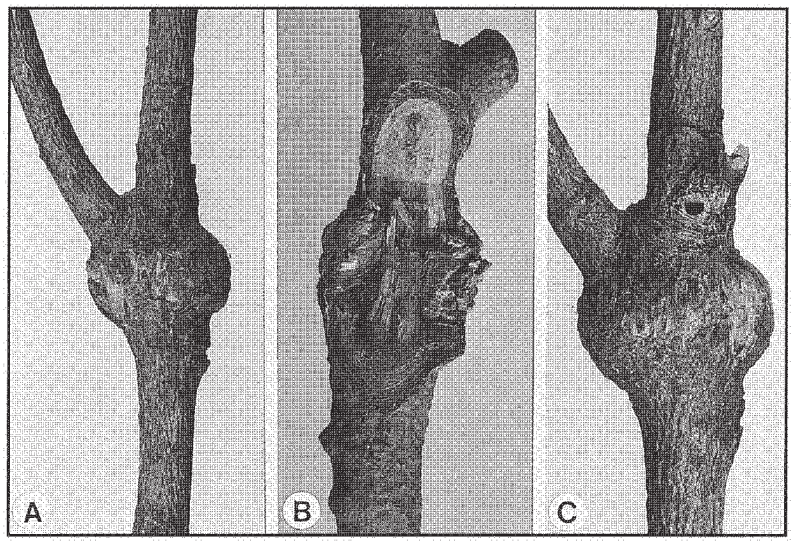

Figure 88—Agrilus criddlei, *[willow gall agrilus]: A, gall on willow stem; B, gall opened to expose larval mines; C, D-shaped exit hole just above gall (specimens courtesy S. Wellso).*

Michigan, Quebec, Ontario, and Manitoba (Chamberlin 1926, Fisher 1928, Stein and Kennedy 1972).

Description. ***Adult.*** Rather robust, moderately shiny, slightly flattened beetle 6.5 to 9.0 mm long. Females slightly more robust than males. Beetles bronzy black with slightly bluish or coppery reflection. Antennae serrated beginning with fourth segment and extend beyond middle of pronotum in males and only to middle of pronotum in females (Fisher 1928, Wellso and others 1976).

Biology. Adults emerge in June (Stein and Kennedy 1972). Females oviposit on 1-year-old or older woody branches. Larvae burrow into the branches and make serpentine mines. Feeding larvae pack their mines with fine granular frass. Galls develop at feeding injuries and gradually encircle the branches. New adults make exit holes in or near the galls.

Injury and damage. Branch galls in the crowns (figure 88A) 5 cm or less in diameter provide good visible evidence of infestation (Stein and Kennedy 1972). Galls often split on one or more sides, exposing galleries (figure 88B) and underlying tissues (Wellso and others 1976). A D-shaped emergence hole may be found in the vicinity of each gall (figure 88C). Galled branches frequently die back. Infestations are widely scattered; thus, damage is of minor importance.

Control. One hymenopterous parasite—*Euderus chillcotti* Yoshimoto—has been reported (Burks 1979). Direct controls have not been needed.

Agrilus politus (Say)

[common willow agrilus]

Hosts. Willow, maple. Preferred hosts are arroyo willow, Scouler willow, Pacific willow, and weeping willow (Burke 1917b, Chamberlin 1926, Fisher 1928). Rocky Mountain maple, striped maple, and dwarf maple also are hosts. California buckeye, coast live oak, hawthorn, honeylocust, hazel, and alder are mentioned as hosts (Chamberlin 1926, Fisher 1928, Mutchler and Weiss 1922), but these hosts were probably attacked by closely related *Agrilus* species.

Range. Throughout the United States and southern Canada (Doane and others 1936, Fisher 1928).

Description. ***Adult.*** Elongate, slightly flattened beetle, 5.0 to 8.5 mm long (Blatchley 1910, Fisher 1928). Bright brassy to coppery, purplish, greenish, or bluish and moderately shiny. Antennae barely reach middle of pronotum. Pronotum wider than long, and sides curved slightly outward. Elytra wider than base of pronotum, widen slightly behind middle, then taper obliquely to narrowly rounded tips with finely toothed margins. Wing covers somewhat separated at tips, giving an almost forked appearance. ***Egg.*** Almost transparent white, shiny, and oval with soft shell. ***Larva.*** Pale white, greatly elongate, and flattened.

Biology. Adults emerge from May through August and feed on the foliage of host plants before ovipositing (Essig 1958). Eggs are deposited in flattened, circular masses of 2 to 12 on the smooth bark of branches near the axils of shoots or near

bark lenticels. Females cover eggs with a protective secretion that hardens into a brown capsulelike cover; these appear as conspicuous scalelike objects on the branches. After incubation of about 3 weeks, new larvae bore through the egg shells into the bark and fill the vacated eggs with frass. Groups of larvae often burrow side by side in the same direction on the surface of the wood, lengthwise along the twig for 7 to 10 mm; then larvae branch out, forming galleries that circumscribe the branch and eventually girdle it. The girdling by larval galleries stimulates abnormal growth, resulting in knotty swellings or galls and cracking the outer bark, eventually killing the branch. The larvae construct pupal cells deep in the wood of trunks and branches from May to mid-June. There is a 1-year life cycle in the southern portion of its range and a 2-year life cycle in the northern portion (Burke 1917b).

Injury and damage. Branch dieback and tree mortality are symptoms of attack (Doane and others 1936). Larvae mine the inner bark and wood of normal, injured, and dying trees and shrubs (Burke 1917b). Removal of bark will reveal many flat, frass-filled larval galleries that often encircle and girdle stems. Attacks often result in swollen areas and gall-like growths on the branches and trunk (Burke 1917b). Good evidence of infestation is D-shaped holes in the bark made by emerging beetles. Trees that are attacked repeatedly and survive often develop bark scars that detract from their esthetic value.

Control. This beetle can be controlled by cutting and destroying infested branches before leaf emergence in spring (Hutchings 1923). Insecticides may be needed to protect valuable trees.

Agrilus burkei Fisher

[blue alder agrilus] (figure 89)

Hosts. Alder. White alder is preferred,* but the insect also has been reared from mountain alder (Burke 1917b, Fisher 1928). Other alders probably serve as hosts.

Range. A western species occurring from California* east through the Rocky Mountains to Wyoming and north to British Columbia (Fisher 1928, Maser and Beer 1971).

Description. ***Adult.*** Elongate beetle, strongly attenuate posteriorly, slightly flattened, deep blue to bluish green, moderately shiny, and 6 to 9 mm long and 1.8 to 2.5 mm wide (figure 89A) (Fisher 1928). Pronotum markedly wider than long and widest at middle. Elytra slightly wider than pronotum at base and sparsely clothed with very short whitish pubescence. Beetles resemble *A. politus* but usually darker blue and less shiny. ***Egg.*** Whitish, oval to round, flattened, and scalelike (figure 89B). ***Larva.*** Slender, flattened, whitish, and 20 to 25 mm long (figure 89C).

Biology. Adults begin emerging during late March in California* and have been collected as late as July 9 in Oregon (Fisher 1928). New adults feed on the foliage of host trees for a week or more, mate, and oviposit on the bark of trunks and branches. Females deposit 3 to 10 eggs in masses

*Koehler, C.S.; Svihra, P. December 16, 1988. (personal communication). University of California, Berkeley, CA.

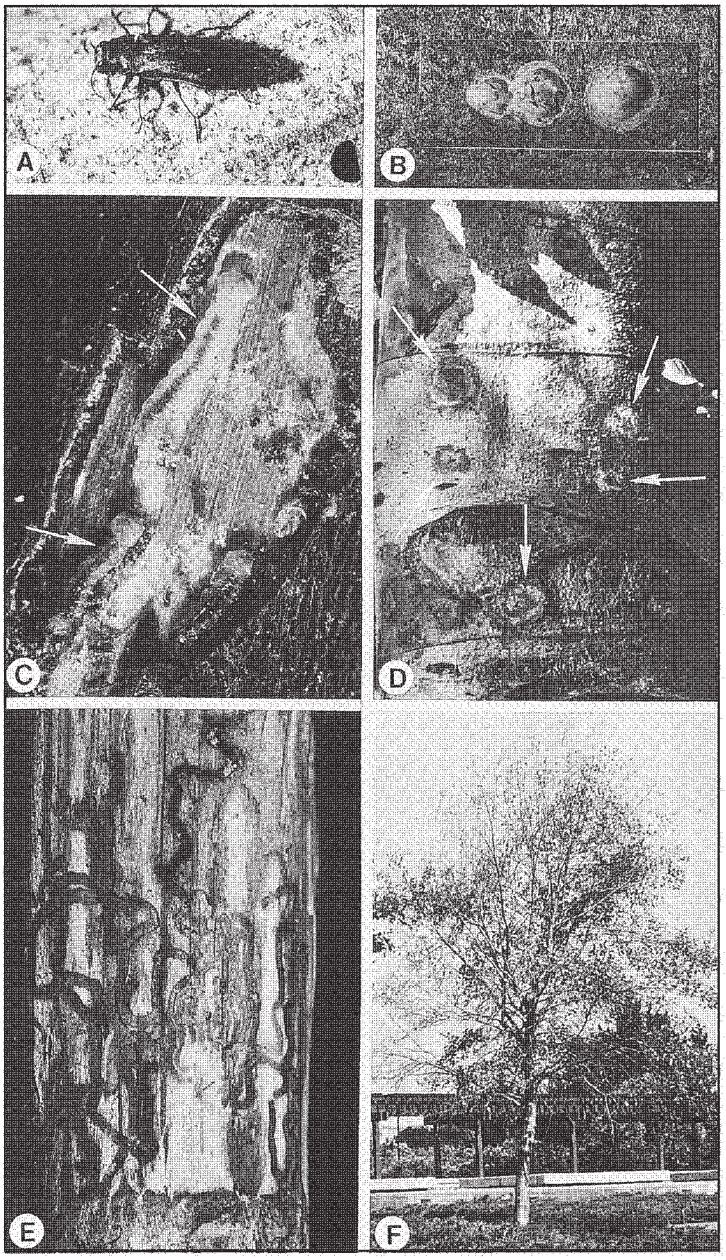

Figure 89—Agrilus burkei, *[blue alder agrilus]: A, adult and D-shaped exit hole; B, eggs; C, larvae under bark; D, sap-stained spots at points of attack; E, galleries under bark; F, dying infested alder (courtesy C. Koehler).*

3 to 5 mm in diameter. Eggs usually are deposited on moderately to severely stressed trees; few eggs are laid on trees that are in either very poor or very good condition. Adults live about 12 days. Eggs hatch in 1 to 2 weeks, and the young larvae burrow through the bottom of the egg chorions into the bark. Larvae feed beneath the bark in the cambium where they make long winding galleries. Larvae overwinter in their burrows, then pupate in spring in enlarged chambers at the end of their galleries. There is one generation per year.

Injury and damage. Most noticeable symptoms are yellowing, wilting foliage, and dieback of branches. Closer examination reveals copious sap exuding from infested sites, which prominently stains the bark (figure 89D). Callus growth at injured sites beneath the bark sometimes causes light-colored blisters, ridging, and swellings similar to those caused by *A. anxius*. Removing bark will reveal the white larvae and numerous long, winding, frass-filled galleries that often intersect and cross many times (figure 89E). Many D-shaped emergence holes are left in the bark by emerging beetles (figure 89A). Heavy infestations can girdle and kill susceptible trees; those that survive may be heavily scarred. Many infested small trees succumb (figure 89F). In 1978, reports of decline of white alder in Napa County, California, were common (Koehler 1985). Two years later, this insect killed native alders in a disturbed riparian zone in Del Norte County. Since about 1980, white alder has been propagated in nurseries and then outplanted to dry California landscapes. Here, the trees are stressed and have suffered greatly from attacks.

Control. This borer prefers stressed trees, so practices that help keep trees in good vigor are recommended. Young trees, especially those newly transplanted, should be shaded to prevent sunscald, which often predisposes them to attack. In lightly infested trees, attacked branches can be pruned out and burned (Burke 1917b). In high-risk areas, resistant species, such as new varieties of Italian alder, should be planted (Koehler 1985). Insecticides may be required to protect high-value trees.

Agrilus pensus Horn

[alder-birch borer] (figure 90)

Hosts. Alder, birch. Reared from speckled alder and river birch, both serving equally well as larval hosts (Carlson and Knight 1969).

Range. Occurs from New Brunswick south to North Carolina and west to Michigan and southern Manitoba, Canada (Carlson and Knight 1969).

Description. ***Adult.*** Long slender beetle with slightly flattened body about 7.5 mm long and 2 mm wide. Pronotum wider than long and lateral margins rounded slightly outward. Elytra about as wide as posterior margin of pronotum. Sides of elytra nearly parallel to just past middle, then taper obliquely toward their narrowly rounded tips. Tips separated and margined with fine teeth. Eyes large and widely separated. Antennae, serrate from fourth segment, extend to about middle of pronotum.

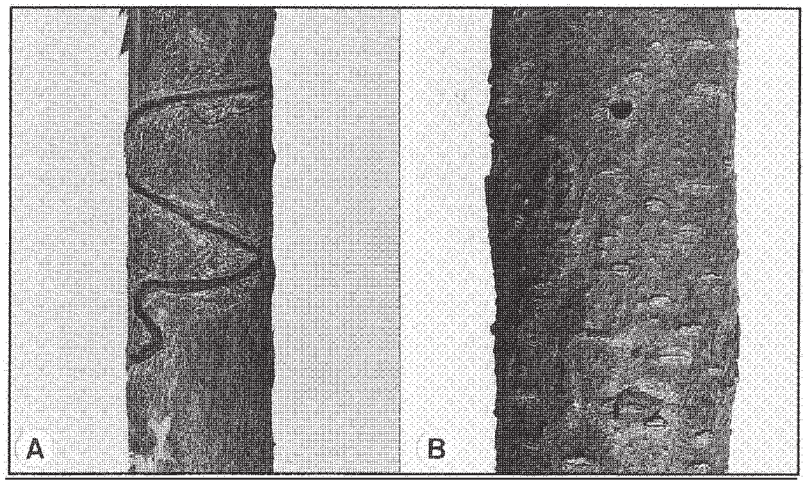

Figure 90—Agrilus pensus, *[alder-birch borer]: A, sinuate gallery beneath bark; B, D-shaped hole made by emerging adult (specimens courtesy S. Wellso).*

Dorsal surface of body feebly shining. Head bronze green, pronotum and elytra dark reddish copper (sometimes with a blackish green tinge), and underside of body reddish copper. Tarsal claws of both sexes cleft near apices (Fisher 1928). ***Egg.*** Creamy white when deposited, flattened and oval, measuring about 1.2 by 0.8 mm (Carlson and Knight 1969). ***Larva.*** Whitish, elongate, legless, and pronotum noticeably wider than other body segments. Thoracic and abdominal spiracles C-shaped. Abdomen ends in chitinous forcep-like structure (Carlson and Knight 1969).

Biology. Pupation has been recorded as early as April (Fisher 1928), with adults emerging in May and June (Carlson and Knight 1969) in the eastern United States. Adults do not emerge until July and August in Nova Scotia (Chamberlin 1926). Females deposit eggs on the bark of healthy to moderately stressed hosts but never on trees where death is imminent. These insects seldom occur in large populations that quickly girdle host trees, unlike related *Agrilus* spp. After embryonic development ends in about 2 weeks, larvae bore into the bark, packing the chorions with frass, and leaving little or no external evidence of infestation. Little is known about the behavior of larvae except that they spend much of their early lives in the xylem (Carlson and Knight 1969). Mortality rates of young larvae are high owing to the resistance offered by vigorous trees. Larvae pupate in the xylem fairly near the surface, and adults emerge directly through the bark. Two years are required to complete development.

Injury and damage. It is often difficult to distinguish infested speckled alders from uninfested ones (Carlson and Knight 1969). Although healthy trees may be attacked, those showing some physiological stress are better candidates. The beetle is more likely to attack alders in a healthier condition than those attacked by most other *Agrilus* species, yet it presumably infests unhealthy river birch (Carlson and Knight 1969). When infestation is suspected, one can readily peel back the bark with a sharp knife to expose galleries and larvae. Galleries are always packed with fine frass and follow no pattern; however, those on the surface of the wood are often sinuate (figure 90A). Galleries seldom spiral around the branch, even on those as small as 25 mm in diameter. They frequently penetrate deep into the xylem, sometimes going completely through the stem to the opposite side. Emerging adults make D-shaped holes (figure 90B). Although populations are seldom as high as those of many other *Agrilus* species, this borer appears to play more of a primary role in killing trees than its near relatives.

Control. Woodpeckers are important in limiting populations, feeding mainly on larvae they find in pupal chambers during winter. On finding one specimen, they will then efficiently find and eat nearly all larvae in the tree (Carlson and Knight 1969).

Agrilus acutipennis Mannerheim

[spotworm borer] (figure 91)

Hosts. Oak. White and overcup oaks are specific hosts (Donley and others 1974,

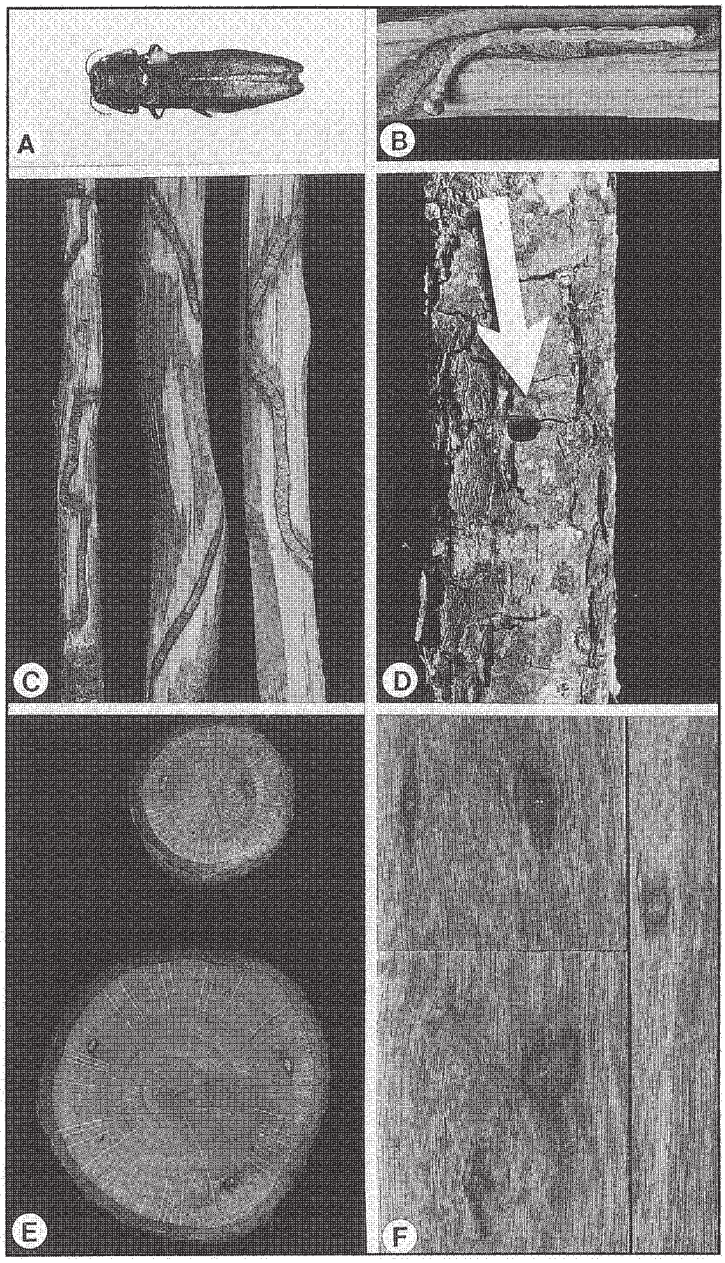

Figure 91—Agrilus acutipennis, *[spotworm borer]: A, adult; B, larva; C, galleries on surface of sapwood; D, D-shaped exit hole; E, cross section of overcup oak showing flattened oval galleries; F, stained spots with galleries in white oak lumber.*

Morris 1964). Other white oaks probably also serve as hosts. Adults have been collected from the foliage of birch, poplar, and hazelnut, but it is doubtful that they are larval hosts (Fisher 1928).

Range. Widely distributed from Maine south to Florida and west to Texas and Colorado (Fisher 1928, Mutchler and Weiss 1922). Also reported from Ontario, Quebec, and Newfoundland.

Description. ***Adult.*** Slender to moderately robust beetle, slightly flattened (figure 91A) (Fisher 1928). Feebly shining, dark blue to black with less distinct greenish tinge. Antennae extend to about middle of pronotum on male; slightly shorter on female. Adults 7.5 to 12.7 mm long. ***Larva.*** Slender, white, and extremely elongate, ranging from 25.4 to 33.0 mm (figure 91B) (Morris 1964). Body noticeably flattened, with prothorax slightly wider than body.

Biology. Adults emerge in May and June and sometimes through July (Chittenden 1900b, Morris 1964). Females deposit eggs in bark crevices on host trees (Morris 1964). Larvae bore through the bark and excavate patches of the inner bark about 13 mm in diameter. They soon enter the cambium and tunnel spirally, primarily in the outermost growth ring. Gallery lengths have not been measured adequately, but individual galleries are at least 1 m or more in saplings and small trees. Larvae pupate in enlarged chambers in the tunnels, and new adults emerge in late spring and early summer. A generation requires 2 years.

Injury and damage. Trees growing on river bottomlands subjected to backwater flooding from December through June are most apt to be infested. Larvae cause injuries by tunneling the outermost growth ring of the sapwood (Morris 1964). By cutting away the bark of infested saplings, one can observe larval feeding sites. Galleries are long, crooked (occasionally spiralling around the stem), flattened, and packed tightly with frass (figure 91C). Adults leave small D-shaped emergence holes in the bark (figure 91D), but there is little other evidence of infestation on the bark surface. Ends of fresh-cut logs usually show irregular lines of stained wood where the spots are exposed. On large sawlogs, the stains resemble scribbled handwriting on log ends, and woodsmen read them as a sign of infestation and poor-quality wood. Cross sections of small stems may reveal tiny frass-packed galleries surrounded by dark stain (figure 91E). In sawn lumber, spotworm damage is characterized by dark stains, oval to diamond or spindle shaped in cross section and about 25.4 to 43.2 mm long with a 1.5-mm frass-packed hole in the center of the stain (figure 91F). Larvae tunnel the outer sapwood of host trees, leaving defects called "grease spots" or "worm spots." Lumber with heavy spotworm defect is graded as Sound Wormy or No. 3A Common, which is worth about $60 less per thousand board feet than lumber without the defect (Morris 1964). Defect has been reported as particularly prevalent in overcup oak from river bottoms of the lower Ouachita, White, Arkansas, Alabama,

and Pearl Rivers and in smaller river bottomlands in Alabama, Arkansas, Louisiana, and Mississippi. Lumber degraded by spotworm defects has been suggested for use as character-marked paneling that could help lumbermen recover some of the losses from degrade (Solomon 1986).

Control. Evidence of woodpecker predation has been observed, but no other natural controls have been recorded. Direct controls have not been investigated.

Agrilus angelicus Horn

[oak twig girdler] (figure 92)

Hosts. Oak. Prefers coast live oak (Johnson and Lyon 1988). Other hosts include California black oak, canyon live oak, Engelmann oak, interior live oak, and several introduced oaks (Burke 1920).

Range. Throughout most of California from sea level to 1,800 m elevation (Burke 1920).

Description. ***Adult.*** Slender, brownish bronze to bluish black beetle with coppery or golden thorax; 5 to 7 mm long and 1.5 to 2.0 mm wide (figure 92A). Males with their green faces can be distinguished from the brownish-bronze-faced females. ***Egg.*** Slightly more than 1 mm in diameter, flattened; darkens before hatching. Covered with sticky, varnishlike material that catches dust and makes it difficult to see on twig bark (Brown and Eads 1965a, Burke 1920). ***Larva.*** Legless, whitish, moderately flattened, and 18 to 25 mm at maturity (figure 92B) (Brown and Eads 1965a). Prothorax widest part of body with head sunken into it. At times, larva resembles minute string of flattened link sausages (Miller and others 1950). ***Pupa.*** Delicate, whitish, and about 7 to 9 mm by 1 to 2 mm (figure 92C) (Burke 1920).

Biology. Adults emerge from May to September, with most appearing during the first half of this period. Adults feed on leaves but do not cause significant damage. Oviposition occurs soon after mating, and females deposit eggs singly on roughened bark of twigs, usually at the junctions of the current and previous year's growth (Brown and Eads 1965a). Living about 2 weeks, females die soon after ovipositing (Burke 1920). Eggs hatch in 2 to 3 weeks. New larvae bore through the bottoms of the eggs into the twigs, leaving the chorions packed with fine frass (Burke 1920). Young larvae tunnel toward the base just beneath the bark, making linear galleries several centimeters long toward older twig growth (Brown and Eads 1965a). After 3 to 6 months, larvae begin to mine spirally around the twigs. Leaves on girdled twigs die and turn brown. The following season, larvae continue the spiral, girdling toward the bases for 30 cm or more, causing infested twigs to die back still further. Mature larvae tunnel 15 cm or more back into the dead twigs where they pupate. The pupal stage lasts 2 to 3 weeks. New adults chew holes in the twigs to exit. The life cycle requires 2 years.

Injury and damage. Patches of yellow, brown, or dead leaves at various locations on the tree are the first evidence of injury. In severe infestations, most of the twigs smaller than 12 mm in diameter may be girdled (figure 92D) and killed. Carefully peeling

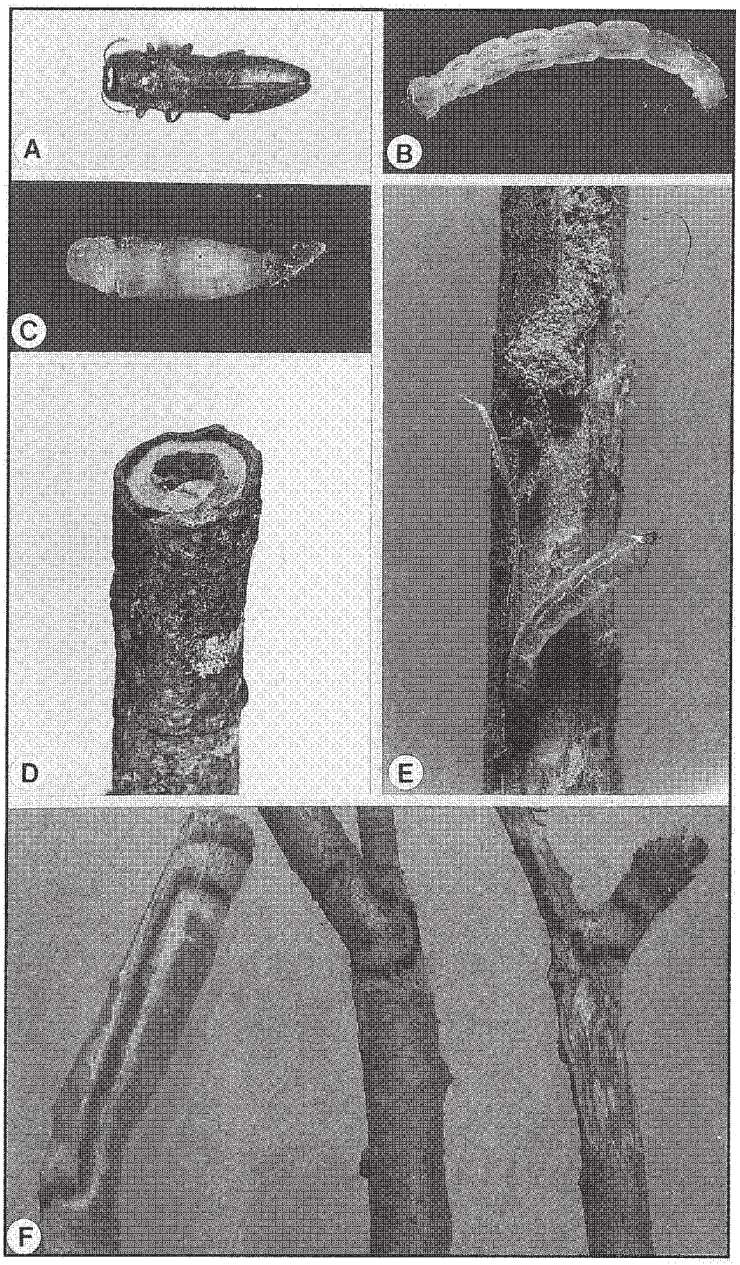

Figure 92—Agrilus angelicus, *[oak twig girdler]: A, adult; B, larva; C, pupa; D, twig end with spiral girdle; E, frass-packed gallery and larva exposed in twig; F, bark removed to expose galleries (A-D, courtesy L. Brown; E & F, courtesy W. Johnson).*

the bark from dying twigs will reveal larvae (figure 92E) and the internal injury. Tunnels are often spiral and filled with brown frass (figure 92F). Larvae may be found in tunnels next to the living part of the twigs (Miller and others 1950). The larvae usually reverse direction near the end of their development and move up the twigs for short distances before entering the wood and pupating (Burke 1920). This borer is considered to be *the* major insect pest of oak trees in southern California (Johnson and Lyon 1988). The ornamental value of heavily infested trees is often greatly reduced by the general ragged appearance caused by girdler damage (Burke 1920).

Control. Nine species of hymenopterous parasites have been reared (Burke 1920, Krombein and others 1979). In one study near Palo Alto, *Doryctes* sp. parasitized 50% of the girdlers. Small girdler populations can be suppressed by pruning and destroying infested twigs, especially on an area or neighborhood basis (Burke 1920, Miller and others 1950). Insecticidal sprays directed at the adult stage and applied during early June along the coast and during early to mid-May inland have effectively controlled the insect (Brown and Eads 1965a).

Agrilus arcuatus torquatus LeConte

[hickory spiral borer] (figure 93)

Hosts. Pecan, hickory. Hickories seem to be preferred, but pecan is readily attacked.

Range. Throughout the eastern half of the United States (Beal and Massey 1942, Brooks 1926).

Description. ***Adult.*** Moderately elongate beetle, rather robust, strongly shining, and moderately flattened (figure 93A) (Brooks 1926, Fisher 1928). Females uniformly brownish copper; males have reddish copper pronotum with greenish or bluish sides and black elytra with violet tinge. Males 8 mm long and females about 10 mm long. ***Egg.*** Flat and disklike, 0.8 to 1.1 mm in diameter, and glued firmly to smooth bark of twigs. Egg resembles shield of small scale insects. Initially, eggs smooth and pale yellowish green, but before hatching become slightly wrinkled and almost black. ***Larva.*** Slender, flat, and legless, with mature specimens reaching 15 to 20 mm long and 2 mm wide (figure 93B). Yellowish white except for dark brown or black mouth parts and anal forceps.

Biology. Adults emerge late April to late June, depending on location, and feed on foliage, chewing elongate notches and slits in the edges of the leaves (Beal and others 1952, Brooks 1926). Females begin oviposition 10 to 14 days after emergence. Eggs are deposited singly on the bark surface of terminals or lateral twigs, usually near the bases of small shoots of current season's growth and are covered with a transparent secretion that glues them to the bark. Females lay 2 to 55 eggs each over 6 to 8 weeks. Eggs hatch in 3 to 4 weeks, and the larvae chew through the bottoms of the chorions and directly into twigs, where they make elongate threadlike burrows under the bark. Late in autumn, they begin spiral burrows that sever the twigs by winter or

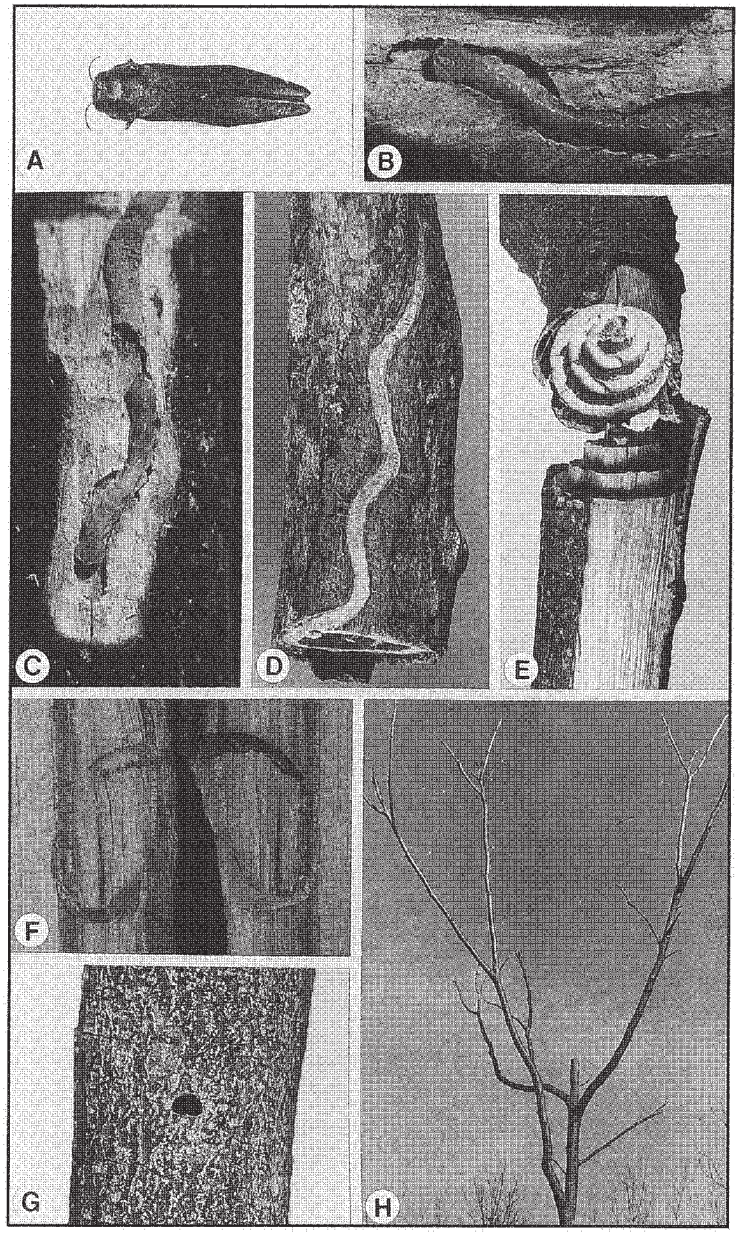

Figure 93—Agrilus arcuatus torquatus, *[hickory spiral borer]: A, adult; B, larva; C, frass-packed gallery with larva; D, cambial gallery turned abruptly inward; E, spiral-girdled branch; F, pupation chamber in wood; G, D-shaped exit; H, terminal severed from young pecan.*

spring. Mining larvae pack their galleries behind with fine frass. During the second summer, they mine downward under the bark along the stem for 20 to 60 cm, leaving shallow (but relatively wide) burrows packed with brown frass. During late fall, they change course abruptly and cut thin, symmetrical rings around the stem. After the first circuit, they bore spirally inward in the same plane, encircling the stem until reaching its center. Larvae then turn and mine upward under the bark for 25 to 76 mm. Here, they form crescent-shaped pupal chambers, with ends that extend to the bark and whose bottoms curve toward the stem center. They plug both ends of pupal chambers with frass, then pupate during May and June for about 3 weeks. A generation requires 2 years.

Injury and damage. Larvae sever branches and terminals during late winter and spring (Brooks 1926, USDA FS 1985). The portion above the girdle usually (but not always) dies in spring before foliage appears, the injury becoming apparent as the rest of the tree puts forth leaves. Most severed branches break and fall to the ground just before or soon after budbreak in spring. The borer severs stems 8 to 40 mm in diameter and 0.5 to 2.5 m long—many are larger than those girdled by *Oncideres* twig girdlers and *Anelaphus* twig pruners but slightly smaller than those pruned by *Psyrassa* branch pruners. Examination and removal of bark from infested branches will reveal the frass-packed galleries (figure 93C) and sometimes the long white larvae. The long winding gallery beneath the bark abruptly spirals inward to sever the branch (figure 93D). The spiral cut made by a larva is characteristic; it is a winding concentric cut from the inner bark to the heart of the branch or stem. The coils of the thin burrow join and completely sever the wood, except for the bark and sometimes a few slender fibers at the center (figure 93E). Later examination will reveal curved pupal cells in the wood (figure 93F) and D-shaped emergence holes in the bark (figure 93G). A major portion of the terminals of young trees is sometimes severed (figure 93H). Serious damage to large trees results in reduced nut production, ragged appearance, and asymmetry. Repeated attacks on young trees may cause stunted, misshapen, crooked, and forked stems. In one study in North Carolina, 7% of 500 young hickories examined had part or all of their main stems killed by this borer (Beal and Massey 1942). Although individual trees may be seriously damaged, entire stands, groves, nurseries, and other plantings are seldom badly harmed. Serious damage is most likely to occur in plantings adjacent to or close to forested tracts containing many heavily infested hickories.

Control. Five insect parasites—*Labena apicalis* Cresson, *L. grallator* (Say), *Monogonogastra agrili* (Ashmead), *Tetrastichus rugglesi* Rohwer, and *Zatropis* sp. near *nigroaeneus* (Ashmead)—help reduce populations (Brooks 1926, Burks 1979, Carlson 1979). To collect and destroy the larvae, young trees in heavily infested nurseries and orchards should be pruned to remove dead branches and terminals as soon as leaves develop in spring (Beal and

Massey 1942, Brooks 1926). Special care should be taken to cut off the small dead twigs that have been severed by the first winter larvae. To be sure of getting the tunneling borers, such twigs should be clipped several centimeters below the dead part. Also, all fallen severed branches and terminals should be picked up and destroyed before adults begin to emerge. It has been suggested that old hickories growing near nurseries should be removed (Beal and Massey 1942).

Agrilus otiosus Say

[hickory agrilus] (figure 94)

Hosts. Hickory, pecan. Water hickory and pecan are commonly infested, but other hickory species undoubtedly are infested (Fisher 1928, Wellso and others 1976). Persimmon, dogwood, maple, redbud, black walnut, butternut, hazel, oak, and black locust mentioned as hosts in the early literature (Chittenden 1900b, Leonard 1928, Mutchler and Weiss 1922), but these observers probably mistook other *Agrilus* species for *A. otiosus* (Fisher 1928).

Range. An eastern species commonly reported from Massachusetts and New York west to Minnesota and Kansas and south to Georgia and Mississippi (Fisher 1928, Franklin and Lund 1956).

Description. ***Adult.*** Small, slender, nearly linear, and moderately shining beetle 4 to 5.8 mm long and about 1.3 mm wide (Fisher 1928, Knull 1925). Head and antennae greenish blue, pronotum dark bronzy green with sides more bluish, and elytra black with strong greenish or bronze tinge. Beneath, beetles dark bronzy green and more shining than above. Pronotum slightly wider than long and elytra slightly wider than pronotum.

Biology. Adults begin emerging in May and June throughout the range of the species and have been collected as late as August in its northern distribution (Fisher 1928, Leonard 1928). Larvae hatch from eggs laid on the bark and burrow into the phloem. Larval burrows generally are in the inner phloem-cambium, but sometimes portions of burrows occur entirely in the phloem. The larvae tunnel downward in spirals or zigzags for long distances, making galleries that measure up to 1.8 m long. In trunks 6 to 16 cm in diameter, early tunneling is characterized by a spiral pattern, but older larvae more commonly make zigzags. Larvae may circle small stems as many as six times in their travel down the trunk. The insect's life history is little known, but based on gallery lengths and characteristics, the life cycle appears to be more than 1 year.

Injury and damage. Active infestations are difficult to detect. After the borers complete development and exit, spiral and zigzag swellings appear in the bark on trunks of young trees (figure 94A). Removing the bark from the swollen areas reveals larval burrows (figure 94B). Years later, multiple spiral and zigzag grooves are prominent on the bark of large trees (figure 94C). Bolts taken from infested trees and sliced, split, or sawn open will reveal the small, oval (in cross section), frass-filled larval burrows in the phloem (figure 94D). In sawn lumber, small, dark brown spots,

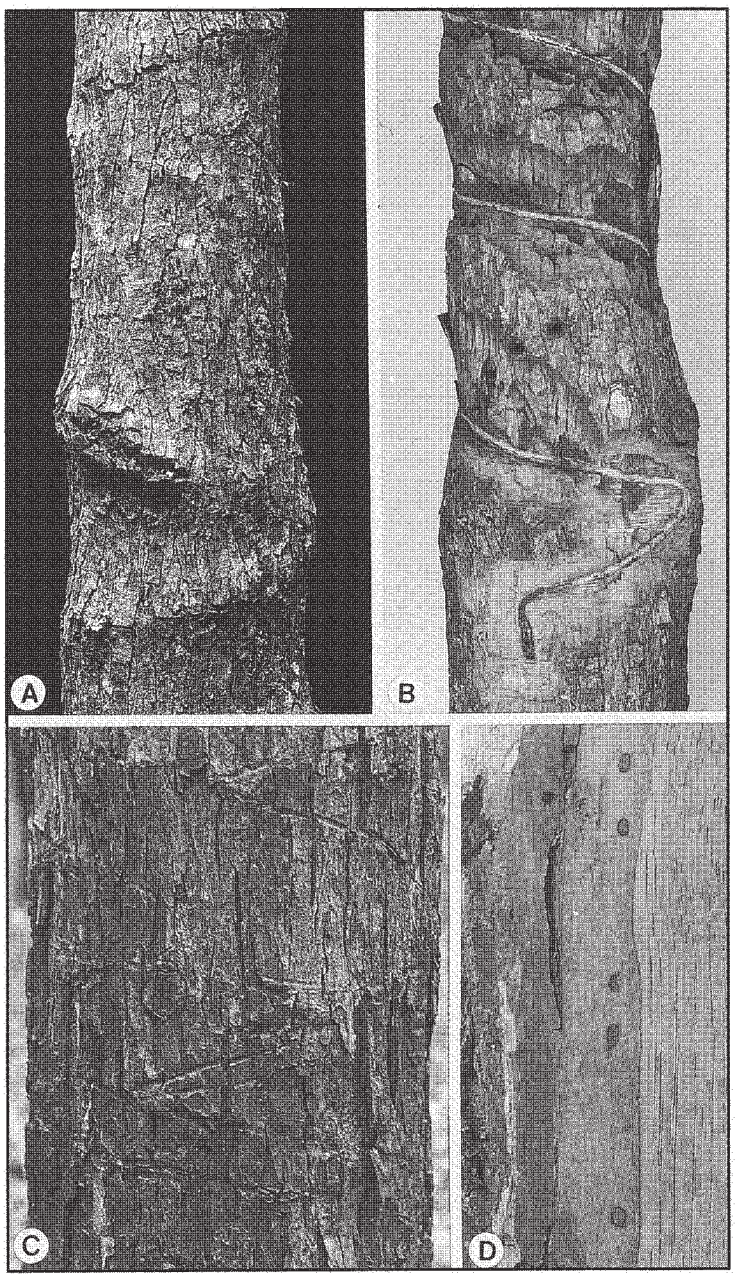

Figure 94—Agrilus otiosus, *[hickory agrilus]: A, young sinuate swellings on bark; B, bark removed to show spiral and sinuate gallery; C, sinuate grooves in outer bark of older hickory; D, pecan log split to show small frass-filled galleries in inner phloem.*

sometimes with bits of frass and ingrown bark, appear as defects similar to bird pecks. Small D-shaped exit holes can sometimes be found in the bark of young trees. This stem-boring beetle produces minor defects in the wood but does not cause mortality. In the Deep South, water hickory on wet sites in the bottomlands of Arkansas, Louisiana, and Mississippi seems particularly susceptible, and young pecan plantings have been heavily infested.

Control. One hymenopterous parasite—*Bephratoides agrili* (Ashmead)—has been reported, but nothing is known of its effectiveness (Burks 1979). Open-grown planted trees appear most susceptible.

Agrilus juglandis Knull

[butternut agrilus]

Hosts. Butternut. Butternut is the only recorded host (Fisher 1928, Knull 1920), but other *Juglans* species possibly serve as hosts.

Range. Occurs in the eastern United States from New York south to Virginia, west to Illinois and Michigan, and in Quebec (Fisher 1928).

Description. ***Adult.*** Slender, somewhat linear beetle about 5.5 mm long and 1.4 mm wide (Fisher 1928, Knull 1920). Head and antennae green with back of head light coppery. Pronotum bronzy brown with sides more greenish. Elytra blackish with slightly brassy green tinge. Beetles black beneath and less shiny than above.

Biology. Adults emerge in May and June (Fisher 1928, Knull 1920). Larvae mine and burrow in the outer bark, where they feed and develop. They often feed together with larvae of other species of flatheaded borers.

Injury and damage. Initial infestations may be difficult to detect, but as attacks progress and are repeated, the bark may crack open to expose mines in the outer bark. The beetle causes little damage itself, but its injury apparently makes trees more susceptible to more serious borers such as the flatheaded appletree borer (Knull 1920).

Control. Controls have not been reported for this species.

Agrilus cephalicus LeConte

[dogwood agrilus] (figure 95)

Hosts. Dogwood. Dogwood is the only well-documented larval host (Fisher 1928); hazel has been mentioned as a host (Chamberlin 1926), but this seems questionable.

Range. Distributed throughout the eastern United States west to the Great Plains and across southern Canada (Fisher 1928, Herrick 1935).

Description. ***Adult.*** Small slender beetle that varies from uniformly dark, coppery brown to nearly black with pronotum of various shades of bronzy green (figure 95A) (Fisher 1928). Beetles elongate, moderately flattened dorsally and about 5.8 mm long and 1.5 mm wide. Pronotum wider than long and broadly rounded laterally. Elytra slightly wider than pronotum at their base; feebly constricted before middle, then narrow obliquely toward tips. Tips of elytra separated, broadly rounded, and finely serrated; sutural margins elevated posteriorly. Antennae serrate from segment 4 to tips and

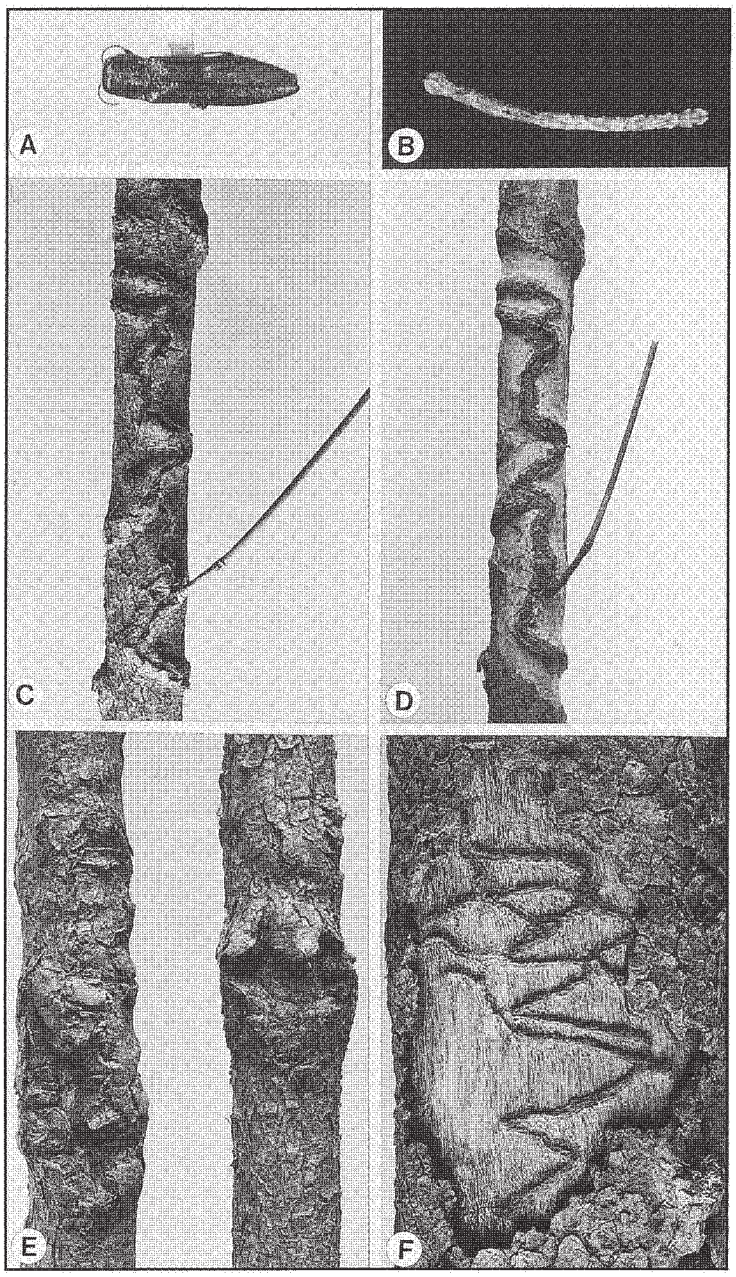

Figure 95—Agrilus cephalicus, *[dogwood agrilus]: A, adult; B, larva; C, bulging bark over gallery in small stem; D, bark removed to expose gallery; E, cankerlike scars left on bark from old attacks; F, sinuate galleries beneath bark on large stem.*

extend to about middle of pronotum (Fisher 1928, Wellso and others 1976). ***Larva.*** Whitish, elongate, and slightly flattened (figure 95B) (Weigel and Baumhofer 1948). First thoracic segment noticeably widened with horny, platelike surface and median bisecting line (Weigel and Baumhofer 1948). Larvae legless with pair of forcep-like spines at posterior end of abdomen.

Biology. Adults emerge from May to July and feed on host leaves before depositing eggs in bark crevices (Herrick 1935). Larvae bore directly from eggs through the bark to the surface of the sapwood, where they make irregular, meandering galleries filled with frass. They pupate below the surface of the wood, and new adults emerge in spring. The life cycle appears to require 1 year.

Injury and damage. Initially, infested trees are easily detected by wet spots on the bark surface made by small feeding larvae. The sap dries, but the bark remains dark stained with small intermingled bleached areas. Larval galleries filled with fine frass meander over the surface of sapwood. When borer wounds on small stems heal, wound tissue bulges along the meandering galleries (figure 95C and D). Sometimes, small localized areas of bark are killed, causing cankerlike openings and scars on the bark (figure 95E). On large trees, galleries often zigzag and may crisscross other galleries (figure 95F). Small weakened trees are sometimes girdled and killed by the tunneling larvae. D-shaped holes through the bark indicate the emergence of adults. This beetle typically attacks weakened trees and occasionally causes considerable damage to ornamentals around homes, along streets, and in recreation areas (Herrick 1935, Weigel and Baumhofer 1948). Trees recently transplanted and those suffering from defoliation, scale insects, disease, or mechanical injuries are particularly susceptible. The considerable decline and mortality of dogwood in the southeastern United States in recent years are partly attributable to this borer.

Control. One hymenopterous parasite—*Doryctes rufipes* (Provancher)—has been reported (Marsh 1979). The best insurance against infestation is to keep trees vigorous. Young transplanted trees should be wrapped with burlap or heavy crepe paper to prevent egg deposition; wraps should be applied before early May and should extend from groundline to the first branches, or higher if the branches are low. Several insecticides protected trees from attack by other *Agrilus* borers in Ohio when stems and foliage were sprayed three times at 2-week intervals beginning in mid-June (Nielsen and Dunlap 1982). Similar treatments should be effective against this species.

Agrilus difficilis Gory

[honeylocust agrilus] (figure 96)

Hosts. Honeylocust. Honeylocust is the only well-documented host (Fisher 1928, Schuder 1958). Willow has been mentioned as a host (Fisher 1928), but this seems doubtful.

Range. New Jersey and Michigan south to Georgia and west to Texas and Colorado (Fisher 1928, Franklin and Lund 1956).

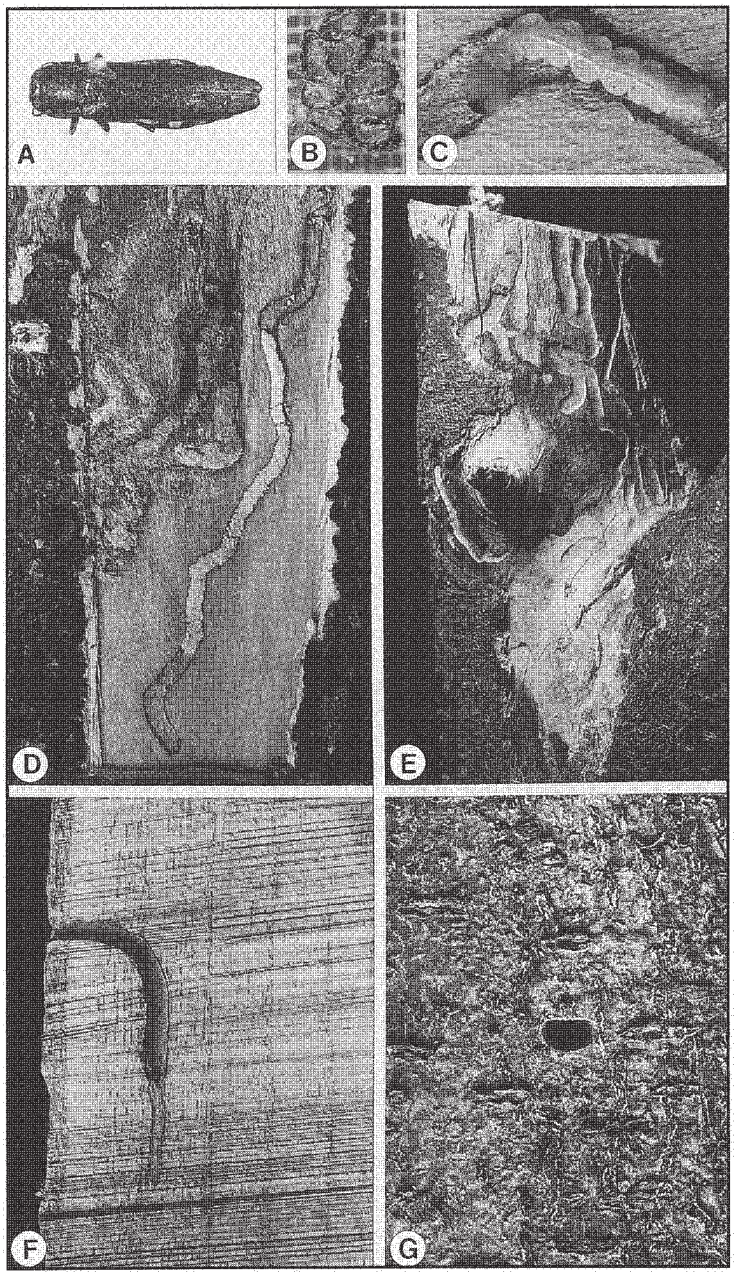

Figure 96—Agrilus difficilis, *[honeylocust agrilus]: A, adult; B, eggs; C, larva; D, frass-filled galleries on surface of sapwood; E, multiple galleries at pruning wound; F, pupal chamber in wood; G, D-shaped exit hole (A & B, specimens courtesy D. Nielsen).*

Range closely approximates the natural distribution of honeylocust (Little 1971).

Description. ***Adult.*** Elongate, slightly flattened beetle 7 to 13 mm long and 1.4 to 3.5 mm wide (figure 96A) (Fisher 1928). Lustrous black with green and purple reflections and coppery ventrally. Broad, flat head in front and large eyes. Antennae extend slightly beyond middle of pronotum and serrate from fourth segment to apex. Elytra slightly wider than pronotum at their base and beyond middle taper toward tips. Sides of abdomen broadly exposed dorsally for nearly their entire length. Two rows of yellow pubescent spots above and below lateral abdominal suture, partially visible from above. Tips of elytra rounded and finely serrate. ***Egg.*** Oval, flattened, and sometimes in clusters (figure 96B). ***Larva.*** Long, flattened, narrow, obviously segmented, and white except for brown mandibles and anal forceps (figure 96C).

Biology. Adults begin emerging in April and May (Fisher 1928). In Ohio, emergence peaks in June and ends in late July (Akers and others 1986), but in Colorado, beetles have been collected as late as September 12 (Fisher 1928). Beetles commonly are found basking in sunlight on the bark of open-grown host trees (Champlain and Knull 1925). After feeding 2 to 3 weeks, females begin ovipositing on the bark of stressed trees (Akers and others 1986, Herms and others 1987). Oviposition studies in Ohio revealed that females average 1 egg per day over about 5 weeks, but clusters of up to 8 eggs have been found elsewhere. Eggs hatch in about 15 days. Young larvae bore through the chorions directly through bark to the cambium, where they feed and develop. Galleries are long, flattened, etched in the surface of the sapwood, and packed with fine frass (figure 96D and 96E). Mature larvae tunnel into the xylem, form pupation cells, and eventually pupate (figure 96F). New adults cut D-shaped holes (figure 96G) in the bark to exit. This borer has one generation per year (Schuder 1958).

Injury and damage. First signs of attack are wet areas on the bark. Exudation of large quantities of gum is common around infested nodes soon after larvae begin feeding (Schuder 1958). The sapstain on bark around infested sites is dark initially but later may lighten. Attacks are most common near bark scars, branch crotches, and around recent mechanical injuries. Borer attacks may occur in stems of all sizes greater than 1.5 cm in diameter (Akers and others 1986) but are most common in large branches and trunks (Herms and others 1987). Removing bark reveals long, flattened galleries packed with fine frass etched in the surface of sapwood. Galleries may extend 25 cm or more in one direction (figure 96D) or may meander and criss-cross in a small area of the stem (figure 96E). In Mississippi, light infestations have occurred beneath bark that surrounds recent mechanical injuries on living host trees. This species may be involved in honeylocust decline (Akers and others 1986), because susceptible trees may be girdled and killed (Schuder 1958).

Control. One hymenopterous parasite—*Leluthia astigma* (Ashmead)—has

been recorded (Marsh 1979). Drought-weakened trees and those suffering from other stresses are most susceptible (Akers and others 1986, Herms and others 1987). Thus, cultural practices that maintain tree vigor will help to minimize damage. Insecticides should help prevent new attacks but have not controlled established infestations (Schuder 1958).

Agrilus champlaini Frost

[hophornbeam borer] (figure 97)

Hosts. Hophornbeam, hornbeam. Eastern hophornbeam, commonly known as ironwood, and American hornbeam, best known as blue beech, are the only known hosts (Frost and Weiss 1920, Knull 1947).

Range. A northeastern species recorded from Connecticut, New York, Pennsylvania, and West Virginia west to Michigan (Fisher 1928, Wellso and others 1976).

Description. ***Adult.*** Elongate, rather robust beetle slightly flattened and 7 to 8 mm long (figure 97A) (Fisher 1928). Beetles uniformly black with feeble purple tinge and nearly opaque. Beneath slightly shinier than above and with vague brassy reflection. Antennae extend to middle of pronotum and serrate from fourth joint, with outer segments as wide as long. Large eyes strongly elongate and about equally rounded above and below. Sides of abdomen narrowly exposed above. ***Larva.*** Long, narrow, and flattened, with prothorax slightly wider than rest of body; brown mouth parts and anal forceps (figure 97B).

Biology. Adults emerge during May and June (Britton 1912b, Fisher 1928). Females oviposit on small stems often high above the ground. Larvae mine within a small area of the twig, causing it to swell as it grows and later becomes gall-like. Larval mines in the gall are irregular but generally spiral and usually packed with fine frass. Mature larvae pupate head downward in the center of the gall, and the new adults emerge from the lower portion of the swellings through small exit holes (Knull 1922).

Injury and damage. Conspicuous swellings and galls (figure 97C, D, and E) on the twigs, small branches, and terminals indicate infestation (Borror and others 1981, Britton 1912b). Multiple galls may occur on small stems (figure 97C). Stem galls cut open contain frass-filled galleries (figure 97E) and tunneling larvae. Emerging beetles leave D-shaped exit holes in the bark (figure 97D and E). Infested stems may be partly girdled and nearly severed, resulting in breakage or dieback.

Control. Four species of insect parasites—*Atanycolus hicoriae* Shenefelt, *Tetrastichus nordi* Burks, *T. rugglesi* Rohwer, and *Xylophrurus nubilipennis luctuosus* (Provancher)—have been reported (Burks 1979, Carlson 1979, Marsh 1979). Branches with galls on ornamental trees can be clipped and burned to destroy the beetles before they emerge in May.

Agrilus sayi Saunders

[bayberry agrilus]

Hosts. Bayberry, sweetfern. Bayberry is the major larval host (Bright 1981, Fisher 1922, Knull 1922). Adults have been taken

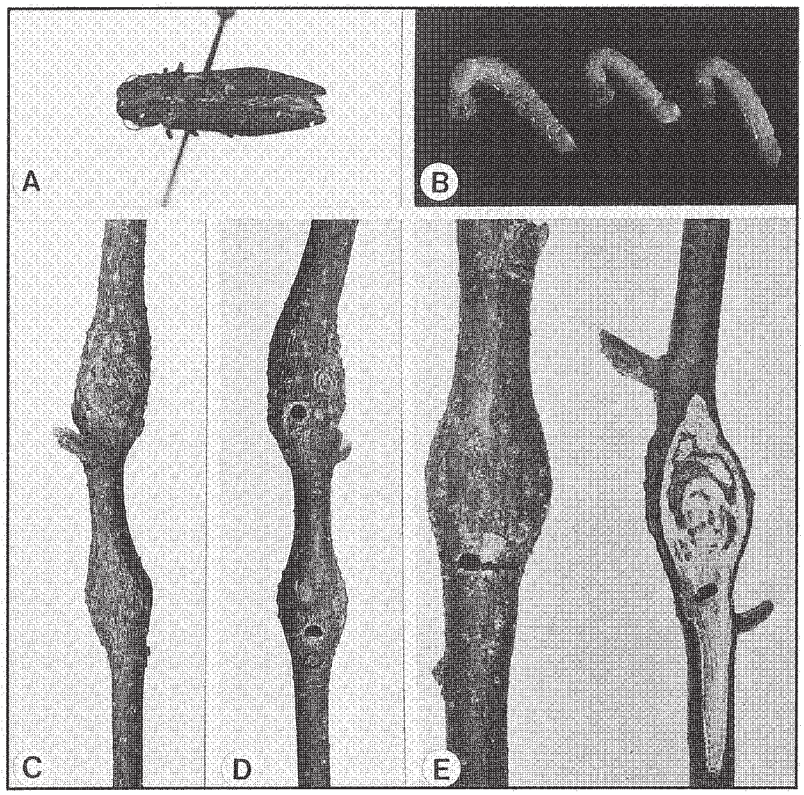

Figure 97—Agrilus champlaini, *[hophornbeam borer]: A, adult; B, larvae; C, twig with two galls; D, D-shaped emergence holes in galls; E, gall with exit hole and larval mines (A & B, specimens courtesy D. Whitehead; C & D, specimens courtesy S. Wellso; E, reproduced from Knull [1925]).*

on apple, oak, and poplar, but these probably are not larval hosts.

Range. An eastern species occurring primarily in the coastal states from Florida north to Nova Scotia, Quebec, and Ontario (Bright 1987, Chamberlin 1926, Fisher 1928). Most references to this species before 1981 call it either *A. lateralis* (Say) or *A. browni* Carlson and Knight (Bright 1981).

Description. ***Adult.*** Elongate beetle, somewhat flattened above, and wing covers taper obliquely from middle toward rear (Fisher 1928). Wide, flat head between large pair of compound eyes. Antennae barely reach middle of pronotum and serrate beyond fourth segment. Pronotum about as wide at anterior margin as at posterior margin and broadly rounded laterally. Elytra slightly wider than pronotum at their base and nearly parallel for basal half, then narrow obliquely to separated broadly rounded tips. Strongly shining body, and head and pronotum brassy copper; elytra black; undersides brassy with strong coppery reflections. ***Egg.*** Oval, somewhat flattened, and white when first deposited but turns to gray similar to bark of bayberry, and finally to black just before eclosion (Fisher 1922). ***Larva.*** Greatly elongate, narrow, somewhat flattened, and white except for brown mouthparts and anal forceps.

Biology. Adults begin emerging in late April in Florida (Fisher 1928), but in the northern range, most emerge during June and July (Chamberlin 1926). Adults often are observed on host foliage in full sunlight, especially on foliage of lower branches protected from wind. When disturbed, adults fly to another leaf but make no effort to hide. After feeding on foliage, females deposit eggs singly on the bark around the base of host plants. New larvae bore directly through the bottom of the eggs into the bark, filling the empty chorions with frass (Carlson and Knight 1969). Larvae burrow in the outermost layers of sapwood and down into the roots, where they spend a first winter. In spring, larvae burrow spirally upward in the stems and branches, often considerable distances. When mature, they bore deeply into the wood, where they pass a second winter. They pupate in the outer sapwood during the second spring. A 2-year life cycle is required (Fisher 1922).

Injury and damage. Unless trees die, diagnosis often is difficult. Initially, one may observe raggedly chewed edges on leaves of hosts, particularly on the lower limbs in sun (Fisher 1922). Closer inspection may reveal slight swellings on limbs that suggest partially healed larval galleries may be under the bark. Galleries made during their first year of development by larvae in bayberry are covered by new wood and may appear as spiral ridges on the surface. Galleries made during the second year are covered by a thin layer of wood through which the dark, frass-filled tunnels can sometimes be observed. Dissection of infested plants will reveal galleries in the main stems, branches, and roots. Larvae tunnel in both above- and belowground parts of sweetfern (Carlson and Knight 1969, Knull 1922). Although lightly infested healthy plants usually recover with only

minor scarring, heavily infested plants often succumb. Great numbers of bayberry shrubs reportedly were killed by this beetle during 1918 near Lyme, Connecticut (Fisher 1922).

Control. Vigorous plants are least likely to be attacked; those attacked frequently heal with little noticeable injury (Fisher 1922).

Agrilus masculinus Horn

[maple agrilus] (figure 98)

Hosts. Maple, hophornbeam, honeylocust. Red maple, sugar maple, boxelder, and hophornbeam listed as hosts (Fisher 1928, Wellso and others 1976). A single specimen has been reared from honeylocust (Hespenheide 1969). Adults have been collected from the foliage of buckeye and oak, but it is doubtful that they reproduce in these trees (Blatchley 1910, Chamberlin 1926).

Range. Occurs from Quebec southward to South Carolina and west to Texas and South Dakota (Fisher 1928).

Description. ***Adult.*** Small, slender beetle, 4 to 7 mm long and 0.85 to 1.5 mm wide (figure 98A) (Blatchley 1910, Fisher 1928). Bronzy green head on male, coppery on female. Antennae extend to about middle of pronotum and serrated from fourth segment. Pronotum bronzy green with brownish tinge, and prosternum of male densely pubescent. Elytra black with bronze reflections. ***Larva.*** White, long, narrow, and slightly flattened with prothorax slightly wider than other segments (figure 98B).

Biology. Adults emerge from April to July and often rest on the foliage of host trees (Chamberlin 1926, Fisher 1928). Eggs are deposited on branches and trunks of susceptible trees. Sampling maple branches from 2 to 64 mm in diameter revealed highest infestation rates in those 16 to 32 mm in diameter (Hespenheide 1969). Mature larvae enter sapwood to pupate. Although duration of the life cycle is unknown, based on times of adult emergence and gallery lengths and shapes, a generation appears to require 2 years.

Injury and damage. Outward evidence of early attacks is usually lacking, so weakened hosts and those with wounds must be checked closely for infestation. Slight swellings on young, thin-barked trees and D-shaped emergence holes (figure 98C) are the only visible bark indicators. Removing pieces of bark from infested trees will reveal larval galleries in the cambium area. Galleries made by young larvae are very narrow, mostly vertical elongate, and interrupted with many short stairsteps (figure 98D). Those of older larvae meander but frequently zigzag (figure 98E). Galleries that heal over in surviving trees become ridgelike on the surface of the sapwood (figure 98F). This beetle attacks weakened, wounded, dying, and recently dead trees (Fisher 1928, Hespenheide 1969). Although infestations sometimes hasten mortality of weakened trees, populations are widely scattered, and overall damage is negligible (Beal and others 1952).

Control. No natural controls have been observed, and direct controls have not been needed.

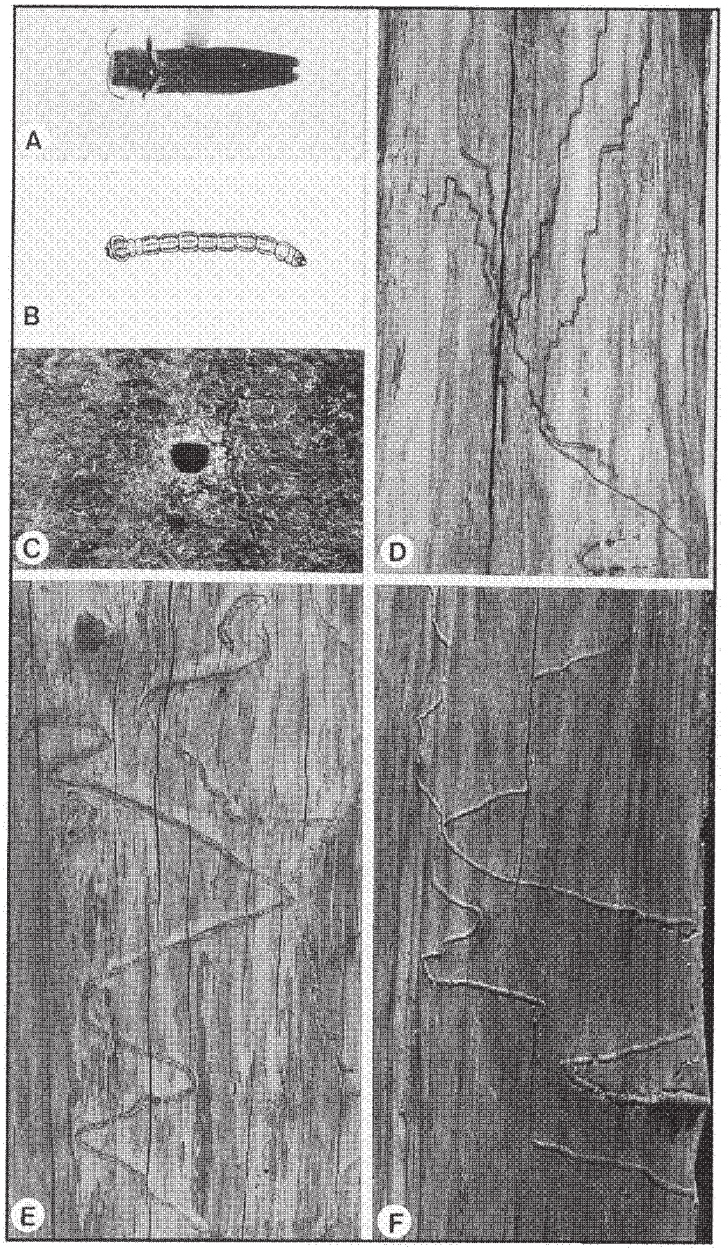

Figure 98—Agrilus masculinus, *[maple agrilus]: A, adult; B, larva; C, D-shaped emergence hole in bark; D, narrow stair-step galleries of young larvae; E, zigzag galleries of large larvae; F, ridgelike overgrown galleries in surviving maple (A, specimen courtesy D. Whitehead).*

Agrilus vittaticollis Randall

[hawthorn root borer] (figure 99)

Hosts. Apple, pear, crabapple, serviceberry, hawthorn. Pear and crabapple only occasionally attacked (Brooks 1914). Adults have been collected feeding on chokecherry.

Range. Most common in the eastern United States but distributed throughout most of North America from Florida north to Maine and west to California and across southern Canada from Quebec to British Columbia (Bright 1987, Fisher 1928).

Description. ***Adult.*** Slender, slightly flattened beetle averaging 10.5 mm long and 2.5 mm wide (figure 99A) (Brooks 1914). Elytra black with tinge of purple; head and thorax iridescent purple or coppery in sunlight. Dense bronze pubescence along sides of thorax and as wide stripe, dorsally extending to front of head. Lines of bronze pubescence extend along sides of abdomen visible dorsally beyond inflected edges of elytra. Elytra somewhat broaden behind middle, tips being separately rounded and finely serrulate. ***Egg.*** Flattened, oblong, disk-like, 1.9 by 1.3 mm. Chorion surface irregularly corrugated, ridges and depressions being more distinct near margin. When first laid, creamy white but in few days change to grayish brown, resembling bark. ***Larva.*** White except for brown mouthparts and anal forceps; 30 to 36 mm long and 3 to 4 mm wide (figure 99B). Long, slender, flattened, distinctly segmented, and nearly uniform in width throughout, except for first thoracic segment slightly wider. ***Pupa.*** Broad, flattened dorsally, and about 12 mm long (figure 99C).

Biology. In West Virginia, adults emerge in May and live about 2 weeks (Brooks 1914). In other parts of the country, adults have been collected from mid-April to late July (Fisher 1928). Eggs typically are laid on the bark a few centimeters above ground, mostly during May and June. Most eggs are glued firmly on smooth bark surfaces, but a few are inserted into cracks or under bark scales. When hatching, larvae bore directly into the bark through the undersides of eggs; as larvae burrow, they push frass back into the vacated egg chorions. Larvae typically tunnel downward in the cambium for 15 to 30 cm to a root, where they burrow spirally around the root once or twice. Here, they bore into the wood of the root and extend their galleries outward 0.9 to 1.2 m toward the root tips. They spend the first winter in root galleries. In the spring, larvae reverse direction and burrow back toward the trunk. They reach the root collar by midsummer, then tunnel upward in the trunk, usually within 2.5 cm of the bark. During fall, mature larvae construct vertical pupal chambers that curve to within 2 mm of the bark. In trees smaller than 15 cm in diameter at their base, pupation occurs within 13 to 25 cm of the ground. On larger trees, it is not unusual for larvae to burrow up to 60 to 90 cm above ground to pupate. A generation requires 2 years.

Injury and damage. The only outward evidence of attack is small adult exit holes. No frass or wood fiber is cast to the outside as it is with roundheaded borers.

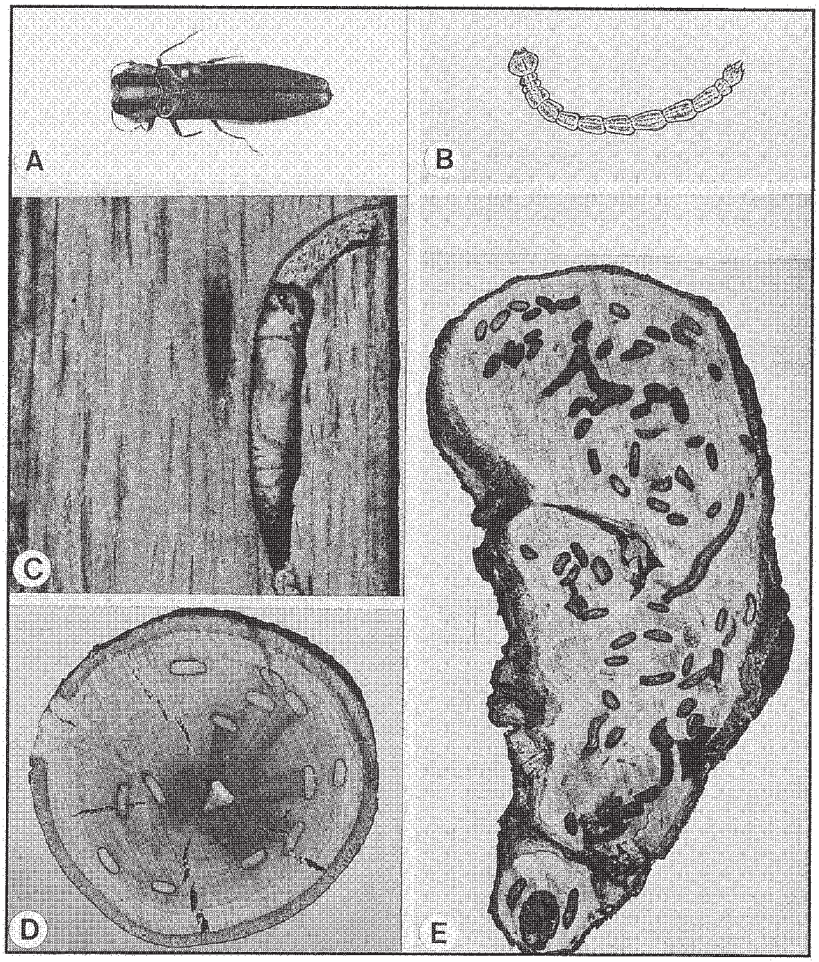

Figure 99—Agrilus vittaticollis, *[hawthorn root borer]: A, adult; B, larva; C, pupa in pupal chamber in wood; D, trunk cross section showing galleries; E, root cross section showing many galleries (A, B, & D, specimens courtesy D. Whitehead; C & E, reproduced from Brooks [1914]).*

Larval galleries often extend through trunks (figure 99D) and roots (figure 99E) for up to 1.8 m (Brooks 1914). Throughout its length, the gallery is packed with dustlike wood. Galleries in cross section are flattened, oval, and about 1 by 3 mm in diameter for mature larvae (figure 99D and E). In heavily infested trees, borers kill roots and weaken the entire tree. Besides injury resulting from the damaged roots, moisture can enter the tree through the exit holes, frequently inducing decay of the heartwood. Trees attacked repeatedly are sometimes killed. Considerable damage to young trees was recorded in the Appalachian fruit-growing region in the early 1900's. In one West Virginia survey, 82% of 125 apple trees under 13 cm in diameter were infested with these borers (Brooks 1914).

Control. The most effective natural enemy is the hymenopterous parasite *Xylophrurus agrili* (Viereck), which destroys from 25 to 40% of the full-grown larvae and pupae (Brooks 1914). The most effective artificial control is prevention of oviposition with a mechanical or insecticidal barrier. This can be done by wrapping the basal 1 m of the tree with a heavy cloth or waterproof paper in early spring. Applying a residual insecticide at least twice, 2 weeks apart, starting at blossom time should also prevent oviposition. Where the borer is troublesome, it is advisable to eliminate any wild host trees near new plantings. Doing so reduces the source of infestation and populations.

Agrilus sinuatus (Olivier)

sinuate peartree borer (figure 100)

Hosts. Pear, hawthorn, quince, cotoneaster, and serviceberry. Pear is the preferred host; other hosts are considered secondary (Glasgow 1934).

Range. A European insect, discovered in New Jersey in 1894, now occurring in the United States principally in New York, New Jersey, and Connecticut (Britton 1921, Metcalf and others 1962). It was probably introduced from France on pear nursery stock.

Description. ***Adult.*** Shiny purplish bronze to brilliant, iridescent, coppery red beetle with body surface finely granulate and covered with small punctures (figure 100A) (Britton 1921, Glasgow 1934). Elongate body (8.5 mm long) somewhat flattened and boat-shaped outline (Metcalf and others 1962). ***Egg.*** Oval, flattened, scalelike and usually found cemented to bark in depressions. ***Larva.*** About 38 mm long, white to yellowish, and flattened throughout (figure 100B). Pair of brown, inwardly curving forceps on anal segment (Smith 1895). ***Pupa.*** Generally has same form and size as adult and initially white but gradually darkens (figure 100C).

Biology. Adults emerge from late May and June and are commonly found on bark and leaves on the sunny side of trees (Britton 1921, Glasgow 1934). Females deposit eggs by cementing them to the bark, in crevices or slight depressions. Hatching larvae bore directly through the bottoms of eggs into the bark and soon into outer sapwood. Young larvae make brown threadlike galleries that

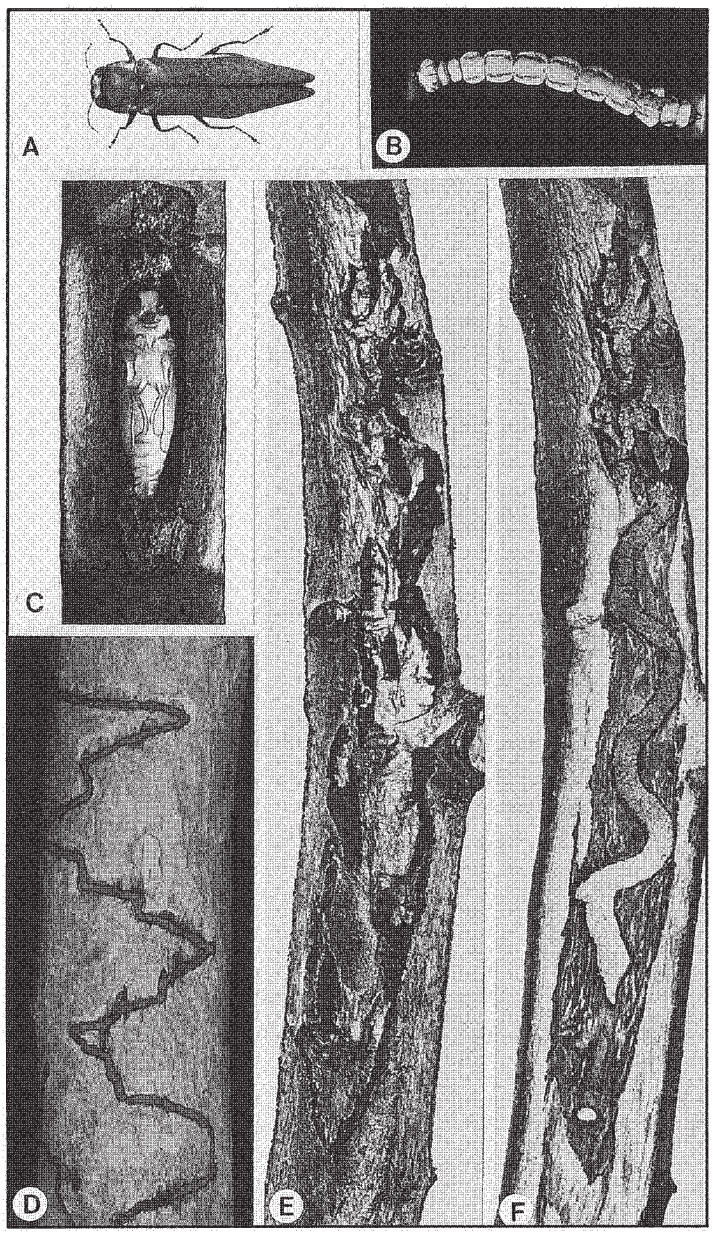

Figure 100—Agrilus sinuatus, *sinuate peartree borer: A, adult; B, larva; C, pupa in pupal chamber; D, narrow sinuate galleries of young larva; E, bark split and loosening over gallery; F, bark removed to expose gallery of large larva (A-C, E & F, reproduced from Glasgow [1934]; D, specimen courtesy D. Whitehead).*

are sinuate or irregularly bent and eventually become zigzag, depending on the size of the branch or trunk, but always toward the base of trees. In spring, larvae make larger, more serpentine galleries readily visible in the bark. In small nursery trees, galleries often extend down to the root collar or slightly below (Smith 1895). By September of the second year, larvae burrow about 6 to 8 mm deep into the wood and construct pupation chambers. Here, the larvae overwinter and pupation begins the next April. A generation requires 2 years.

Injury and damage. Large trees attacked by the borer display gradual dieback of branches and poor vigor and may eventually succumb; young trees may die quickly (Glasgow 1934, Metcalf and others 1962). The most obvious signs of injury are the narrow galleries following a sinuous, serpentine, or zigzag course beneath the bark and outer sapwood (figure 100D). Galleries generally start in a branch and always extend downward to the trunk, often to the base of the tree. On young trees, the bark splits (figure 100E) or swells, forming a continuous raised streak or welt parallel to the zigzag course of the larval gallery (Parrott and Glasgow 1915). Galleries of second-year larvae are larger (figure 100F), and the splits, ridges, and welts are more easily seen on the bark surface. The locations of pupal chambers are usually visible on the bark of small stems and branches as somewhat sunken, blackened, and cankerlike; the black discoloration extends into the wood. New adults emerge from D-shaped holes on trunks and branches. No reports on this introduced species have been published in recent years, and so its current status as a pest is not known.

Control. Several practices can help to minimize damage and loss (Glasgow 1934, Metcalf and others 1962, Slingerland and Crosby 1919). To avoid new infestations, nursery stock should be inspected before it is planted. Infested branches and trees should be cut and burned to destroy developing broods. Wild host trees close to valuable plantings should be eliminated to reduce the reservoir of infestation. The trunks and major branches of young trees in high-risk areas can be wrapped with crepe paper. Only one hymenopterous parasite—*Tetrastichus agrili* Crawford—has been recorded (Burks 1979). Insecticides used against other pests in orchards in recent years apparently have minimized infestations by this insect.

Agrilus crataegi Frost

[hawthorn agrilus] (figure 101)

Hosts. Hawthorn. Several unidentified species of hawthorn are attacked (Chamberlin 1926, Fisher 1928).

Range. Reported from Pennsylvania south to Alabama, west to Iowa and from Alberta and Quebec (Fisher 1928, Nelson and others 1981).

Description. ***Adult.*** Rather slender, elongate, very slightly flattened beetle from 6 to 8 mm long (figure 101A) (Fisher 1928). Greenish to brownish copper head. Pronotum and elytra olive bronze, suffused with copper colors, becoming distinctly reddish copper on apical third of elytra and moderately shiny. Antennae serrate

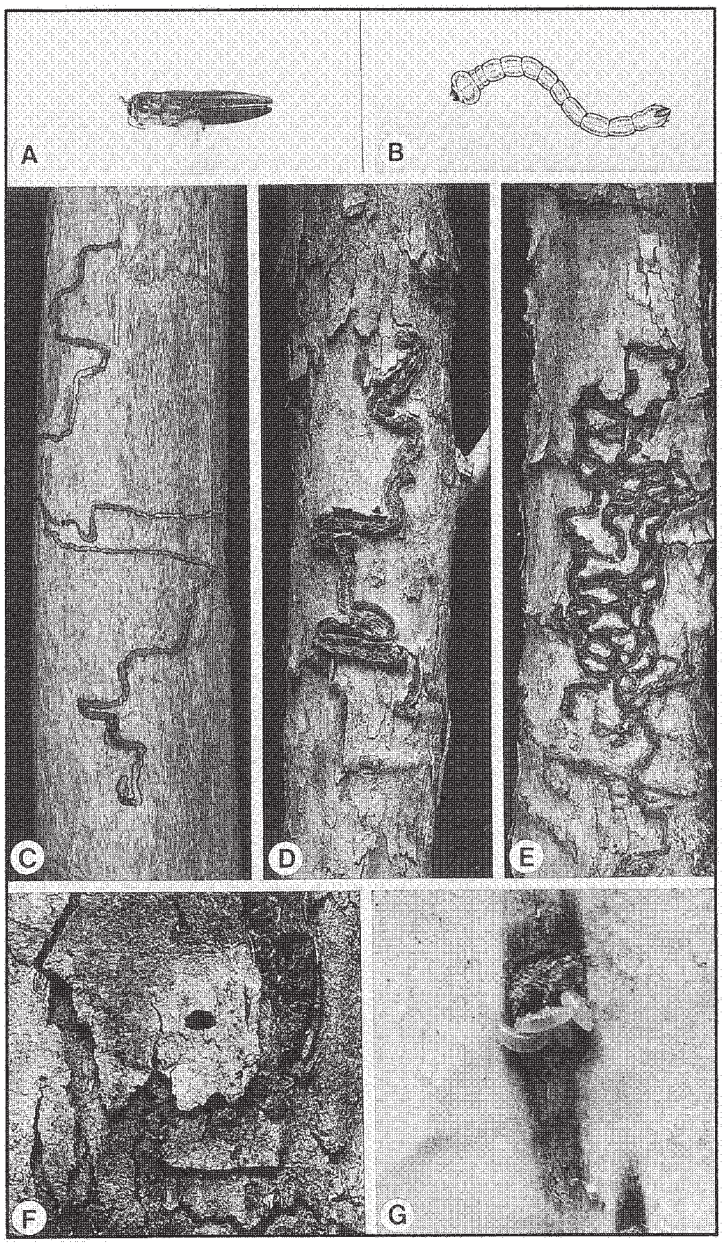

Figure 101—Agrilus crataegi, *[hawthorn agrilus]: A, adult; B, larva; C, bark removed to expose current gallery; D, bulging bark over single gallery; E, bulging bark scar over multiple galleries; F, D-shaped exit hole; G, parasite larvae exiting from pupal cell (A, specimen courtesy S. Wellso).*

from fourth joint; pronotum wider than long; and elytra slightly wider than pronotum at base. ***Larva.*** White, elongate, moderately flattened, and 12 to 15 mm long (figure 101B).

Biology. Adults emerge during June and July (Fisher 1928, Knull 1925). Young larvae bore into the cambium, where they feed and develop. Larvae make meandering galleries, packed tightly with frass, that initially extend downward, but many reverse directions one or more times, usually for short distances. Completed galleries measure up to 2 mm wide and sometimes reach 20 to 30 cm long. When mature, larvae burrow 2 to 5 mm deep in the wood and form pupation chambers. New adults cut holes through the wood and bark to emerge.

Injury and damage. Removing bark reveals larval galleries in the cambium (figure 101C). Bark immediately over the healed larval burrows swells, splits, and puckers, making prominent bark scars. Although the bark scars meander or zigzag crookedly over bark surface, they generally extend longitudinally (figure 101D). Bark scars over multiple or repeated attacks may crisscross many times and become very noticeable on the stems (figure 101E). Small D-shaped exit holes can be found in the bark (figure 101F). Heavy infestations can sometimes girdle and kill small plants. Some mortality in hawthorn thickets in Mississippi has been attributed to this borer.

Control. Parasite larvae have been found in pupal chambers (figure 101G), but no adults have been reared for identification. Direct controls have not been needed.

Agrilus fuscipennis Gory

[persimmon agrilus] (figure 102)

Hosts. Persimmon. Persimmon is the only confirmed larval host, but adults have been collected on sourwood (Chamberlin 1926, Fisher 1928).

Range. A southeastern species, recorded mostly from North Carolina west to Texas but reportedly occurring as far north as Ohio (Chamberlin 1926, Fisher 1928).

Description. ***Adult.*** Large, elongate, robust, and slightly flattened beetle, 12 to 14 mm long and 3.3 to 4 mm wide (figure 102A) (Fisher 1928). Head and pronotum dark copper with strong reddish purple tinge and black elytra. Beetles more shiny below than above, and bronzy black with anterior parts blending to blackish olive. Pronotum three-fourths wider than long and widest at middle. Sides of abdomen narrowly exposed and visible from above. ***Larva.*** Long, very slender, and white except for dark brown mouthparts and anal forceps (figure 102B). Prothorax slightly wider and mesothorax and metathorax slightly narrower than abdominal segments.

Biology. Adults begin emerging in spring and have been collected from March to July (Fisher 1928). Females apparently oviposit on the lower trunk. Larvae burrow into the wood and make long galleries in both the lower trunk and roots. Dissections reveal that galleries are most prevalent around the root collar and commonly occur 1.2 m up into trunks and 0.5 m down into roots. However, a few galleries have been found in trunks to 2 m and in roots to 1 m. Pupation occurs in

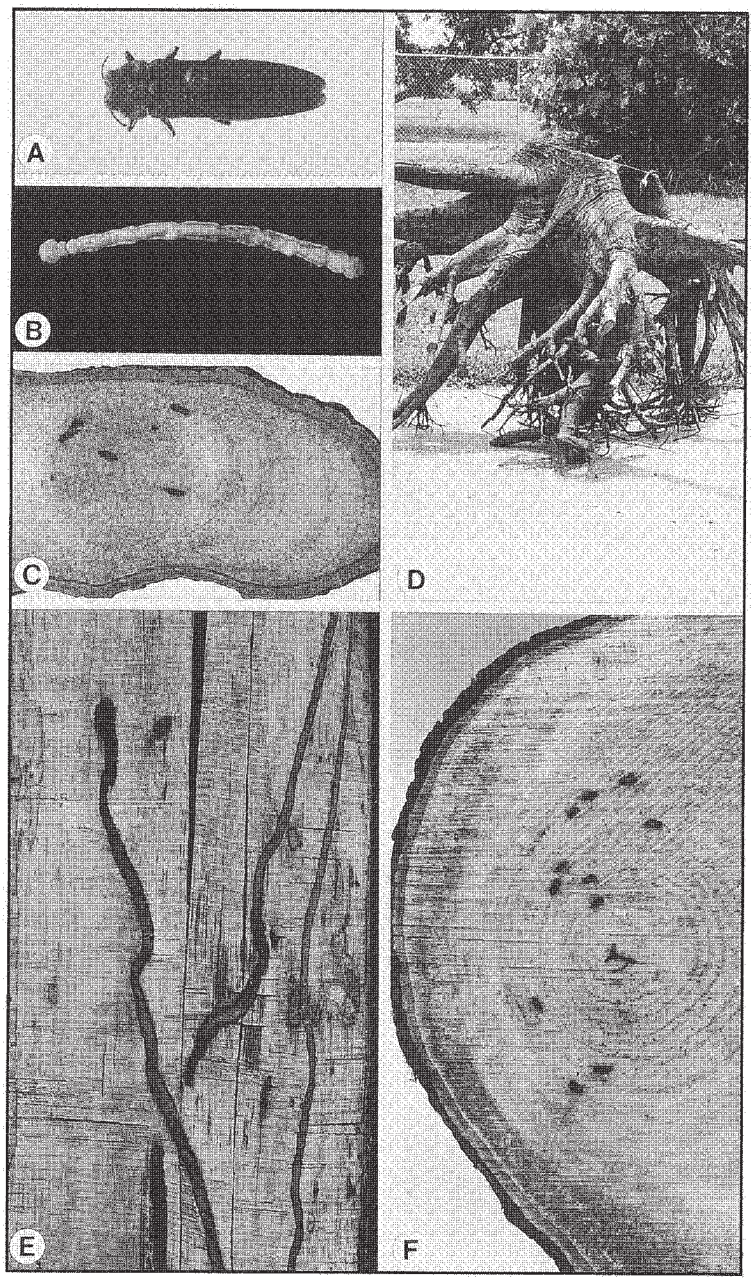

Figure 102—Agrilus fuscipennis, *[persimmon agrilus]: A, adult; B, larva; C, root cross section showing flattened oval galleries; D, large upper roots contain most galleries; E, galleries in wood of trunk; F, trunk cross section showing multiple galleries.*

chambers in the lower trunk. The life cycle is little known, but based on gallery lengths and sizes, it is likely that development takes more than 1 year.

Injury and damage. Infestations are difficult to detect in living trees. Although removing bark sometimes reveals burrows, cutting into the trunk and excavated roots is usually required to expose galleries (figure 102C and D). Long, narrow galleries within wood in the lower trunk and roots extend longitudinally and generally straight courses with only slight bends (figure 102E). Galleries are flattened ovals in cross section and measure 1.0 to 3.5 mm by 0.5 to 1.0 mm (figure 102F). Galleries are tightly packed with fine frass that is slightly lighter to slightly darker than surrounding wood (figure 102C, E, and F). A thin layer of wood (0.5 to 2.0 mm) immediately surrounding the galleries in both trunk and roots is typically stained black. Up to 15 galleries per tree have been observed in cross sections from the lower trunk. This borer apparently causes little or no mortality. However, its tunnels in the wood are considered defects that interfere with the manufacture of specialty wood products and result in degraded logs of less value.

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

Agrilus ruficollis (Fabricius)

rednecked cane borer (figure 103)

Hosts. Raspberry, blackberry, dewberry. Shows a decided preference for blackberry (Hutchings 1923) but attacks all varieties of raspberry and dewberry—wild and cultivated (Fisher 1928).

Range. Distributed from eastern Canada and New England westward to Minnesota and Kansas and southward to Texas, covering nearly the entire eastern half of the United States (Chittenden 1922, Fisher 1928).

Description. ***Adult.*** Narrowly elongate and cylindrical beetle (figure 103A) (Chittenden 1922, Slingerland and Crosby 1919). Elytra vary from beautiful velvety black to blue black with bluish reflection. Thorax usually coppery red but sometimes golden, brassy, or blue. Readily distinguishable from other *Agrilus* spp. by its red pronotum (neck) from which it gets its name. Head small, dark, bronze, and deeply grooved. Antennae and legs very short relative to rest of body. Beetles 6 to 8 mm long and about a fourth as wide. ***Egg.*** Irregularly oval and flattened, dirty white with brownish edges, from 1.0 to 1.5 mm across (Hutchings 1923). ***Larva.*** Greatly elongated and flattened (figure 103B) (Chittenden 1922, Lugger 1899, Slingerland and Crosby 1919). First thoracic segment prominent, being moderately flattened and widened at sides. Last segment of abdomen ends in pair of slender, forcep-like horns with three blunt teeth on inner edge of each. Larvae white to pale yellowish with brown head, measure 16 to 19 mm long (Chittenden 1922, Lugger 1899).

Biology. Around Washington, DC, adults appear as early as the first week in May. In more northern regions, they emerge from

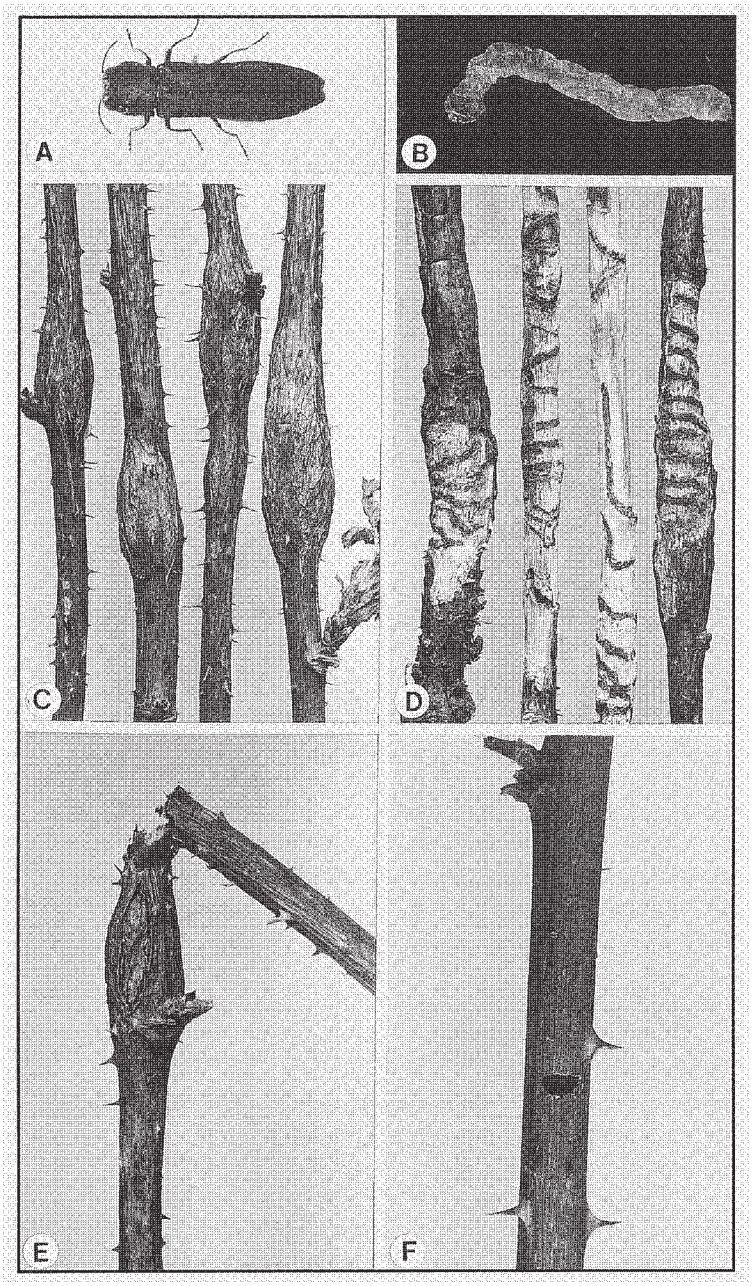

Figure 103—Agrilus ruficollis, *rednecked cane borer: A, adult; B, larva; C, swellings on raspberry canes; D, bark removed to expose spiral galleries; E, cane broken at girdled site; F, D-shaped exit hole.*

June until August (Chittenden 1922). Females oviposit from June to August on young cane growth, first near the root collar and later at points on the main stem and branches. Eggs are inserted in the bark near leaf bases and hatch in about 3 weeks (Hutchings 1923). The minute larvae feed beneath the bark and proceed spirally upward or downward in the wood parts causing the stems to swell and become gall-like (figure 103C) (Chittenden 1922). They typically tunnel spirally around the cane two to six or more times, often girdling it (figure 103D) (Slingerland and Crosby 1919). Later, larvae bore into the pith and continue upward or downward for 10 to 20 cm or more, sometimes causing stems to break (figure 103E). Mature larvae form oval pupal cells in the pith where they overwinter. Pupal cells typically are only a short distance above the ground and a few centimeters below the first gall. Pupation occurs during April and May and lasts 7 to 10 days. Adults exit through D-shaped emergence holes (figure 103F). This cane borer has one generation annually.

Injury and damage. Larval tunneling causes irregular swellings or galls 2.5 to 10.2 cm long (figure 103C). Swellings initially are elongate or spindlelike but gradually enlarge and often exhibit multiple splits and become greatly roughened in appearance. The swellings sometimes form goutylike galls—hence, one of the earlier common names, the "gouty-gall beetle." Spiral burrows around the stem in these gall-like swellings are common, especially in raspberry canes (figure 103D); spindle-shaped swellings with splitting are more typical in blackberry and dewberry canes. Swellings and galls may occur at any point on the main stem and branches, but more commonly in the lower 0.3 to 0.9 m. Infested plants appear weakened and unthrifty, and fruits develop poorly. Cane breakage is common (figure 103E). The borer has been particularly destructive in cultivated plantings; heavy damage to blackberries in New Jersey has resulted in crop losses.

Control. Three species of insect parasites—*Bracon* sp., *Microbracon xanthostigmus* (Cresson), and *Ptinobius magnificus* (Ashmead)—have been reared (Chittenden 1922, Hopkins 1891). In one study, 18% of the larvae were destroyed by parasites (Hopkins 1891). Culturally, infested canes should be cut and burned during fall, winter, and early spring to destroy larvae (Chittenden 1922, Lugger 1899). Also, wild host plants in nearby fencerows and ditchbanks should be destroyed to reduce the source of outside infestation. Insecticides directed toward the adults and applied just before the plants flower effectively reduce populations (Johnson and Mayes 1989, Metcalf and others 1962).

Agrilus aurichalceus Redtenbacher
rose stem girdler

Hosts. Rose, raspberry. Cultivated and wild varieties are attacked; the cultivated varieties seem to be preferred (Davis and Raghuvir 1964, Fisher 1928).

Range. Species apparently introduced from Holland in the early 1920's (Mutchler and Weiss 1922) and now recorded from

Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Michigan, and Utah (Davis and Raghuvir 1964, Fisher 1928).

Description. ***Adult.*** Small, slender beetle, flattened above, and measuring 4.0 to 6.2 mm long and 1.0 to 1.7 mm wide (Fisher 1928). Pronotum and elytra greenish bronze with decidedly coppery tinge. Antennae serrate from fourth segment outward and extend to middle of pronotum in males but barely to pronotum in females. Elytra slightly wider than pronotum at their base and narrow obliquely beyond middle. Tips of elytra separated, rounded, and minutely serrulate. ***Egg.*** Lemon colored, brittle, and flattened oval (scalelike), measuring 1.50 by 0.75 mm (Davis and Raghuvir 1964). ***Larva.*** Long, narrow, and flattened with slightly enlarged prothorax; white except for dark brown mouthparts and anal forceps; and 12 to 15 mm long (Davis and Raghuvir 1964).

Biology. Adults emerge from May to July and deposit eggs singly on the bark of canes usually near the ground. Young larvae make a series of two to five spiral galleries close together beneath bark; swellings or galls form over such galleries. Eventually, larger larvae construct zigzag galleries beneath the bark or in the pith. Larvae overwinter in canes and pupate within their burrows in spring. A generation is completed in 1 year in Utah but may require 2 years in the northeastern United States (Davis and Raghuvir 1964, Herrick 1935).

Injury and damage. First-year canes typically wilt, turn yellow, and break or die back when attacked (Davis and Raghuvir 1964, Mutchler and Weiss 1922). Gall-like stem swellings vary from barely noticeable to twice the stem diameter. The bark surface of galls often splits longitudinally (Herrick 1935). Dissection can reveal the larval galleries beneath the bark, which spiral downward 60 to 100 mm then turn upward in a zigzag, either in the pith or just under the bark, for 130 to 150 mm. Weakened stems frequently break. The borer causes considerable damage to roses and raspberries, killing them above the sites of larval feeding. It damages nursery roses extensively in New Jersey (Weiss 1914) and makes raspberry production in Utah impractical (Davis and Raghuvir 1964).

Control. Infested canes should be pruned and those broken and lying on the ground collected during winter and early spring (before May) and destroyed (Herrick 1935, Mutchler and Weiss 1922). Insecticides may be needed to protect commercial and ornamental plantings.

Eupristocerus cogitans Weber

[alder gall buprestid] (figure 104)

Hosts. Alder, birch. Speckled alder is the only living host known, but the species has been recorded from dead river birch (Knull 1920, 1930).

Range. A little-known species recorded in the eastern United States from Vermont and New Hampshire south to Florida, west to Mississippi and Michigan, and in Ontario and New Brunswick (Bright 1987, Capelouto 1949, Nelson and others 1981, Wellso and others 1976).

Description. ***Adult.*** Small, oval, cop-

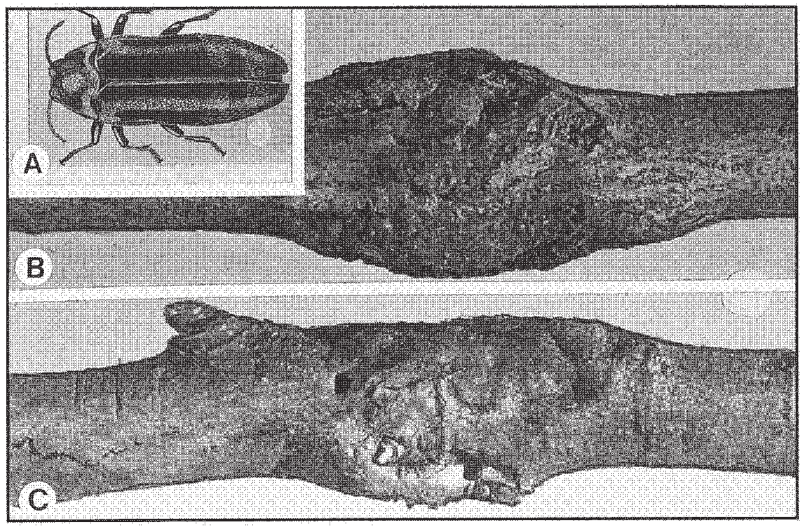

Figure 104—Eupristocerus cogitans, *[alder gall buprestid]: A, adult; B, gall-like swelling on alder; C, D-shaped emergence hole on side of swelling (reproduced from Knull [1925]).*

pery black beetle, measuring 8 to 9 mm long (figure 104A) (Franklin and Lund 1956, Knull 1925). Head and thorax cupreous, and the thorax twice as wide as long. Elytra black, rounded from middle to apices, with two transverse apical pubescent spots united along the lateral margins.

Biology. Adults oviposit at rough spots on the bark or near a node on the plant (Knull 1920). Eggs hatch, and the young larvae bore beneath the bark, where they move down the stem for a short distance. They encircle the stem, which causes swollen areas or galls to develop. Mature larvae prepare pupal cells at the top of the galls. Development requires 2 years.

Injury and damage. Galls on small stems of hosts are evidence of infestation (figure 104B) (Knull 1925). Dissection of the galls and surrounding bark reveals the burrows and larvae. Emerging adults leave small D-shaped holes in the bark at the uppermost part of the galls (figure 104C). The species apparently is of little importance.

Control. Controls have not been needed.

Chrysobothris femorata (Olivier)

flatheaded appletree borer (figure 105)

Hosts. Pecan, hickory, apple, pear, peach, apricot, plum, cherry, quince, currant, walnut, poplar, willow, beech, chestnut, oak, elm, hackberry, sycamore, mountain-ash, serviceberry, hawthorn, redbud, maple, horsechestnut, linden, persimmon, boxelder. Maple, apple, and poplar are preferred hosts, but many other trees are also readily attacked.

Range. A pest of many deciduous trees from Mexico throughout the United States into Canada (Brooks 1919a, USDA FS 1985).

Description. ***Adult.*** Broad, oval, flattened beetle about 7 to 16 mm long (figure 105A) (Brooks 1919a, Moznette and others 1931). Metallic hued and indistinctly marked with dull gray spots and irregular bands. Underside coppery bronze and beneath the wings metallic greenish blue. ***Egg.*** Pale yellow, flattened, disk-like, wrinkled, and about 1.5 mm in diameter. Firmly attached to bark by their flat surfaces. ***Larva.*** Yellowish white, legless, and about 25 mm long fully grown (figure 105B). Three thoracic segments much broadened and compressed, giving larva appearance of having large flattened head, which accounts for its name. Within galleries, larvae nearly always assume shape of horseshoe. ***Pupa.*** Somewhat yellower than larva; resembles adult; 7 to 19 mm long.

Biology. Adults appear from March to November but are most abundant during May (Fenton 1942, Moznette and others 1931). Beetles, most active in full sunlight, run rapidly and take flight quickly when disturbed. On hot, clear days, beetles are found on the sunny sides of trunks and larger branches. Females spend much time running over the surface, probing the bark with their ovipositors for oviposition sites. Females mate and begin ovipositing in 4 to 8 days and live about a month. Females lay about 100 eggs each, depositing them singly in cracks or crevices of the bark, under bark scales, and at bark injuries. Eggs hatch in 8 to 16 days. Newly hatched larvae chew through the bark and feed in the phloem and surface

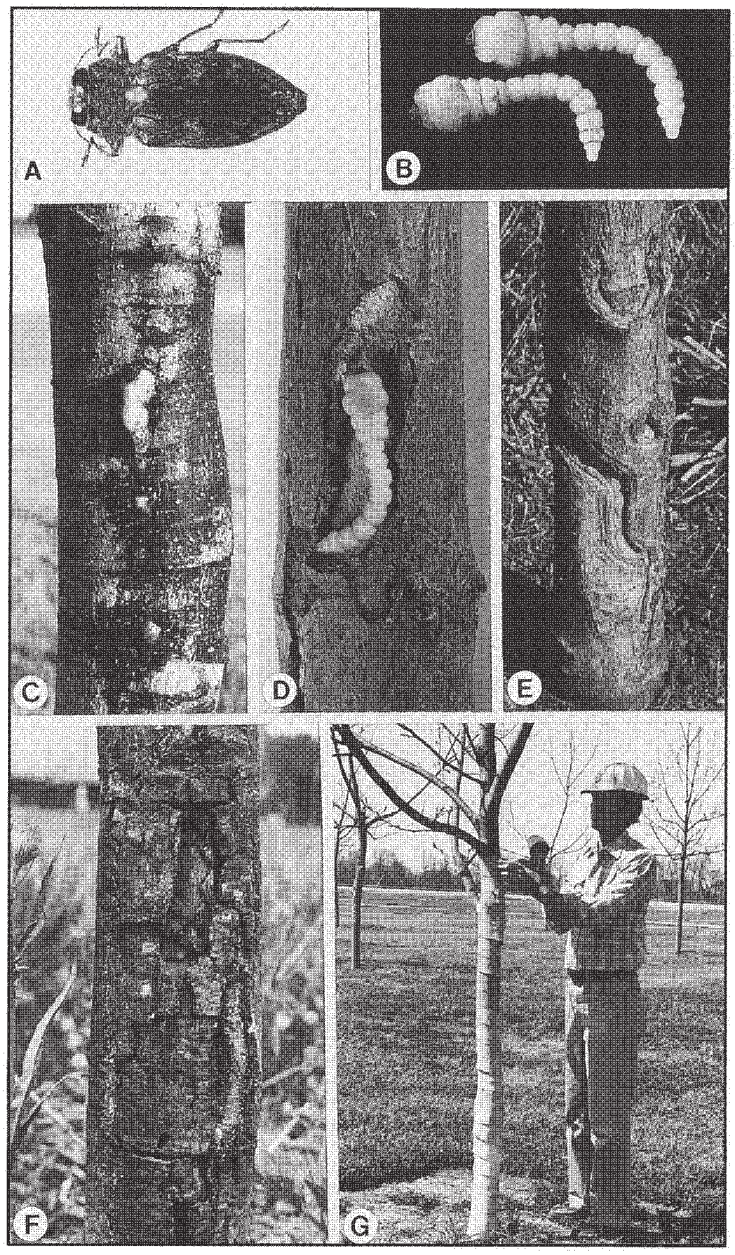

Figure 105—Chrysobothris femorata, *flatheaded appletree borer: A, adult; B, larvae; C, sap spot at borer attack site; D, bark removed to expose larval mine and larva; E, spiral gallery; F, sunken area of bark over mined area; G, wrapping trunk to protect from borer attack (E, courtesy D. Potter).*

of the sapwood. In sufficiently weak trees, larvae produce long torturous burrows and develop rapidly. In more vigorous trees, larvae develop slowly, and many die. As soon as larvae are fully developed, they tunnel from the cambium radially into the sapwood. Here, they prepare pupal chambers by plugging the burrows tightly with frass and pass the winter still as larvae within the pupal chambers. Larvae pupate for 8 to 14 days in spring or early summer. Adults emerge by cutting oval emergence holes through the bark (figure 105F). In most areas, one generation is produced per year, but in some areas, the species requires 2 to 3 years.

Injury and damage. Points of infestation can usually be detected by white, frothy sap oozing from cracks in the bark (figure 105C) (Brooks 1919a, Fenton 1942, Moznette and others 1931). Bark gradually becomes darkened, wet, and greasy in appearance. Little or no frass is ejected except at cracks in the bark. Attacks occur on both trunks and branches and are most common on the sunny aspect of trees. Burrows under the bark are broad and irregular and packed tightly with fine, sawdustlike frass (figure 105D). In young trees with thin bark, tunnels are usually long and winding, sometimes encircling the tree (figure 105E). Injured areas usually become depressed, and later the bark may split at injured sites (figure 105F). In older trees with thick bark, burrows are confined to a circular area within the bark. Wounds may be enlarged by succeeding generations. This borer generally attacks trees that have recently been transplanted, stressed, or whose bark has been damaged by tools, disease, rodents, sunscald, or other insects. Leaning and drought-stressed trees are especially attractive to beetles. Injury results from larvae tunneling in the bark and cambium. Trees 5 cm or less in diameter may be girdled and killed, and larger trees may be severely weakened and scarred. Because wooded tracts often harbor large populations, damage is usually most prevalent when plantings are close to woodlands or old declining orchards.

Control. Twelve species of hymenopterous parasites help to reduce infestations (Krombein and others 1979). Predators include the insects *Andrenosoma fulvicauda* Say, *Chariessa pilosa* Forester, and *C. pilosa onusta* Say and woodpeckers. Because flatheaded borers rarely injure healthy trees, it is most important to practice cultural methods that will keep trees vigorous (Brooks 1919a, Fenton 1942, Moznette and others 1931, USDA FS 1985). Because young transplanted trees are stressed and particularly susceptible, additional measures may be warranted such as wrapping the trunks (figure 105G) or shading them from sunlight. Painting trunks white to reduce sunscald may also help. Borers can be physically removed from individual trees, but unnecessary cutting and damage should be avoided. Dead and dying trees and pruned branches should be removed from ornamental and orchard plantings to reduce breeding sites for the beetles. Chemical control may occasionally be required.

Chrysobothris mali Horn

Pacific flatheaded borer (figure 106)

Hosts. Alder, birch, ash, ceanothus, oak, boxelder, mahogany, maple, poplar, sycamore, willow, apple, pear, beech, elm, cotoneaster, peach, plum, avocado, loquat, cherry, currant, fig, apricot. At least 70 species belonging to 40 genera in 21 plant families have been reported as hosts (Burke and Boving 1929). Sycamore, mahogany, ceanothus, and fruit and nut trees seem particularly susceptible (Davis and others 1968, Essig 1929).

Range. Widely distributed throughout western North America west of the Rocky Mountains from California to British Columbia and Manitoba (Burke and Boving 1929, Fisher 1942). Its economic effects are particularly felt in California.

Description. ***Adult.*** Dark bronze to reddish copper beetle with distinct copper spots on the elytra; 6 to 11 mm long (figure 106A). ***Egg.*** About 1 mm in diameter, subcircular or disk-like, and yellowish white (Brown and Eads 1965a). Form of egg varies with the crevice or depression in which they are laid (Burke and Boving 1929). ***Larva.*** Varies from yellowish white to yellow and 15 to 18 mm long when mature (figure 106B). Thoracic segments—not head, as name implies—greatly enlarged and flattened. Abdomen bent back, making larva look like hook when exposed in feeding burrow. ***Pupa.*** Translucent white when first formed, dark bronze near adult emergence, and 6 to 11 mm long (Brown and Eads 1965a).

Biology. Adults emerge from April through August but mostly in June and July. Soon after emergence, mating and egg-laying begin (Brown and Eads 1965a). Eggs are deposited singly but may be laid close enough together to form clusters. The eggs are usually deposited in bark crevices or depressions (Burke and Boving 1929). During eclosion, larvae bore through the bottoms of their egg shells directly into the bark. Most larvae reach maturity by September or October, construct pupal chambers in the heartwood, and then molt into the last larval instar. Borers overwinter as prepupae. Pupation occurs mid-March into June, with most larvae pupating between mid-April and mid-May. Adults emerge in the pupal cells and chew their way to the outside. Usually, there is one generation per year, but the life cycle may be longer at higher elevations and in its northern range (Brown and Eads 1965a).

Injury and damage. The first evidence of feeding is usually dark wet spots on the bark, which may later crack slightly and expose borings (Burke and Boving 1929). Some tree species, especially those in the genus *Prunus*, show a slight flow of gum from the affected area. Little (sometimes no) frass is ejected to the outside, but as they burrow, larvae pack it behind them within mines. The area around and over the wound often becomes roughened (figure 106C). Feeding burrows are winding, shallow mines in the inner bark and outer wood of the tree (figure 106D). Mines, oval in cross section, sometimes spiral and girdle branches or the trunks of small trees (figure 106E). Mines end in the outer wood

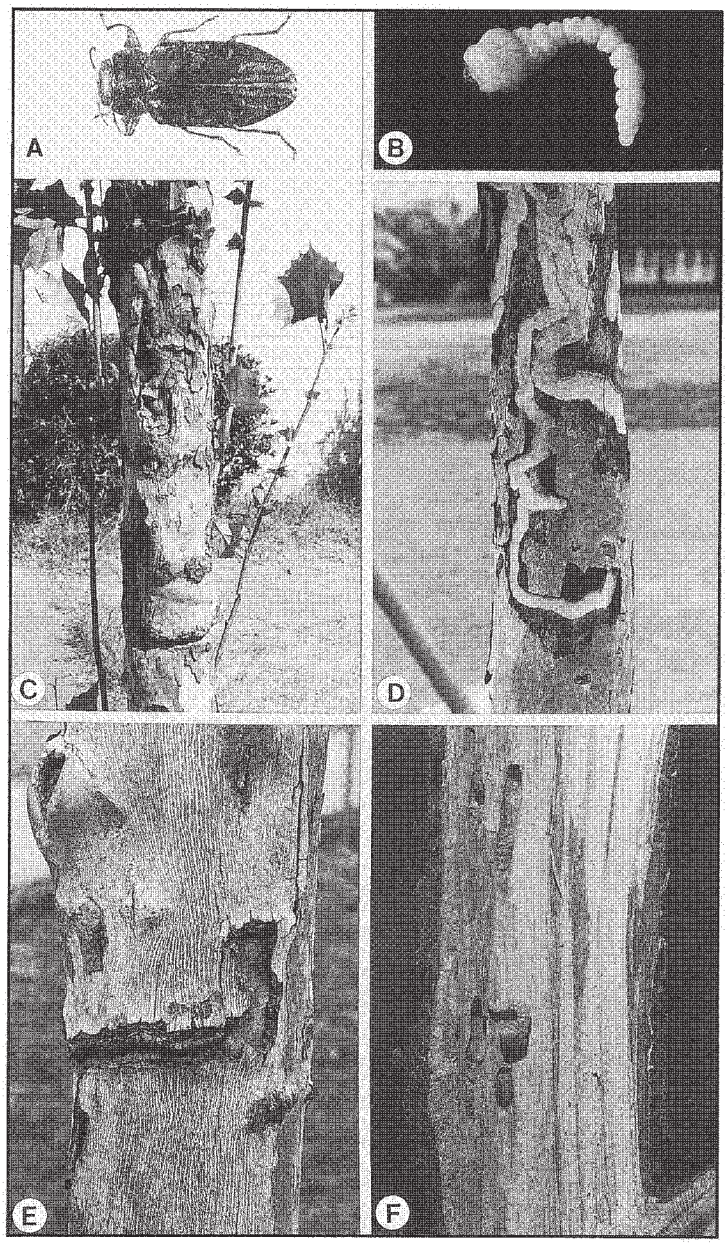

Figure 106—Chrysobothris mali, *Pacific flatheaded borer: A, adult; B, larva; C, roughened bark over previous attacks on sycamore; D, wide, winding galleries on surface of sapwood; E, bark scar; F, galleries extending into wood (A & B, specimens courtesy D. Whitehead).*

(figure 106F) in pupal cells that open to the surface through oval exit holes. Usually, bark over the tunnel cracks and peels, but thick bark may not crack. Either a ridge or a depression may occur in the bark over a tunnel. After larvae mine extensively, the bark often loosens and drops away, leaving ugly cankerlike spots. Larval feeding may occur in any part of the bark from the roots to the tree top; however, feeding typically occurs in the main trunk, especially in smaller trees. The extent of damage to the tree is related to the location in the tree of feeding sites and often to whether or not the borers encircle and girdle the branch or trunk. This borer is considered one of the most damaging pests of newly planted deciduous trees. It is an important pest in nurseries, where trees may be killed or so severely injured that their value is diminished. Also, shade, fruit, and nut trees may be killed or disfigured. In native forests, branch mortality is common, but the insect rarely kills an entire tree (Burke and Boving 1929).

Control. Five species of larval parasites have been found—two braconids, one chalcid, one ichneumonid, and one tetrastichid (Burke and Boving 1929). The chalcid *Trigonura californica* Rohwer is the most important parasite, being found in 29 of 151 infestations studied. A chalcid egg parasite has also been found, but little is known of its effectiveness. A mite—*Pediculoides ventricosus* Newport—the most important predator, was reported to destroy a high proportion of the developing brood in heavily infested plants in California. Field observations suggest that birds remove immature stages of the borer from infested trees. Control can be enhanced by cultural practices that encourage vigorous, healthy plants. Young transplanted trees can be protected by mechanical covers over the trunks. Mechanically removing larvae is an effective control for valuable trees. Sanitation practices include removing weakened, injured, dying, and dead trees from the area. Chemical controls are sometimes needed to protect valuable plantings (Davis and others 1968).

Chrysobothris bacchari Van Dyke

[coyote brush buprestid]

Hosts. Baccharis. Coyote brush seems to be the principal host, but other *Baccharis* spp. reportedly have been attacked (Benoit 1966, Chamberlin 1926, Essig 1929).

Range. A western species with very limited distribution, being reported only from California (Benoit 1966, Fisher 1942).

Description. ***Adult.*** Broadly elongate beetle strongly depressed or flattened and bronzy brown (Fisher 1942). Head coppery and slightly greenish along anterior margin of clypeus. Beneath, brownish copper and much shinier than above. Elytra slightly wider at base than pronotum and nearly twice as long as wide. From 8.5 to 11.0 mm long and about 3.8 mm wide. ***Larva.*** Whitish and about 9 to 17 mm long (Benoit 1966). Thoracic segments greatly broadened and compressed, giving appearance of large flattened head. Separated from related species by thoracic spiracles in longitudinal rows and toothless prothoracic asperities.

Biology. Adult beetles emerge and are present from April through July (Fisher 1942). Females deposit eggs on the bark of host plants. The larvae bore into the cambium where they feed and develop.

Injury and damage. Larvae bore in healthy, injured, and dead hosts (Essig 1929). Weakened and dying plants within the borer's range suggest infestation. Removal of the bark reveals the frass-packed mines and the flatheaded larvae within them. Because host plants are used only occasionally as food by wildlife and because of the insect's limited range, its economic significance is limited.

Control. Controls are not needed.

Chrysobothris gemmata LeConte

[purple mesquite buprestid]

Hosts. Mesquite. Only known host is mesquite (Essig 1929, Fisher 1942).

Range. A southwestern species of limited distribution, reported only from Arizona, New Mexico, and Mexico (Fisher 1942, Horn 1886).

Description. ***Adult.*** Moderately elongate, robust beetle about 19 to 22 mm long (Essig 1929, Fisher 1942, Horn 1886). Purple to violet with greenish reflections above and bright green with purplish reflections below and on sides. Antennae purplish black except for three basal segments bronzy green. Elytra slightly wider at base than pronotum and about twice as long as wide.

Biology. Adults are present in August (Fisher 1942). Females deposit eggs on the bark. Larvae mine and feed in the bark, sapwood, and heartwood, sometimes girdling the tree (Burke 1918, Essig 1929, Fisher 1942). Wood may be severely damaged.

Injury and damage. This buprestid attacks living, dying, and dead trunks and limbs of hosts and often kills parts or even the entire tree (Burke 1918, Essig 1929). Dying and recently killed plants are signs of infestation. Removing bark reveals frass-filled burrows in the bark and wood and often larvae within mines.

Control. Controls have not been needed.

Chrysobothris merkelii Horn

[merkel buprestid]

Hosts. Acacia, mesquite, ebony, guajillo. Has been reared from catclaw, honey mesquite, ebony, and Gulf Coast guajillo (Essig 1929, Fisher 1942, Vogt 1949a).

Range. A southwestern species occurring in Texas, New Mexico, Arizona, and California (Essig 1929, Fisher 1942).

Description. ***Adult.*** Broadly elongate and rather robust beetle (Fisher 1942, Horn 1886). Blackish with faint purplish or bronzy reflection and strongly shiny. Antennae brownish copper to bronze in female and reddish copper in male. Beneath, copper with greenish tinge. Beetles range from 15.0 to 19.5 mm long.

Biology. Adults emerge from April to August (Fisher 1942). Females deposit eggs on the bark of weakened host plants. Larvae tunnel the bark, sapwood, and heartwood of susceptible hosts (Burke 1918, Fisher 1942).

Injury and damage. Weakened, dying, and recently killed plants within the insect's range provide evidence of infestation; often

kills weakened trees (Burke 1918). Frass-filled mines and larvae within the burrows can be found in infested plants. Except where host plants provide food and protection for wildlife, the pest is of negligible importance.

Control. Controls have not been needed.

Descarpentriesina cyanipes (Say)

[eastern poplar buprestid] (figure 107)

Hosts. Poplar, willow. Has been reared from eastern cottonwood, black cottonwood, quaking aspen, bigtooth aspen, and willow (Chamberlin 1926, Evans 1957, Wellso and others 1976). Beetles have been collected from ash, sycamore, and pine, but it is unlikely that these serve as larval hosts.

Range. The most common and widely distributed member of *Descarpentriesina* in North America. Recorded from southern Arizona northward along the Rocky Mountains to the Yukon, eastward to New Brunswick, and southward to the Gulf Coast; it does not occur along the Pacific Coast (Chamberlin 1926, Evans 1957).

Description. ***Adult.*** Elongate to moderately slender, somewhat oval, dark bronze beetle (figure 107A) (Chamberlin 1922, Evans 1957). Head sparsely covered with fine pubescence and slightly flattened along with pronotum. Elytra with dark bluish bronze, abbreviated, elevated, irregular lines tinged with coppery bronze. Females slightly broader and darker than males. Beetles 9.3 to 18.0 mm long and 3.25 to 7.00 mm wide. ***Larva.*** Clublike or pestlelike in shape with thoracic segments and head moderately flattened (figure 107B) (Burke 1917a). Thoracic plates smooth and marked dorsally with inverted V, and ventrally with one groove (USDA FS 1985). Larvae yellowish white with dark brown heads, measuring 17.8 to 25.4 mm long.

Biology. Adults emerge late April through June in its southern range but have been taken in flight as late as August and September in its northern range (Essig 1929). On sunny days, adults are frequently found resting, crawling, and ovipositing on host trees. Females prefer weakened stems for oviposition. It has also been reared from galls of *Saperda concolor* LeConte in aspen and from galls of *Agrilus criddlei* in willows (Chamberlin 1922, Wellso and others 1976). Larvae initially excavate small cavities just under the bark, then extend their galleries into the wood usually to the pith of stems up to 25 mm in diameter. In large stems, most larvae burrow to about 12 mm then continue longitudinally. Larvae overwinter within their galleries. Mature larvae prepare chambers typically at one end of the galleries and pupate. New adults gnaw exit holes directly through the bark to emerge. A generation is completed in 1 to 2 years (USDA FS 1985).

Injury and damage. This beetle commonly attacks stems 12 to 32 mm in diameter, but it is occasionally found in stems up to 75 mm in diameter. The earliest evidence of injury is small wet or stained spots on the bark. Little or no frass is ejected from the sites. The bark sometimes cracks open (figure 107C), exposing a frass-packed cavity just beneath. Galleries are oval to irregular in cross section and 6.4 mm in

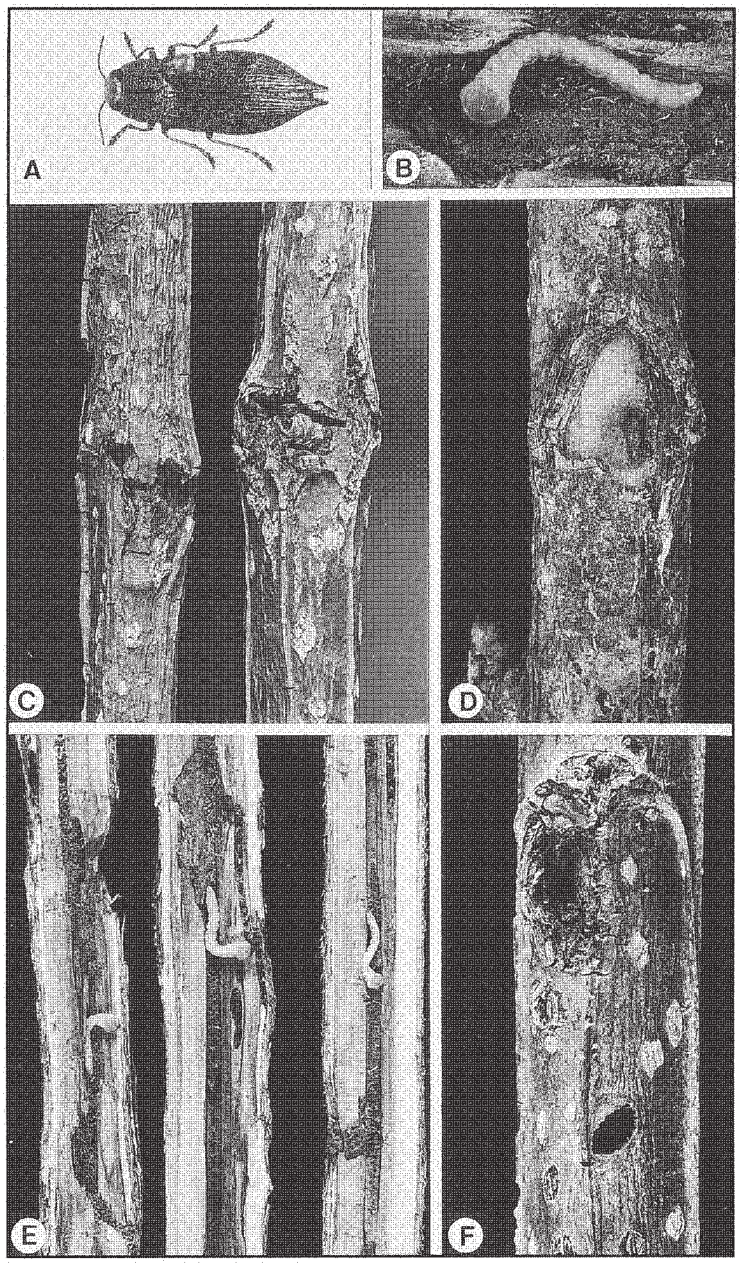

Figure 107—Descarpentriesina cyanipes, *[eastern poplar buprestid]: A, adult; B, larva; C, bark cracked and loosened at points of attack; D, cambial cavity and oval entrance into wood; E, stems split exposing galleries and larvae; F, oval exit hole in bark.*

diameter, extend 6.4 to 12.7 mm into the wood (figure 107D), and run 5 to 30 cm longitudinally within the stem (figure 107E). Galleries are almost entirely filled and packed tightly with a frass mixture of fine particles and short fibers. Oval-elongate exit holes (figure 107F) 2.3 to 4.8 mm across can be found in the bark after beetles emerge. Healed wounds leave irregularly shaped scars over the entrances and small oval to round scars over the exit sites. Beetles usually attack wild and ornamental trees that are weakened, injured, or decadent. In its southern range, this buprestid prefers the lower branches of cottonwoods that are weakened, dying, or being shaded out and self-pruned (Solomon and Wellso 1983). This borer rarely attacks boles of healthy trees and is found largely in weakened branches, so it might even be considered beneficial in helping the tree to self-prune its lower branches, thereby improving the quality of the wood.

Control. Light incidence of woodpecker predation has been observed, but no parasites have been found. Maintenance of high vigor in ornamental and other high-value trees can prevent infestation. Direct controls have not been needed.

Descarpentriesina californica Chamberlin

[western poplar buprestid]

Hosts. Poplar. Quaking aspen and cottonwood recorded as hosts (Barr 1971, Evans 1957). Other *Populus* species probably serve also.

Range. A western species from Oregon and California, east into the Rocky Mountains of Idaho, Nevada, and Utah (Chamberlin 1922, Doane and others 1936, Evans 1957).

Description. ***Adult.*** Moderately broad, robust beetle of medium size, 9 to 18 mm long and 3.9 to 7.8 mm wide (Barr 1971, Chamberlin 1922, Evans 1957). Vary from gray brown to dark bronze to almost black. Coppery green head and antennae dark coppery blue green. Elytra usually coppery bronze with elongate raised greenish areas. Females typically slightly larger, more robust, and darker than males.

Biology. Adults emerge during June and July (Chamberlin 1922). Larvae mine under the bark and into sapwood and heartwood, extending galleries much more horizontally than vertically, sometimes to the center of the tree. In most cases, infested trees remain thrifty despite the burrowing.

Injury and damage. Burrows typically cause small patches of bark to turn black, split, and peel away (Chamberlin 1922). Swellings sometimes develop on the trunk over tunnels. Oval exit holes are left in the bark by emerging beetles. The insect is much more likely to attack small trees than old large trees. Occasionally, small trees may be girdled and killed. This borer prefers trees growing at relatively high altitudes. Overall, it causes some damage to individual trees, but entire stands suffer little.

Control. Two unidentified hymenopterous parasites have been reared (Chamberlin 1922). Direct controls have not been needed.

Descarpentriesina thureura (Say)

[eastern willow buprestid]

Hosts. Willow. Black willow is a specific host, but other willow species probably also serve as hosts (Evans 1957).

Range. Widely distributed from the Atlantic Coast west to eastern Arizona and north to Manitoba (Evans 1957).

Description. ***Adult.*** Stout, oblong-oval, slightly flattened beetle (Casey 1909, Chamberlin 1922, Evans 1957). Color varies from dark metallic blue green to coppery brown, brassy green, or bronzy copper. Elytra with numerous small shiny greenish spaces that coalesce in some areas, forming irregular patches and giving mottled appearance. Elytral apices short compared to most members of genus. Range from 12.0 to 18.8 mm long and 4.9 to 7.8 mm wide.

Biology. Adults begin emerging in May and are present until August (Chamberlin 1926, Knull 1922). Females oviposit on the trunks of hosts (Knull 1922). Larvae burrow between the inner bark and outer sapwood but do not travel through the wood as do some related species. Instead, they remain near where the eggs were laid, because the callus of the tree provides sufficient nourishment. At maturity, the larvae form pupal cells surrounded by frass. A generation requires at least 2 years.

Injury and damage. Rough bark scars and oval emergence holes in the bark are evidence of infestation. Bark removal and dissection will reveal that burrows remain local and are not extensive as in other species of this genus (Evans 1957, Knull 1922). Pupal cells surrounded by frass can be found between the bark and sapwood. This borer appears to cause little economic loss.

Control. Controls have not been needed.

Dicerca lepida LeConte

[embossed hawthorn buprestid] (figure 108)

Hosts. Hawthorn, hophornbeam. Hawthorn is the favored larval host (Knull 1922, Nelson 1975). Adults collected on oak and elm, but these species probably do not serve as larval hosts (Nelson 1975).

Range. New York and Pennsylvania south to Georgia and Alabama and west to Kansas, Texas, and New Mexico (Franklin and Lund 1956, Nelson 1975).

Description. ***Adult.*** Slightly elongate, moderately convex beetle, lustrous, brassy to coppery above and below, with conspicuous smooth black areas (figure 108A) (Nelson 1975). Head flattened, slightly impressed, and short antennae, with apical triangular joints that do not reach middle of pronotum. Elytra slightly wider than pronotum at base, widest at middle, then tapered to weakly prolonged bidentate apices. Adults 13.5 to 17.5 mm long and 4.5 to 4.8 mm wide. ***Larva.*** Elongate, clublike, and white except for dark brown mouthparts and light amber thoracic plate; measures 20 to 25 mm long (figure 108B). Thorax, especially prothorax, noticeably widened and moderately flattened.

Biology. Adults are in flight from March 27 to August 15 (Knull 1922, Nelson 1975). Females oviposit at dead branch stubs and partially healed wound sites. Larvae burrow downward at an angle and extend their

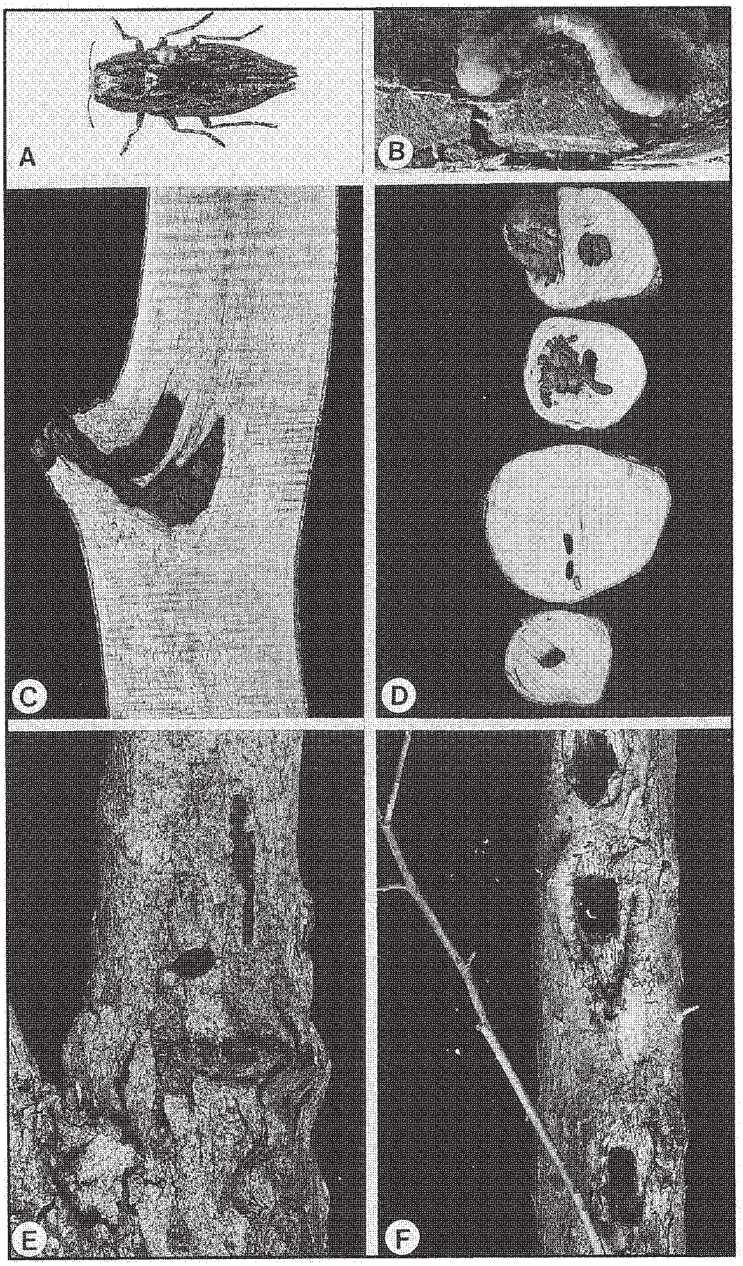

Figure 108—Dicerca lepida, *[embossed hawthorn buprestid]: A, adult; B, larva; C, gallery entrance at branch stub in hawthorn; D, cross section of frass-packed galleries; E, adult emergence hole; F, signs of woodpecker predation of larvae.*

galleries into the living wood. After burrowing 1 to 3 cm, many larvae turn upward for another 1 to 3 cm. Some burrows are cave-like with two or more short extensions. Pupation occurs near the ends of the burrows. New adults cut exit holes to the outside, usually within 1 to 4 cm of the entrance sites. Adults reportedly have been found hibernating around the bases of hawthorn trees (Knull 1922).

Injury and damage. This buprestid attacks trunks and branches 2 to 12 cm in diameter and nearly always in stems with surface defects. Infested trees exhibit little outward evidence, making active attacks difficult to diagnose. Most attacks are found in wood beneath dead branch stubs, but some occur in stems that have mechanical wounds and other bark injuries. Gallery patterns vary in shape but usually extend in and downward, then turn upward with the wood grain (figure 108C). In cross section, the galleries are mostly flattened and oval (figure 108D). Portions of galleries are packed tightly with fine reddish brown frass. Oval emergence holes 5 by 3 mm in the bark mark the infested sites (figure 108E). This species is recorded mostly from dead trees (Franklin and Lund 1956, Knull 1922); however, it is found commonly in living hawthorn in Mississippi. Attacks in living trees usually are associated with defects on the trunk. Damage is not serious.

Control. Woodpeckers have been observed preying on the larvae in hawthorn in Mississippi (figure 108F). One hymenopterous parasite—*Sclerodermus carolinensis* (Ashmead)—has been recorded (Carlson 1979).

Dicerca pugionata (Germar)

[witch-hazel borer]

Hosts. Witch-hazel, ninebark. Witch-hazel seems to be the favored host (Knull 1920, Nelson 1975). Adults have been collected on speckled alder, which may serve as a larval host. Oak and maple have been mentioned as hosts, but are unconfirmed (Leonard 1928).

Range. Ranges from Massachusetts and New York south to Georgia and west to Indiana, Michigan, and Ontario (Blatchley 1910, Nelson 1975).

Description. ***Adult.*** Small, elongate beetle 11 to 15 mm long and 3.9 to 5.3 mm wide (Blatchley 1910, Nelson 1975). Strongly convex with flattened heads and vary from copper, to bronzed copper, to almost black in few specimens. Elytral apices elongate and pointed, bidentate, and more coppery (Crotch 1873). Antennae short, not reaching middle of pronotum.

Biology. Adults present and active from January to October (Franklin and Lund 1956, Leonard 1928, Nelson 1975). Females deposit eggs on the bark, and the larvae bore through the bark, where they mine, feed, and develop.

Injury and damage. Unlike other members of this genus, this beetle reportedly prefers to attack perfectly healthy plants (Knull 1920, Nelson 1975). Plants deteriorating in health or suddenly dying may be infested and should be examined for borers. Removing bark will reveal the granular, frass-packed galleries and the larvae. Witch-hazel is sometimes girdled and killed by the tunneling.

Control. Controls have not been needed.

Dicerca tenebrica (Kirby)

[poplar dicerca]

Hosts. Poplar. Poplars appear to be the only hosts; recorded from black cottonwood, narrowleaf cottonwood, quaking aspen, and bigtooth aspen (Graham and Harrison 1954, Nelson 1975). Willow listed as a host and boxelder mentioned, but these are doubtful (Stein and Kennedy 1972).

Range. Widely distributed throughout most of the United States, except possibly the Deep South, and throughout Canada, except Newfoundland (Nelson 1975).

Description. ***Adult.*** Robust, sculptured, metallic, elongate, moderately convex, brassy to black beetle of medium size, measuring 14.5 to 26.0 mm long and 4.5 to 9.0 mm wide (Furniss and Carolin 1977, Nelson 1975). Sometimes with bluish tint and appears coppery beneath. Elytra with small, inconspicuous, black raised areas and prolonged and narrow tips.

Biology. Adults are present from March to November (Nelson 1975). Females lay eggs mostly during July and August on rough bark around branches and branch stubs (Graham and Harrison 1954). Adults are sunloving and prefer to oviposit on open-grown trees with the trunks exposed to sunlight. Larvae bore down through the bark to the sapwood and, unlike the *Agrilus* species, make rather large openings in the bark. Burrows are elliptical in cross section and packed with granular frass (Stein and Kennedy 1972).

Injury and damage. Larvae bore under the bark and into the wood of trunks and branches (Furniss and Carolin 1977, Graham and Harrison 1954). Wounded, sickly, dying, and recently dead trees are apt to be attacked. Adults make rather large oval openings in the bark for emergence. This borer has been directly associated with hypoxylon canker and decadence of poplars in the North (Graham and Harrison 1954). In fact, many of the cankers on quaking aspen and bigtooth aspen in low-quality stands have been attributed to this borer.

Control. Cultural practices that help to keep trees vigorous and healthy help to minimize infestation and losses.

Texania campestris (Say)

[hardwood heartwood buprestid]
(figure 109)

Hosts. Sycamore, beech, willow, maple, yellow-poplar, basswood, oak. Sycamore and beech seem to be principal hosts; other species are attacked to a lesser extent (Burke 1909, Champlain and Knull 1925, Knull 1920, USDA FS 1985).

Range. Found throughout the eastern and southern United States (Blatchley 1910, Burke 1909). Previous references to this species are found under the genus name *Chalcophorella*.

Description. ***Adult.*** Large, oval-shaped beetle, 18 to 33 mm long and 6 to 9 mm wide (figure 109A) (Blatchley 1910, Burke 1909). Grayish bronze with greenish cast above and polished copper or bronze beneath. Antennae reach to posterior margin of pronotum. Thorax with median groove and elytra with fine raised lines. Elytra strongly serrate near tips. ***Larva.*** Slender; thoracic segments enlarged; and

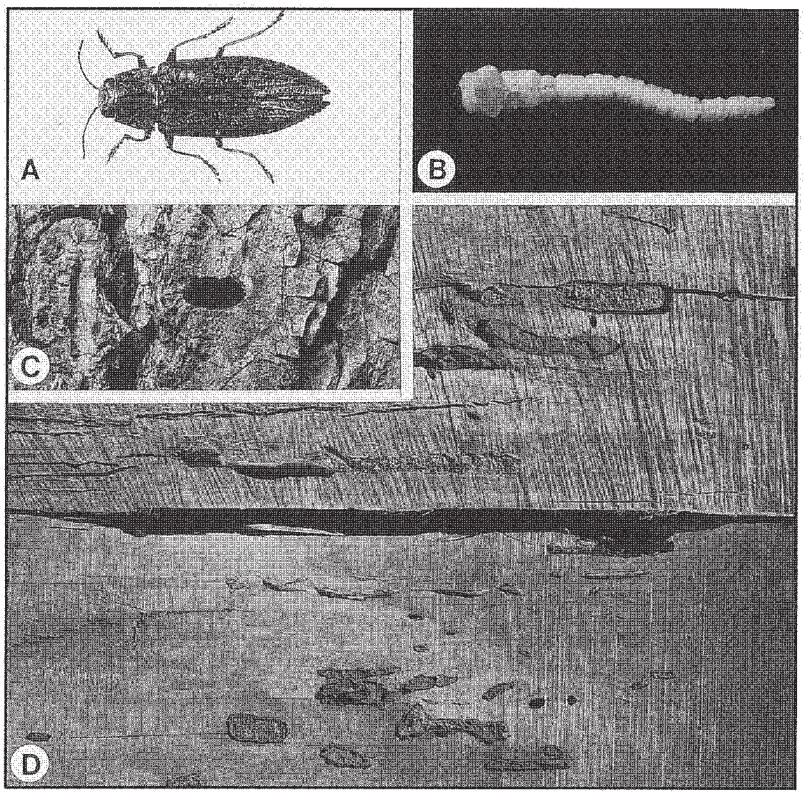

Figure 109—Texania campestris, *[hardwood heartwood buprestid]: A, adult; B, larva; C, large oval adult emergence hole; D, large frass-packed galleries in wood.*

measures about 62 mm long and 9 mm wide (figure 109B). Black mouthparts, brownish elevations on thoracic plates, and V-shaped mark on dorsal plate.

Biology. Adults emerge from April to July (Blatchley 1910). Larvae bore through the bark and make winding galleries into sapwood and heartwood (Burke 1909). Mines are broad, flattened, slightly oval, up to 9 mm wide, and packed with frass. Galleries terminate in large, open pupal cells, usually near the surface of the wood. Pupal and adult stages apparently transform in late fall and winter, and new adults emerge during spring and summer.

Injury and damage. Oval emergence holes in the bark, particularly around wounds, are evidence of infestation (figure 109C) (Burke 1909). Cross sections reveal extensive flattened-oval galleries packed tightly with fine frass in both the sapwood and heartwood. (figure 109D). Infestations often begin around wounds and sometimes riddle the wood beneath (USDA FS 1985).

Control. Cultural practices that prevent bark wounds and promote tree vigor help to minimize infestations (Burke 1909).

Ptosima gibbicollis Say

[flatheaded redbud borer] (figure 110)

Hosts. Redbud. Eastern redbud is the only known larval host; however, adults have been taken on sassafras and black cherry (Knull 1920, Nelson 1978).

Range. Occurs from Pennsylvania south to Georgia and west to Kansas and Texas (Knull 1920, Nelson 1978).

Description. ***Adult.*** Elongate, oval, subcylindrical, moderately robust, slightly flattened beetle, dark blue maculated with yellow (figure 110A) (Knull 1925, Nelson 1978). Prothorax pubescent and wider than long with elevated ridge on each side. Each elytron with large, oblong, yellow spot on side reaching from base to beyond middle and smaller transverse spot on apical third. Beetles small, ranging from 6 to 8 mm long.

Biology. Adults overwinter in pupal chambers, emerge the following spring, and are in flight from March to July (Knull 1920, Nelson 1978). Larvae hatch from eggs deposited on the bark and bore into the bark and wood. They feed, tunnel, and develop mainly in the heartwood. Pupation occurs in fall in shallow chambers in the sapwood (figure 110B).

Injury and damage. This insect bores into the stems of healthy, stressed, weakened, dying, and recently cut trees. Infestations are difficult to detect from bark surface examination. Cutting into bark and wood exposes small flattened-oval galleries packed tightly with frass meandering through the wood. In cross section, the galleries with light-colored frass in the heartwood are readily visible (figure 110B). Oval holes may be found in the bark after development is complete and the adults exit. It reportedly hastens the death of living trees and promotes the decay of cut stems (Knull 1920).

Control. Evidence of woodpecker predation has been observed. Direct controls have not been needed.

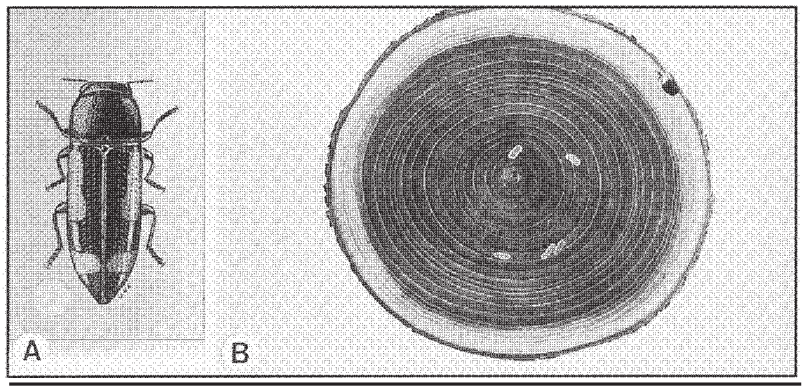

Figure 110—Ptosima gibbicollis, *[flatheaded redbud borer]: A, adult; B, cross section of redbud showing small oval frass-packed galleries in heartwood and pupal cell in outer sapwood at upper right (A, reproduced from Knull [1925]).*

Family Bostrichidae—False Powderpost Beetles

The bostrichids are best known for their damage to felled timber and unseasoned roundwood with the bark on; however, a few attack and oviposit in weakened living trees (Fisher 1950, USDA FS 1985). Some species have the damaging habit of tunneling into green shoots and branches for food or hibernation. Three species with these habits are covered here. Adults are elongate, cylindrical, and the head is not easily seen from above. They resemble the scolytids but can be distinguished by their rasp-like pronotum, straight instead of elbowed antennae with a three- or four-segmented club, and five-segmented tarsi. The larvae are white to yellow and curved with globular head and three pairs of five-jointed legs.

Genus and Species

Amphicerus
bicaudatus (Say) *284*
Xylobiops
basilaris (Say) *286*
Melalgus
confertus (LeConte) *288*

Amphicerus bicaudatus (Say)

apple twig borer (figure 111)

Hosts. Apple, peach, plum, cherry, pear, apricot, Osage-orange, ash, butternut, pecan, hickory, maple, grape. Apple and grape appear to be favored hosts, but many other trees, especially fruit- and nut-producing trees, are readily attacked (Banks 1902, Fisher 1950, Munro and Riddle 1930).

Range. Throughout the eastern United States west to the Rocky Mountains in Colorado and New Mexico and also in southern Canada (Essig 1929, Fisher 1950).

Description. ***Adult.*** Elongate, cylindrical beetle, about 6 to 13 mm long and 1.2 to 3.5 mm wide (figure 111A) (Dean 1920, Fisher 1950). Color uniform for individuals but varies among beetles from reddish brown, dark chestnut brown, brownish black, to almost black (Fisher 1950, Gossard 1913, Lugger 1889). Dorsal surface of body with sparse, short, recumbent, yellowish hair. Males with two small hornlike tubercles projecting forward on thorax and a smaller tubercle on rear of each elytron. ***Larva.*** White with brown head and mandibles, curved body, three pairs of thoracic legs, thoracic segments enlarged; mature larva about 10.2 mm long (figure 111B) (Slingerland and Crosby 1919).

Biology. Adults emerge in early spring and deposit eggs from April to June in the bark of twigs and small branches (Munro and Riddle 1930, Slingerland and Crosby 1919). Young larvae burrow into the twig, usually to the pith, and tunnel along the stem, packing the frass behind themselves through the summer. Larvae mature and pupate in fall and early winter. Many pupae transform to adults in fall. Adults usually hibernate head downward in the larval galleries through winter. Some adults emerge in fall and move to new, living twigs where they burrow in and overwinter. This twig borer has one generation per year.

Injury and damage. The insect breeds in injured, diseased, dying, and recently

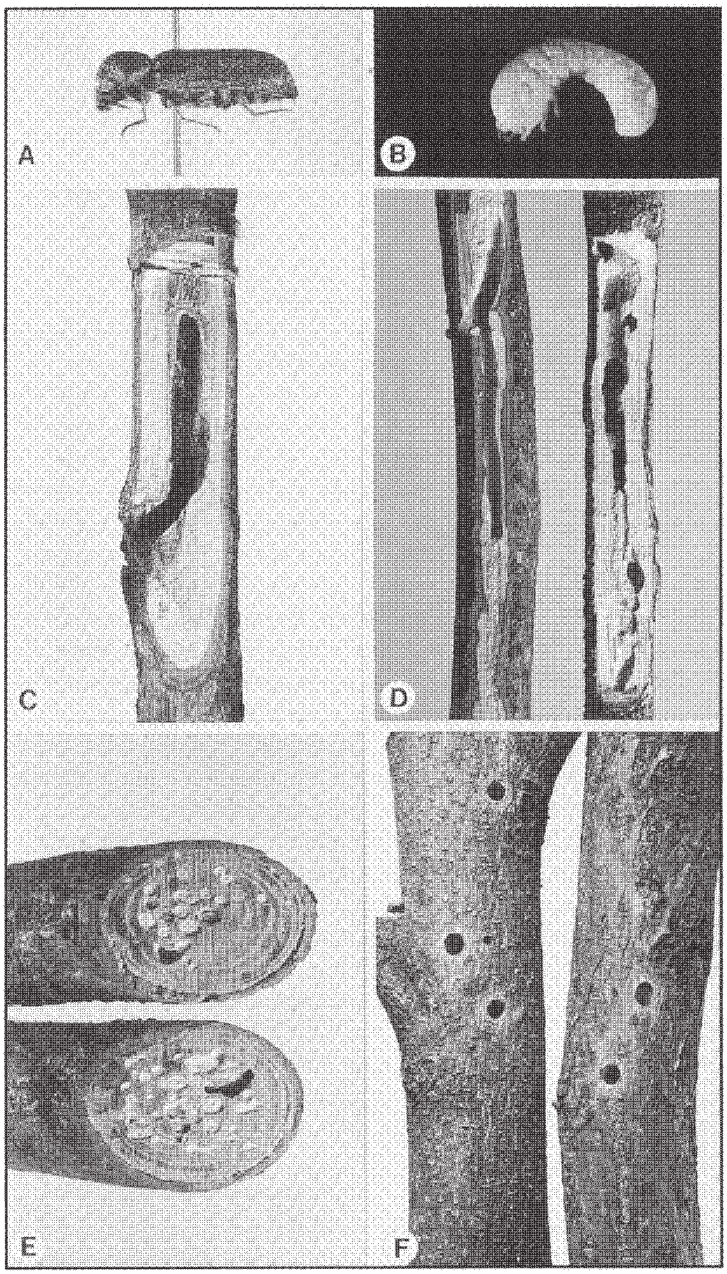

Figure 111—Amphicerus bicaudatus, *apple twig borer: A, adult; B, larva; C, hibernation tunnel made by adult beetle in pecan branch; D, longitudinal view of larval galleries; E, cross section of larval galleries packed with frass; F, adult exit holes.*

dead trees (Munro and Riddle 1930, Slingerland and Crosby 1919). However, adult beetles bore into living healthy branches to feed and shelter, usually killing them. Twigs and branches of living hosts may wilt, droop, and die back. Examination of twigs reveals single round entrance holes 3.5 mm in diameter immediately above buds. Dissecting the stem reveals tunnels 5 to 8 cm long, usually extending downward, but sometimes extending up or down or both from entrance holes (figure 111C). A beetle may be found in the tunnel from late fall through winter and spring and sometimes until early summer (Dean 1920, Slingerland and Crosby 1919). Dissection of diseased, dying, and dead infested material reveals larval burrows (figure 111D) 8 to 10 cm long, packed with powderlike frass (Slingerland and Crosby 1919). Heavily infested twigs and branches are sometimes converted to powdered frass (figure 111E). Round exit holes 3.5 mm in diameter are left in the bark by emerging beetles (figure 111F). Occasionally, fruit and ornamental trees, shrubs, and vines have suffered noticeable dieback of small branches.

Control. Infested branches, broken limbs, and prunings should routinely be collected and destroyed (Dean 1920, Munro and Riddle 1930). Any wilted and dying branches with hibernating beetles should also be pruned and destroyed. In problem areas, favored wild hosts such as wild grape should be cut and destroyed. Chemical sprays occasionally may be needed to protect plantings. Two species of hymenopterous parasites—*Eusandalum amphi-cerovorum* (Ashmead) and *Ptinobius magnificus* (Ashmead)—have been reported (Burks 1979).

Xylobiops basilaris (Say)

[red-shouldered bostrichid] (figure 112)

Hosts. Hickory, pecan, persimmon, black locust, oak, redbud, mulberry, elm, Osage-orange, apple, ash, peach, honeylocust, pear, poison sumac, poison ivy, eucalyptus. Hickory, pecan, and persimmon are favored hosts, but the range is diverse, occasionally including conifers and some vines (Beal and others 1952, Fisher 1950).

Range. Eastern half of the United States from Florida north to New York, west to Texas and Kansas and in southeastern Canada (Fisher 1950).

Description. ***Adult.*** Brownish black to dark reddish brown beetle with basal half of elytra reddish to brownish yellow, 3.3 to 7.0 mm long and 1.5 to 2.5 mm wide (figure 112A) (Beal and others 1952, Fisher 1950, Gill 1924). Wing covers taper to oblique angle at posterior end, edges armed with three conspicuous teeth on each side. Antennae, palpi, and tarsi brownish yellow. ***Larva.*** Yellowish white, wrinkled, C-shaped, 5 to 6 mm long (figure 112B). Small globular head with mouthparts extending forward. Thorax, and especially prothorax, greatly enlarged with three pairs of conspicuous legs. ***Pupa.*** Pale yellow (Lugger 1899).

Biology. Adults emerge during summer and fly in search of suitable host trees, where they bore through the bark and into the sapwood (Gill 1924, Lugger 1899).

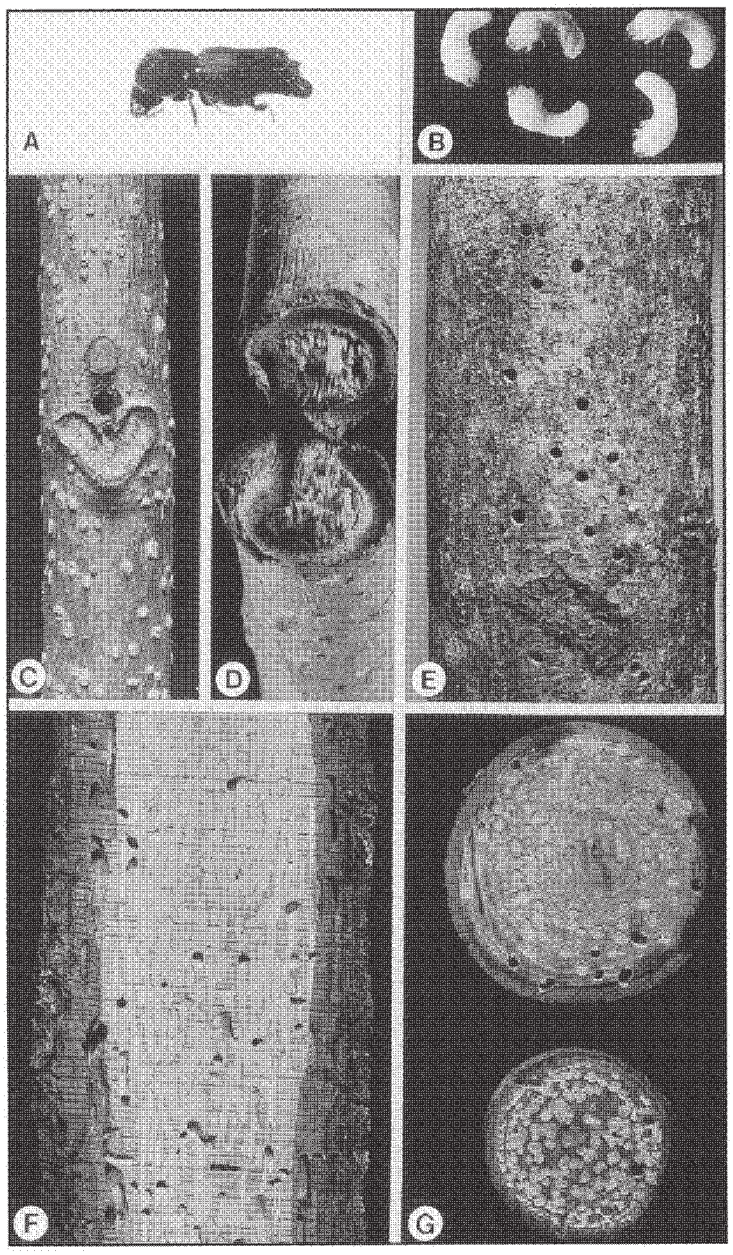

Figure 112—Xylobiops basilaris, *[red-shouldered bostrichid]: A, adult; B, larvae; C, adult entrance hole just above leaf scar on pecan branch; D, branch girdle made by adult; E, adult exit holes; F, longitudinal view of frass-packed galleries; G, cross section of many round frass-packed galleries.*

Adult tunnels are constructed across the grain just under the bark surface in sapwood. Tunnels may girdle limbs and trunks of small diameter. Eggs are deposited at intervals along the sides of tunnels. Larvae feed mostly in sapwood and to some extent in heartwood, tunneling parallel to the grain. They spend winter in galleries, mostly as mature larvae, but sometimes as pupae or adults. Adults often bore into healthy twigs for food and shelter and commonly spend the fall, winter, and spring in galleries within twigs and branches. A generation can develop in 1 year under optimum conditions, but longer periods are sometimes required.

Injury and damage. Stressed, dying, and recently dead trees are most susceptible to attack (Beal and others 1952, Gill 1924, Moznette and others 1931). Branches that fail to bud in spring and flagged branches having withered and brown leaves, along with girdled and fallen branches, are good indicators of infestation. Inspection of such branches reveals one round entrance hole 2 to 3 mm in diameter adjacent to one or more buds or leaf scars (figure 112C). Branches are easily broken at these sites because they have been partially to completely girdled beneath the bark (figure 112D). Emerging beetles leave many 2- to 3-mm round exit holes that give the appearance of shotholes (figure 112E) (Gill 1924). Dissection of infested branches reveals numerous parallel galleries filled with very fine, powderlike frass (figure 112F). The round frass-packed galleries are most characteristic when viewed in cross section (figure 112G). Infested trees cut for use as wood products can be quickly destroyed if not processed promptly. These insects may cause some twig dieback and possibly hasten the death of trees already stressed or dying from other causes, but the threat to healthy trees is minimal.

Control. Natural control includes four species of hymenopterous parasites—*Bephratoides* n. sp., *Ecphylus flavus* Marsh, *Glyptodoryctes caryae* (Ashmead), *Wroughtonia ferruginea* (Brues), and an unidentified dipteron (Beal and others 1952, Burks 1979, Marsh 1979). Because borers present little threat to healthy well-kept trees, good cultural practices should be followed to maintain tree vigor (Moznette and others 1931). Sources of infestation can be eliminated by promptly removing and destroying all dead and dying twigs, branches, and prunings. Any dying or dead trees to be used for wood products should be processed promptly with assurance that boards do not contain wane edges with bark that encourage beetle attack.

Melalgus confertus (LeConte)

[olive twig borer]

Hosts. Almond, apple, apricot, avocado, cherry, currant, fig, elm, peach, pear, quince, olive, orange, grape, maple, oak, acacia, manzanita, laurel, madrone, birch. Fruit, nut, and ornamentals are favored (Essig 1958, Fisher 1950).

Range. Pacific Coast species, occurring primarily in California and Oregon, but reported north to British Columbia (Fisher 1950, Furniss and Carolin 1977).

Description. ***Adult.*** Elongate (7 to

15 mm long, 1.7 to 3.7 mm wide), cylindrical, and uniformly reddish brown to black beetle with brown elytra, (Essig 1958, Fisher 1950). Antennae, palpi, and tarsi pale brown and thorax and elytra densely clothed with short yellowish pubescence. ***Egg.*** Elongate, smooth, white, slightly pointed at one end. ***Larva.*** Robust, curved, white, largest anteriorly, clothed with fine hair.

Biology. Adults emerge during early summer and burrow in living twigs and branches to feed (Herbert 1920). Females move to recently broken or pruned branches and deposit their eggs in cracks and crevices (Essig 1958, Fisher 1950, Herbert 1920). Larvae mine extensively in the sapwood and heartwood for a year or more before maturing. Eggs are occasionally laid in branch stubs of pruned trees. Here, the larvae burrow down the stub to living tissue where they may delay the healing process. Adults bore into twigs and branches, either killing them or sometimes causing severe pruning, especially among young trees (Essig 1958, Herbert 1920). Reproduction occurs in dead wood; thus, the larvae are of minor importance.

Injury and damage. Young trees suffer most. Broken twigs and branches 3 to 12 mm in diameter often signal attacks by the adults. Breakage occurs at sites where beetles burrow into twigs. Close examination reveals 2- to 4-mm diameter round holes at forks, branch crotches, and bud axils. Whitish frass, ejected by the beetles, may be present at entrances and on the bark surface. Dissection reveals burrows and sometimes the adults (Essig 1958, Fisher 1950, Herbert 1920). Orchards occasionally suffer light damage.

Control. Good sanitation helps to minimize damage (Essig 1958, Herbert 1920). All prunings, broken branches, and debris in and around orchards should be collected before spring and burned to destroy breeding places. Chemical sprays are rarely needed.

Family Lymexylidae—Timber Beetles

Members of this family attack severely weakened, dying, and recently dead timber, and areas around cankers and dead areas on living trees. The adults are elongate, slender, and subcylindrical; the head is deflexed and narrowed behind the eyes to form a neck; and the antennae are short and serrate (Arnett 1968, Craighead 1950). Larvae are elongate and cylindrical with globular heads; segments have minute asperites; and the abdomen is armed with teethlike or taillike structures. These insects bore deeply into both the sapwood and heartwood.

Genus and Species

Melittomma
sericeum (Harris) *290*
Hylecoetus
lugubris Say *292*

Melittomma sericeum (Harris)

chestnut timberworm (figure 113)

Hosts. Chestnut, oak. American chestnut, before its demise, was the preferred host (Hopkins 1894); now found chiefly in white oak (USDA FS 1985).

Range. An eastern species, range corresponds closely with that of American chestnut in the eastern United States (Snyder 1927).

Description. ***Adult.*** Slender, elongate, chestnut brown beetle with deflexed head, clothed with fine, silky hair, 11 to 15 mm long (figure 113A) (Herrick 1935, USDA FS 1985). ***Larva.*** White to yellowish brown, smooth, elongate, and cylindrical with a large, yellow, rounded head partially covered by enlarged hood-shaped tergum of prothorax (figure 113B) (Peterson 1960). Ninth abdominal segment enlarged and conspicuously armed with dark brown scooplike structure bearing many toothlike spines. Full-grown larvae 15 to 18 mm long.

Biology. Adults deposit eggs in cracks and crevices on the surface of wood, often at wounded sites (Hopkins 1894, USDA FS 1985). Young larvae bore directly into wood, forming tiny holes that are scarcely visible. As larvae grow, galleries are enlarged and extended for many centimeters through the sapwood and heartwood. Pupation occurs in cells constructed near the surface. New adults chew circular exit holes. The life cycle has not been established, but a generation probably requires several years.

Injury and damage. Fine powdery frass may be found at tiny holes that initially are barely visible. Attack sites are found in both sapwood and heartwood and most often are associated with wounds (figure 113C and D) and broken or decayed branches (Herrick 1935, Hopkins 1894); dying trees, stumps, and fresh-cut logs are also attacked (figure 113E). Holes in lumber are generally unstained or only slightly stained, round, and vary from 0.3 to 6.4 mm in diameter (figure 113F) (Snyder 1927). Most American chestnut was killed by the mid-1900's by chestnut blight, a disease introduced from the Orient in the early 1900's (Clapper and Gravatt 1943). Diseased and dying trees were riddled by

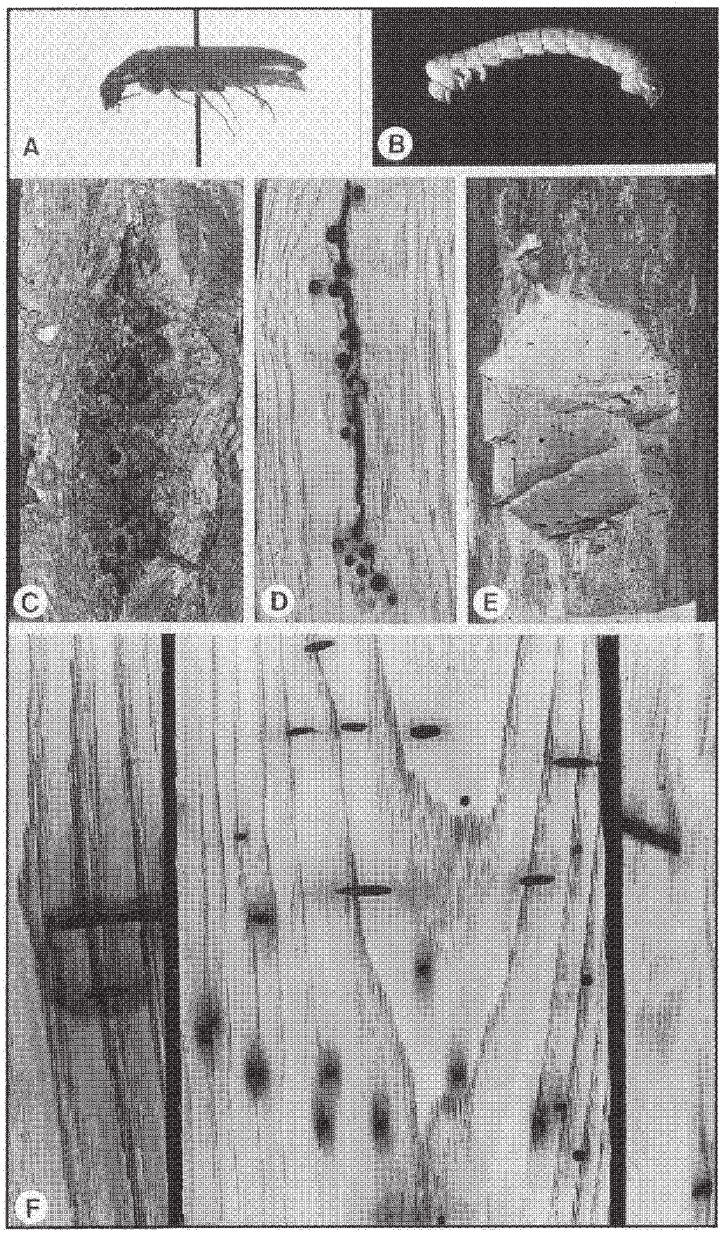

Figure 113—Melittomma sericeum, *chestnut timberworm: A, adult; B, larva; C, adult exit holes in bark at old wound site; D, exit holes in sapwood along old wound seam; E, chip removed from chestnut log to show galleries in wood; F, wormy chestnut lumber (specimens courtesy D. Whitehead).*

chestnut timberworms. Nearly every tree of merchantable size contained some injury. Lumber from such trees was downgraded to "sound wormy," resulting in sizeable losses. Today, affected lumber is considered character marked and sold as "wormy chestnut" for decorative purposes at handsome prices.

Control. Minimizing wounds from harvesting equipment, stand improvement work, wildfire, and other insect borers can help to reduce infestations and losses (Craighead 1950).

Hylecoetus lugubris Say

sapwood timberworm (figure 114)

Hosts. Poplar, birch, yellow-poplar, basswood, buckeye, black walnut, chestnut. Poplar has been mentioned as major host (Peterson 1960, Snyder 1927).

Range. Eastern United States (Arnett 1968).

Description. ***Adult.*** Slender, elongate, brown beetle with short antennae; long, slender legs; 9.5 to 15.0 mm long (figure 114A) (Anderson 1960, USDA FS 1985). Pronotum with raised edges. ***Larva.*** Yellow with light brown head partially covered with enlarged hood-shaped tergum of prothorax (figure 114B). Ninth abdominal segment terminates in elongate, tail-like projection with toothlike spines along margin.

Biology. Adults emerge from April to July and deposit eggs in bark crevices mainly on dying trees and green logs (Snyder 1927, USDA FS 1985). Larvae tunnel and feed under the bark and across and into the sapwood. The life cycle has not been studied.

Injury and damage. Weakened and dying trees and green sawlogs may become infested (Peterson 1960, Snyder 1927). Many galleries 0.3 to 5.0 mm in diameter extend throughout sapwood (Snyder 1927, USDA FS 1985). Removing the bark reveals many laterally oriented galleries across the surface of the sapwood (figure 114C). When development is complete, a series of round, vertical holes is found on the sapwood surface (figure 114D). Pinhole or wormhole defects in products sawn from infested trees result in losses of 5 to 10%.

Control. Susceptible trees and logs should be promptly removed from the forest to avoid infestation during spring and summer. Direct controls have not been needed.

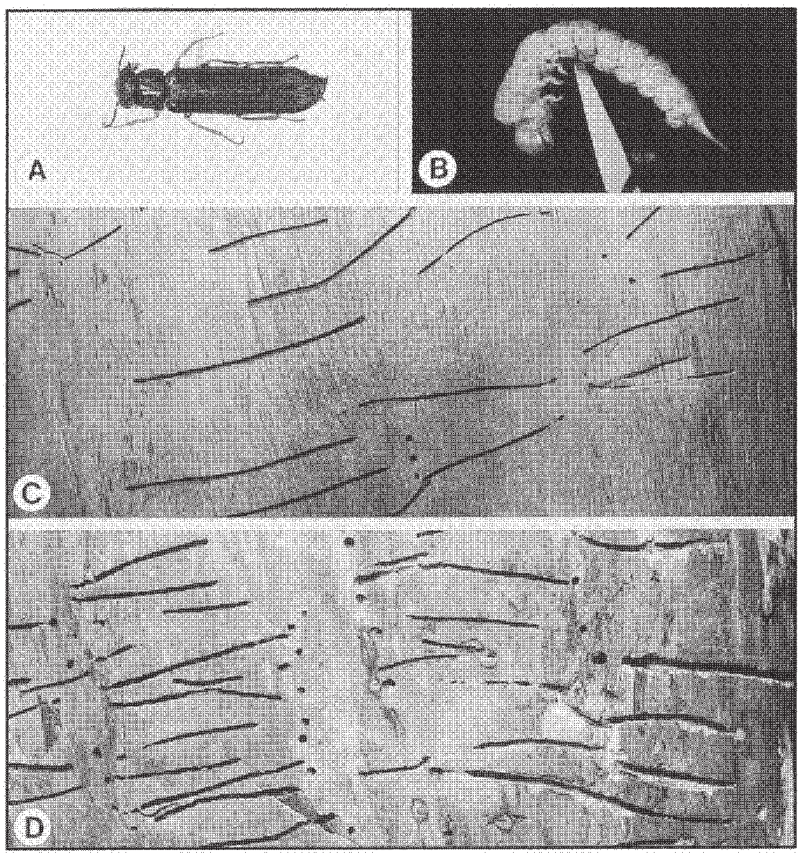

Figure 114—Hylecoetus lugubris, *sapwood timberworm: A, adult; B, larva; C, laterally oriented galleries across surface of sapwood; D, vertical series of round holes near ends of lateral galleries (A & B, specimens courtesy D. Whitehead; C & D, specimens courtesy J. Simeone).*

Family Cerambycidae—Longhorn Beetles, Roundheaded Borers

This family is one of the largest and most important among woodboring insects. Adults are oblong to elongate, more or less cylindrical, vary greatly in size and color, and are long legged with 11-segmented antennae that are often longer than the entire body (Furniss and Carolin 1977, USDA FS 1985). The adults of most species are short lived, nocturnal, shy, and seldom seen. Larvae are fleshy, thin skinned, white to yellowish, sparsely covered with fine setae, and more or less cylindrical or depressed. In some species, the body tapers posteriorly, but the anterior segments are never conspicuously larger than the adjoining segments. Larvae may or may not have prolegs but have two circular bands of skin between segments that expand and contract, together with dorsal and ventral pads or ampullae that aid movement within the burrows. Most species are cambium feeders in that they first mine in the cambium and then extend their tunnels into the sapwood and sometimes into the heartwood. Trees from seedling to sawlog size may be attacked, and all parts of the tree—including terminal shoots, branches, trunks, and roots—are susceptible, but some borers are quite selective about size, portion, and condition of the tree. A few species are girdlers and pruners. Although some mine under the bark and girdle or deface ornamentals, the most harmful species bore into the wood and cause defects that seriously degrade lumber sawn from infested timber.

Genus and Species

Goes
- *tigrinus* (De Geer) *296*
- *tesselatus* (Haldeman) *299*
- *debilis* LeConte *302*
- *pulverulentus* (Haldeman) *304*
- *novus* Fall *307*
- *pulcher* (Haldeman) *308*

Plectrodera
- *scalator* (Fabricius) *311*

Neoptychodes
- *trilineatus* Linnaeus *314*

Synaphaeta
- *guexi* LeConte *316*

Dorcaschema
- *wildii* Uhler *318*
- *alternatum* (Say) *321*

Oncideres
- *cingulata cingulata* (Say) *323*
- *pustulatus* LeConte *326*
- *rhodosticta* Bates *329*
- *quercus* Skinner *331*

Aegomorphus
- *morrisi* (Uhler) *332*

Saperda
- *calcarata* Say *334*
- *concolor* LeConte *338*
- *inornata* Say *339*
- *populnea moesta* LeConte *342*
- *populnea tulari* Felt and Joutel *344*
- *candida* Fabricius *346*
- *cretata* Newman *349*
- *fayi* Bland *351*
- *vestita* Say *353*
- *tridentata* Olivier *356*
- *horni* (Joutel) *359*
- *obliqua* Say *359*
- *lateralis* (Fabricius) *363*

discoidea (Fabricius) *363*
puncticollis Say *365*
Oberea
schaumii LeConte *367*
quadricallosa LeConte *370*
delongi Knull *370*
tripunctata (Swederus) *374*
bimaculata (Olivier) *376*
ruficollis (Fabricius) *379*
gracilis (Fabricius) *381*
ocellata (Haldeman) *383*
Parandra
brunnea (Fabricius) *385*
Prionus
imbricornis (Linnaeus) *388*
laticollis (Drury) *390*
californicus Motschulsky *393*
Archodontes
melanopus melanopus (Linnaeus) *396*
melanopus serrulatus (LeConte) *398*
melanopus aridus (Casey) *398*
Stenodontes
dasytomus dasytomus (Say) *399*
dasytomus masticator (Thomson) *401*
lobigenis (Bates) *402*
Desmocerus
palliatus (Forester) *402*
californicus Horn *404*
auripennis Chevrolat *406*
Leptura
pacifica (Linsley) *408*
Strophiona
nitens (Forester) *410*
Styloxus
fulleri (Horn) *411*
Tylonotus
bimaculatus Haldeman *413*
Aneflus
prolixus insoletus Chemsak and Linsley *416*
protensus (LeConte) *416*
Psyrassa
unicolor (Randall) *417*
Aneflomorpha
subpubescens (LeConte) *419*
lineare (LeConte) *421*
Enaphalodes
rufulus (Haldeman) *422*
cortiphagus (Craighead) *426*
Anelaphus
parallelus (Newman) *429*
villosus (Fabricius) *431*
inflaticollis Chemsak *433*
Parelaphidion
incertum (Newman) *435*
Phoracantha
semipunctata (Fabricius) *436*
Dryobius
sexnotatus (Linsley) *438*
Physocnemum
brevilineum (Say) *441*
Xylocrius
agassizi (LeConte) *443*
Megacyllene
robiniae *445*
snowi snowi (Casey) *448*
robusta (Linsley and Chemsak) *450*
Glycobius
speciosus (Say) *451*
Megacheuma
brevipennis (LeConte) *453*
Xylotrechus
aceris Fisher *454*

insignis LeConte *457*
quadrimaculatus (Haldeman) *457*
obliteratus LeConte *461*
nauticus (Mannerheim) *463*
Neoclytus
acuminatus (Fabricius) *464*
tenuiscriptus Fall *466*
cordifer (Klug) *468*
Callona
rimosa (Buquet) *469*
Crioprosopus
magnificus (LeConte) *471*
Purpuricenus
dimidiatus LeConte *471*
axillaris Haldeman *473*
Amannus
pectoralis LeConte *474*

Goes tigrinus (De Geer)

white oak borer (figure 115)

Hosts. Oak. Decidedly prefers oak species. The major host in upland forests is white oak, whereas overcup oak is preferred in bottomland stands. Attacks post oak, swamp chestnut oak, and chestnut oak less frequently. Hickory and walnut are mentioned (Beal and others 1952), but it appears likely that these attacks were by another borer—*Goes pulcher* (Haldeman).

Range. Throughout the eastern and central United States east of the Great Plains, wherever its preferred hosts grow (Beal and others 1952, Solomon and Donley 1983).

Description. ***Adult.*** Large, elongate, robust, and cylindrical longhorn beetle, 22 to 30 mm long, 6 to 8 mm wide, with antennae that extend beyond tips of elytra (figure 115A). Females slightly larger than males, with heavier abdomens but slightly shorter antennae. Body color dark brown with lighter mottled areas of dense white pubescence. Mottling on elytra form distinct dark bands at base and just beyond middle. ***Egg.*** Creamy white, translucent, parchmentlike, elongate, averages about 4 mm long and 1 mm wide (figure 115B and C). ***Larva.*** Somewhat robust, elongate, almost cylindrical, slightly flattened on dorsal and ventral surfaces, and somewhat broadened anteriorly (figure 115D) (Craighead 1923). Yellowish white with dark brown mandibles and light amber spiracles. Legless but able to propel themselves through their galleries by means of ampullae, or wartlike protuberances on abdominal segments. At maturity, 24 to 32 mm long. ***Pupa.*** Newly transformed pupa white with greenish tinge; mandibles, eyes, and appendages darken and become distinct before transformation.

Biology. In Mississippi, adult beetles emerge from late April to late May and are relatively long lived, having been trapped as late as July 10. In Ohio, adults emerge from mid-May to mid-July (Solomon and Donley 1983). Adults have been found in Michigan from late July to early August (Gosling and Gosling 1977). After emergence, adults feed for a week or two on twigs and leaf petioles, mate, and then females begin oviposition. Females deposit 9 to 15 eggs each. To oviposit, females chew oval niches 5 to 8 mm in diameter in the bark (figure 115B) and then, with the long ovipositor, force one egg per niche between the bark and wood (figure 115C). Up to 14 fresh egg niches have been found on a tree (Solomon and Donley

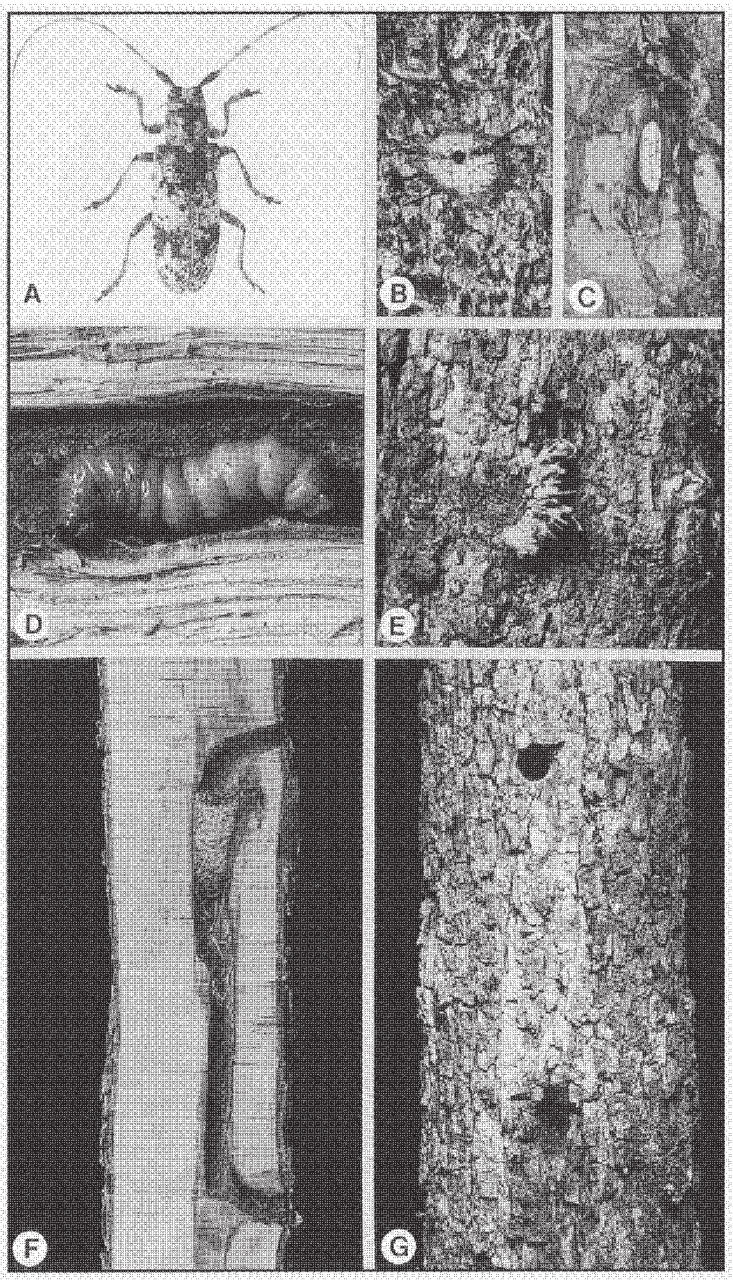

Figure 115—Goes tigrinus, *white oak borer: A, adult; B, egg niche; C, bark removed to expose egg; D, larva; E, fibrous frass extruded from entrance; F, gallery with entrance below and exit above; G, entrance hole below and exit hole above.*

1983). Newly hatched larvae do little or no mining in the inner bark but tunnel directly into the sapwood. Sap oozes from the point of entry and discolors the surrounding bark. Soon after eggs hatch, tiny strands of fine, moist, yellowish frass are extruded through the entrance holes. As the larvae grow, frass strands become larger and often assume the shape of yellow ribbonlike pieces from being forcefully extruded through the vertically elongate entrance holes (figure 115E). Short pieces of shredded wood appear in the frass during the second year. Excelsior-like wood fibers 12 to 18 mm long in the frass indicate approaching larval maturity. Yellow frass often accumulates in piles around the bases of heavily infested trees. Larval galleries extend horizontally or obliquely upward in the sapwood 2 to 6 cm, rise vertically another 8 to 17 cm, then turn horizontally back to the surface (figure 115F). Borers in large stems usually enter and exit on the same side of the tree, but on small stems, they sometimes exit on the opposite side. Galleries are relatively uniform in shape, but occasionally, short diverticula occur at the junctions of horizontal and vertical portions of the galleries. Completed galleries range from 11 to 23 cm long and 1.0 to 1.5 cm in diameter. One larva occupies each gallery, but galleries intersect occasionally in heavily infested hosts. Mature larvae prepare pupal chambers at the uppermost part of galleries by plugging them tightly with excelsior-like frass. Pupation in Mississippi occurs during April and early May and lasts 15 to 19 days. Newly formed beetles emerge by chewing circular exit holes. Three or 4 years are required to complete a generation.

Injury and damage. Infested trees are most easily recognized in late summer and fall when the frass ejected from vertically elongate larval entrance holes is yellowish, coarse, and fibrous (figure 115E), and often accumulates around the base of infested trees (Solomon and Donley 1983, Solomon and Morris 1965). Repeatedly reinfested trees have two types of holes on the trunk (figure 115F and G): elongate entrance holes (8 to 12 mm long) that larvae keep open throughout their development and through which frass is expelled and circular holes (7 to 9 mm in diameter) several centimeters above the entrance holes through which the adults exit. During the oviposition period, and for 1 or 2 months after, the characteristic shallow oval-shaped egg niches, 5 to 8 mm in diameter, are visible on the bark surface (figure 115B). As the entrance and exit holes close with wound tissue, they often appear as branch scars and may be surrounded with roughened, irregularly shaped bark scales. On poorly drained heavy clay sites in bottomlands and bayous of the Mississippi River drainage system, overcup oaks sustain more borer damage than those on more fertile, well-drained, silty sites along the edges of sloughs and bayous. In contrast, in Ohio, the fastest growing young white oaks are reportedly most susceptible to attack (Donley 1978a). This borer is one of the most serious pests of sapling and young pole-sized white oaks from 10 to 25 cm in diameter at breast height (dbh) and prefers to infest the basal 7.6 m of such trees. Conse-

quently, the most valuable butt-log portion of future crop trees often becomes riddled with galleries and either is rendered completely useless or severely degraded. The white oak borer reportedly is the insect most responsible for the rejection of defective staves by the cooperage industry in Ohio (Donley and others 1969). Moreover, white oak borers predispose infested trees to damage by carpenterworms, carpenter ants, wood stains, and decay fungi.

Control. During winter and early spring, woodpeckers destroy up to 30% of the larvae, particularly in trees 12 cm or less in diameter that have multiple borer attacks (Solomon and Donley 1983). Soon after the eggs hatch, many small larvae are killed by excessive sap flow at egg niche sites. No insect parasites of the white oak borer have been reported. Studies on the spatial, height, and density distribution of white oak borers indicate that populations occur in small trees 8 to 25 cm in dbh that exhibit evidence of previous attack (Donley 1978a, Solomon and Donley 1983). Analyses suggest that 50% of resident borer populations can be killed silviculturally by removing brood trees, which make up as little as 5% of a stand's basal area. Insecticidal control of white oak borers is probably not economically justified in forest stands.

Goes tesselatus (Haldeman)

oak sapling borer (figure 116)

Hosts. Oak. White oak, chestnut oak, and others in the white oak group are preferred. Chestnut, serviceberry, and elm mentioned as hosts (Brooks 1923, Linsley and Chemsak 1984), but this is questionable.

Range. New York and Pennsylvania south to Georgia and Louisiana and to Indiana in the Midwest (Blatchley 1910, Linsley and Chemsak 1984, USDA FS 1985). Injuries to young trees typical of those of the oak sapling borer have been observed in Arkansas and Mississippi.

Description. ***Adult.*** Elongate, robust, cylindrical, grayish brown, longhorn beetle 20 to 27 mm long and 7 to 9 mm wide (figure 116A) (Brooks 1923). Body covered with short, prostrate, yellowish hairs. Yellowish spots formed by dense hairs on elytra. Antennae much longer than body in males and only slightly longer than body in females. Females larger and more robust than males. ***Egg.*** Elongate, yellowish white, wrinkled, parchmentlike, and averaging 2 by 6 mm. Eggs removed from their position in the tree have the impression of wood grain on chorion surface. ***Larva.*** Full-grown larva (figure 116B) 25 to 30 mm long, 4 to 6 mm wide, elongate, slightly robust, fleshy and yellowish, nearly cylindrical, slightly flattened dorsally and ventrally, and broader anteriorly (Brooks 1923). ***Pupa.*** Yellowish white and about 25 mm long. Yellowish brown hairs coarser and denser than those of other *Goes* species (Brooks 1923).

Biology. After transformation to the adult stage, new beetles remain in pupal chambers for 5 to 7 days. They exit the pupal chambers by gnawing round holes directly through the bark at the upper end of the chamber. Adults emerge in May and June, feed on the tender bark of young oak twigs, and live 3 to 5 weeks. Seven to

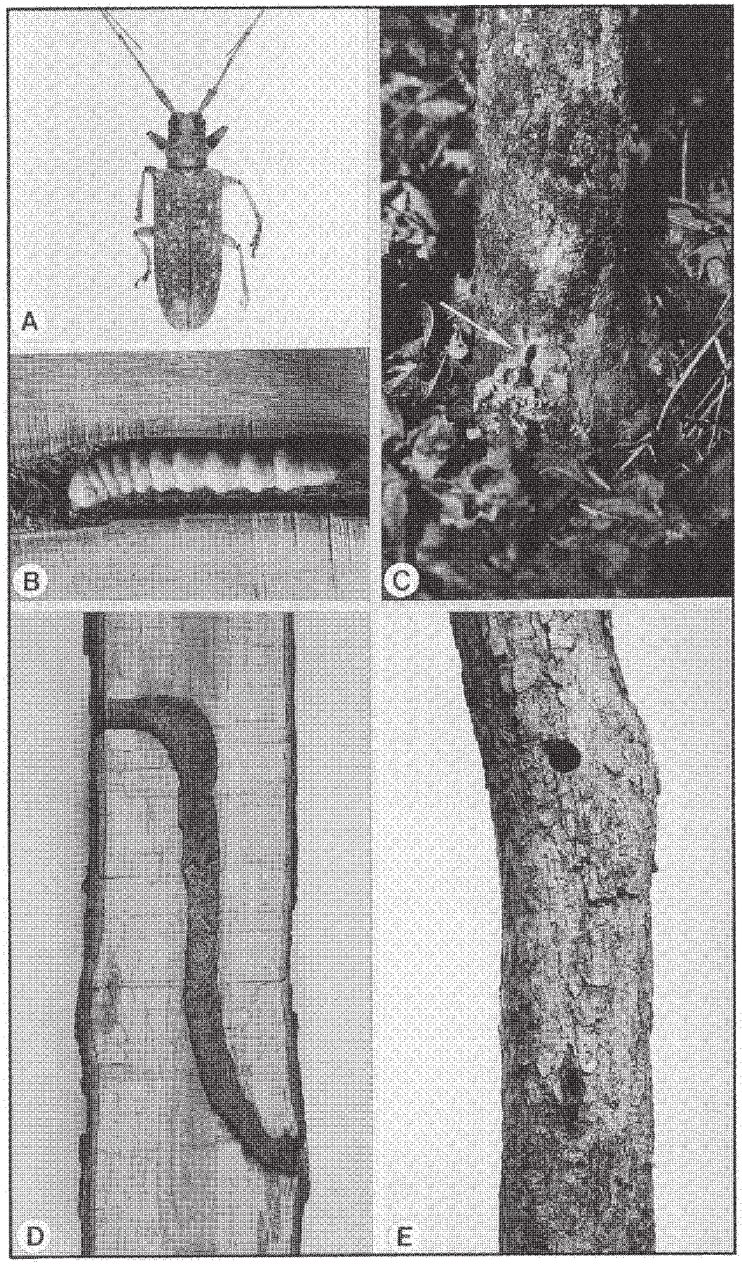

Figure 116—Goes tesselatus, *oak sapling borer: A, adult; B, larva; C, entrance hole and frass at base of sapling; D,gallery—entrance below and exit above; E, entrance hole below, exit above.*

10 days after emergence, females begin to oviposit. They gnaw small cavities or niches in the bark and place the eggs singly between the bark and wood. After hatching, young larvae begin to feed in the bark around the oviposition site but soon move deep into the wood. Larvae of various sizes may be seen in the trees at any season. With the onset of cold weather, larvae sometimes bore downward and overwinter near ground level. The larval period requires 3 to 5 years. During their last summer in the tree, larvae extend their tunnels several centimeters above the ground and enlarge the upper end to form pupal chambers. Mature larvae overwinter in these chambers and pupate in spring. Pupation takes place in April and lasts 5 to 6 weeks (Brooks 1923).

Injury and damage. Attack sites are found most often on the lower trunk, particularly around the base (figure 116C). Small trees 13 to 50 mm in diameter at stump height are most susceptible and suffer most. Summer examination reveals egg niches cut in the bark. Oozing sap at these sites soon stains the bark, making new attack sites more noticeable. Fine frass, sometimes extruded in small threads, appears at the egg sites. During the second and subsequent years, frass becomes coarser, including some fibrous or excelsior-like fibers. Moreover, the frass is typically extruded through the gallery opening in ribbonlike pieces that accumulate in piles on the ground at the base of the tree (figure 116C). Internal injury is characterized by wide irregular burrows that extend upward in the wood (figure 116D), but the galleries sometimes extend downward from the point of entrance. Galleries become more extensive each year of the life cycle and eventually affect considerable portions of small trunks. Each borer leaves two holes—an elongate entrance hole and a 7- to 9-mm round exit hole (figure 116E). Small bark scars usually are visible for several years after borers mature and leave the tree. Damage is restricted mostly to large seedlings, saplings, and sprouts. A single larva may sometimes completely hollow out the base of a small tree and kill it. Many young trees are structurally weakened by the galleries and typically break at exit holes. Trees that survive the feeding injuries frequently develop bulblike swellings around wounds near the groundline (USDA FS 1985). About 25% of the infested trees die from the direct effects of larval feeding or from breaking at exit holes made by larvae a few centimeters above the ground. The borer shows a tendency to colonize, attacking nearly every young tree in some stands while infesting few trees or none in other stands (Brooks 1923).

Control. No predaceous or parasitic insects have been reported (Brooks 1923), but because this borer occurs mostly in small stems, it is particularly susceptible to woodpecker predation. The hairy, downy, and pileated woodpeckers excavate and devour many larvae. Open-grown trees such as sprout growth in small, recently cutover areas and young trees planted as ornamentals or for nut production are most susceptible. Direct control measures occasionally may be needed to protect valuable trees.

Goes debilis LeConte

[oak branch borer] (figure 117)

Hosts. Oak. Members of the white oak group, especially white, overcup, and post oaks, are preferred hosts (Solomon 1977a). In the red oak group, black and northern red oaks have been listed as hosts. Hickory has been mentioned (Dillon and Dillon 1972), but the borer was probably mistaken for *Goes pulcher* (Haldeman), a borer common in hickory.

Range. Primarily an eastern species, reported in 18 states from New York south to Florida and west to Arizona (Dillon and Dillon 1941, Linsley and Chemsak 1984, Solomon 1977a).

Description. ***Adult.*** Elongate, slightly robust longhorn beetle, ranging from 10 to 16 mm long and 3 to 5 mm wide (figure 117A). Antennae about as long as body in females and slightly longer in males. Elytra reddish brown and apical portions mottled with light brown pubescence; basal portions mottled with light gray and light brown pubescence. Distinct crossbands of darker brown mark elytra just before and behind middle. Two distinct longitudinal brown stripes on thorax with short, blunt spine on each side (Dillon and Dillon 1972, Knull 1946, Solomon 1977a). ***Egg.*** Elongate, creamy white, and averaging 3 mm long and 1 mm wide. ***Larva.*** Cylindrical, slightly robust, 14 to 18 mm long when fully grown and yellowish white with brown mandibles and amber spiracles (figure 117B). Slightly flattened head usually withdrawn into fleshy prothorax, with only mouthparts exposed. Larvae legless and restricted to movement within galleries. ***Pupa.*** White, gradually darkening, 7 to 15 mm long (figure 117C) (Solomon 1977a).

Biology. In Mississippi, the earliest that adults emerge is around May 7 and the latest about June 3; the greatest numbers emerge between May 20 and 30 (Solomon 1977a). Adults have been collected in July in Indiana (Blatchley 1910) and New York (Linell 1889). Females lay single eggs between the bark and sapwood in the center of 2 to 4 mm diameter oval niches chewed in the bark. The niche openings made by the female ovipositor are sealed by a secretion that hardens to protect the eggs from dessication. Egg niches are usually made singly or in groups of two or three. Terminal shoots and small branches preferred by ovipositing females are 9 to 38 mm in diameter, averaging 17 mm (Solomon 1977a). Newly hatched larvae tunnel directly into the wood with little or no mining in either the phloem or cambium. The size and shape of galleries vary much more than the relatively uniform tunnels of other *Goes* species. Generally, galleries extend radially inward from the entrance hole for 5 to 10 mm, then turn abruptly in either direction parallel to the wood grain for 20 to 60 mm, and finally turn back to the surface. Some galleries extend in both directions from the entrance, and the larvae make a few irregular cavities below the entrance before tunneling back to the surface on any side of the stem. Gallery entrances are almost always tightly plugged with yellow frass, and portions of the gallery are commonly filled with frass. One larva occupies

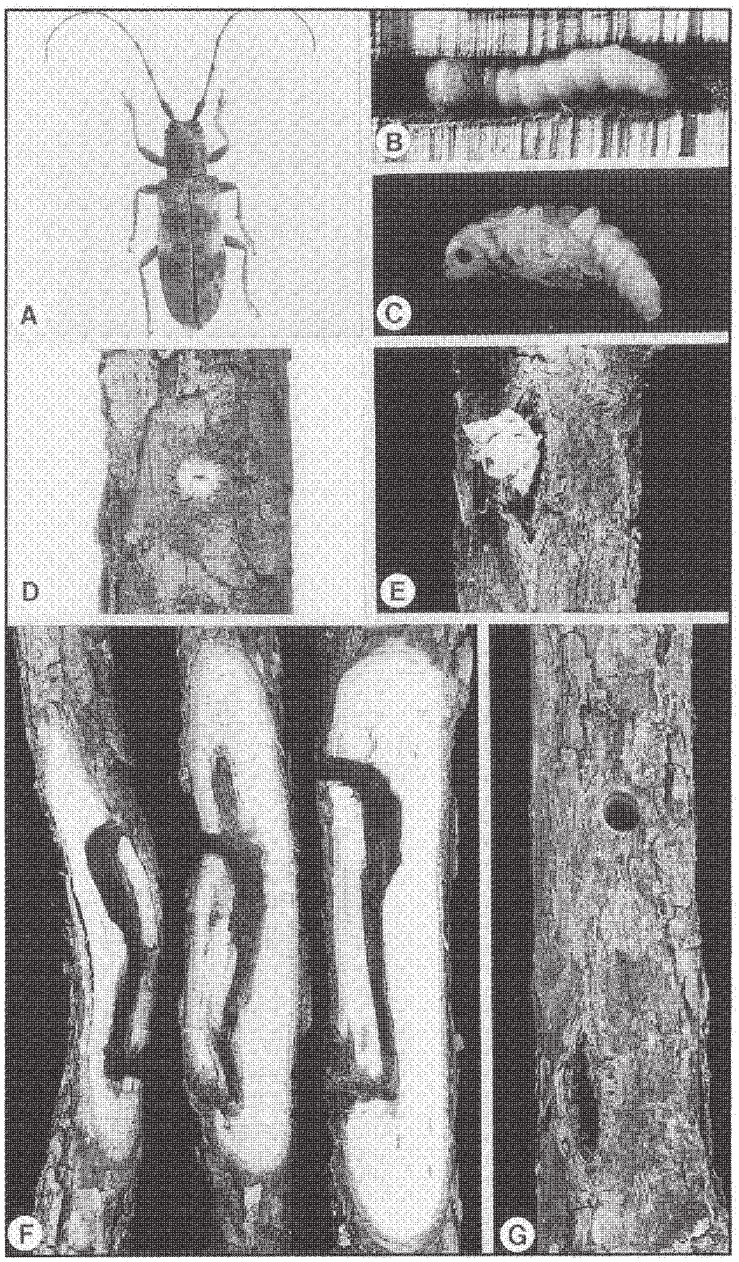

Figure 117—Goes debilis, *[oak branch borer]: A, adult; B, larva; C, pupa; D, egg niche; E, yellow frass ribbon extruded from entrance; F, galleries; G, entrance hole below, exit hole above.*

each gallery, but other larvae occasionally intersect vacated galleries (Solomon 1977a). Pupal chambers are constructed at the innermost part of galleries and are closed off by tight plugs of short, fibrous, shredded wood. Pupation occurs in April and May and lasts 14 to 17 days. Each borer leaves two holes, an elongate entrance hole and a circular exit hole. The wounds heal eventually and appear as bark scars for several years (Solomon 1977a). In Mississippi, part of a brood develops in 3 years, and the remainder requires 4 years. It seems likely that development of more than 4 years is required farther north.

Injury and damage. The earliest indication of attack is tiny egg niches cut in the bark (figure 117D) (Solomon 1977a). The most obvious evidence is the yellowish frass extruded from small elongate entrance holes (figure 117E) and sapstained bark. Dissection reveals galleries 3 to 8 cm long and 4 to 6 mm in diameter (figure 117F). A year or more after becoming infested, many branches and terminals become swollen or gall-like. Sometimes cankerlike lesions develop, especially at infested sites pecked by woodpeckers. Broken branches and dieback are additional symptoms of infestation. Round exit holes 3 to 4 mm in diameter may be found in the bark (figure 117G). Because this borer, as its common name implies, primarily infests branches, it does not directly degrade logs. However, the borer sometimes attacks terminals, resulting in forks and crooks or poorly formed trunks that prevent development of long, straight sawlogs. Woodpecker excavations in infested terminals and branches sometimes result in breakage and dieback. Clumps of heavily infested trees occur in some locations, but in other areas, borer damage is negligible to rare.

Control. Woodpeckers are among the most important natural enemies of this borer. In one study of 200 attacks in Mississippi, 65% of the larvae were taken by woodpeckers (Solomon 1977a). Eggs and newly hatched larvae are subject to mortality in vigorous trees because of excessive sap-ooze at oviposition sites. No parasites have been recovered. Control by removing and destroying infested branches from valuable trees is effective, especially on a neighborhood basis.

Goes pulverulentus (Haldeman)

[beech borer] (figure 118)

Hosts. Nuttall, willow, black, cherrybark, and water oaks, beech, elm, and sycamore. The red oaks appear to be major hosts, followed by American beech (Solomon 1972). Attacks American elm less commonly, and sycamore rarely. White oak and wild cherry have been listed as hosts (Knull 1946), but these records are questionable.

Range. Reported mostly from the eastern United States, including 23 states from Florida west to Texas, north to Minnesota and Massachusetts, and in southern Canada (Dillon and Dillon 1941, Linsley and Chemsak 1984).

Description. ***Adult.*** Robust, elongate longhorn beetle, 18 to 25 mm long and 6 to 8 mm wide (figure 118A) (Dillon and

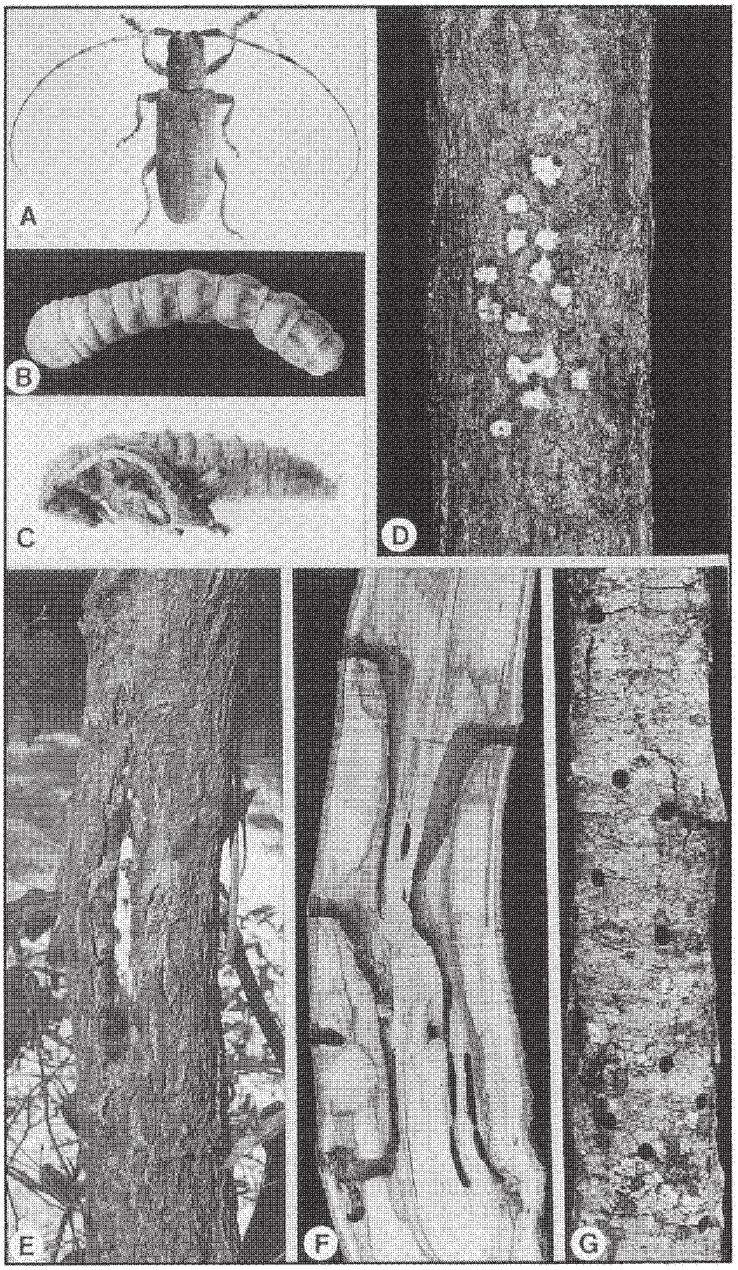

Figure 118—Goes pulverulentus, *[beech borer]: A, adult; B, larva; C, pupa; D, cluster of egg niches; E, attacks at elongate scar on sapling; F, galleries; G, cluster of round exit holes.*

Dillon 1941, Knull 1946, Linsley and Chemsak 1984). Female slightly larger than male, but with decidedly shorter antennae. Body covered with brownish gray pubescence; elytra with band of darker pubescence at base and just beyond middle. Small spine on each side of pronotum. ***Egg.*** Yellowish white, almost translucent, parchmentlike and elongate, averaging 4 mm long and 1 mm wide (Solomon 1972). ***Larva.*** Newly hatched larva about 4 mm long; 20 to 30 mm at maturity (figure 118B). Body somewhat robust, fleshy, and almost cylindrical, but slightly flattened dorsally and ventrally, and slightly broader anteriorly. White to cream colored, except for brownish mandibles; legless, but moves along gallery with the aid of roughened, fleshy ampullae on abdominal segments. ***Pupa.*** Newly formed pupa (figure 118C) white, resembling a mummy with antennae; legs held tightly against body; 18 to 23 mm long (Solomon 1972).

Biology. In Arkansas and northern Mississippi, adults emerge April 25 to June 24 and live for an average of 27 days (Solomon 1972). Adults feed on tender twigs and leaf midribs, occasionally killing the apex of small twigs. Caged females oviposit an average of 12 eggs on Nuttall and willow oaks from early May to late June. After chewing oval, 5- to 7-mm-diameter niches in the bark, females deposit single eggs between the bark and wood. Females typically deposit eggs in clusters of niches; 17 (range 2 to 60) niches per cluster is the average. Apparently, several females contribute to large clusters with numerous egg niches. Generally, one cluster is found on a tree, but as many as four have been observed. The frequent presence of fresh egg clusters adjacent to active larvae suggests that previously infested trees attract females. On one study tree, fresh niches were observed next to the previous year's attack sites for 4 years in succession. When eggs hatch, larvae feed for only a short time in the phloem and cambium before entering the wood. Tiny strands of fine moist frass are extruded through the elongate entrance holes, and as the larvae grow, strands become larger and contain numerous excelsior-like wood fibers. Adults emerge the year after the fibers reach 10 to 15 mm long (Hay 1968). The strands of frass are noticeably darker than the yellow frass produced by the closely related species *Goes tigrinus*. Galleries occasionally intersect, and when they do, cannibalism is common. During late fall of the last year of development, larvae prepare pupal chambers in the innermost part of galleries and remain there in a resting stage until early March. Mature larvae pupate for 13 to 16 days in April or May. Adults chew holes through the bark to emerge. In Mississippi, most individuals complete the life cycle in 3 years, but a few require 4 or 5 years.

Injury and damage. Clusters of egg niches on trunks of small trees are the earliest evidence of infestation (figure 118D). Sap leakage from the egg niches begins within a few days of oviposition and gradually discolors the bark around and below the site. The young larvae burrow into the wood and begin feeding. Bark

surrounding the clusters of attacks often dies, then after 1 or 2 years, the growth of bark around the infestation forms an oblong sunken area. Longitudinal bark scars up to 1 m long develop over these wounds and remain for several years. Dead bark over the scar often splits, curls outward, and breaks away (figure 118E). Dissection reveals clusters of larval galleries that extend obliquely upward for 3 to 6 cm, vertically for another 8 to 15 cm, then turn back to the surface (figure 118F). Completed galleries range from 11 to 17 cm long and 12 to 15 mm in diameter. Multiple, round exit holes about 8 mm in diameter are left in the bark by emerging adults (figure 118G). Exit holes heal in 1 or 2 years and leave circular bark scars, which resemble overgrown branch stubs. In the Deep South, vigorous trees are sometimes infested, but suppressed, intermediate, leaning, and partially vine-covered trees are most vulnerable (Solomon 1972). Tree stems 8 to 12 cm in diameter are most commonly attacked, but occasionally stems up to 20 cm in diameter are attacked. Attacks on the main stem are most prevalent at heights of 2 to 3 m, but occur anywhere from groundline to 9 m. Branches of larger trees may become infested (Solomon 1972). Larval tunnels in the wood provide entry for stains, decay fungi, and carpenter ants and predispose trees to attack by carpenterworms and other borers. Small trunks and large branches are often so weakened by the borer that they break in high winds (Solomon 1972). This borer generally is of minor importance because it tends to attack smaller suppressed trees in forest stands. However, in some young stands, many sapling and pole-sized trees are heavily attacked, ruining their potential as crop trees.

Control. In vigorous trees, copious sap flow from fresh oviposition sites results in considerable natural control of eggs and young larvae (Solomon 1972). Also, carpenter ants, attracted to fermenting sap, chew the bark around egg niches and destroy many eggs and young larvae. In one study of woodpecker predation, 75% of the infested trees had been worked and 39% of the larvae had been destroyed (Solomon and Morris 1971). Unless hardwood silviculture intensifies, direct control of this borer does not appear to be warranted. However, since infested trees are usually small in size and number, it may be feasible to remove them during stand-improvement cuts. Chemical controls may be needed occasionally to protect ornamentals and other valuable trees.

Goes novus Fall

[live oak goes]

Hosts. Oak. Live oak is the only known host (Hovore 1983).

Range. Recorded from several locations in Texas, mainly in the Davis Mountains in western Texas (Dillon and Dillon 1941, Hovore 1983). It has been mentioned as occurring in Illinois (Dillon and Dillon 1941), but this record is questionable.

Description. ***Adult.*** Elongate ovate, rather robust longhorn beetle, subcylindrical and 19 to 24 mm long and 6 to 8 mm wide (Dillon and Dillon 1941). Head covered with dark gray pubescence with denser line outlining eyes. Pronotum entirely covered

with dark gray pubescence with two small brownish yellow spots on either side of median line. Elytra subconvex with brown and dark gray pubescence interspersed, giving irregular mottled appearance and forming faint bands at basal, middle, and apical quarters. Legs and antennae dark reddish brown to black and usually well covered with dark gray pubescence. Antennae with darker basal segments and about 1.5 times body length in males and about as long as body in females.

Biology. The habits appear similar to those of *Goes pulcher* (Haldeman) (Hovore 1983). On emergence, adults ascend to the foliage to feed and mate before oviposition. Adult beetles have been collected from healthy oak foliage both day and night. Beetles are attracted to light. Little else is known about the biology.

Injury and damage. Attacks are limited mostly to small trees and outer branches of large trees. Injuries are similar to those of *G. pulcher* in hickory (Hovore 1983). Entrance holes usually have frass plugging and protruding from the openings. Attacks are found in trunks and branches 15 to 85 mm in diameter; however, the stem bases of saplings 0.5 to 2.0 m tall are favorite sites for attack. Larvae, pupae, and adults have been taken from galleries and pupal cells from living oak stems. Damage has been of little consequence.

Control. Controls have not been needed.

Goes pulcher (Haldeman)

[hickory borer] (figure 119)

Hosts. Hickory, pecan. Commonly attacks water, mockernut, and bitternut hickories (Beal and others 1952, Solomon 1974). Other hickories are probably susceptible, and evidence of attack on black walnut has been observed. Occasionally infests grafted pecan. Oak species have been reported as hosts (Dillon and Dillon 1941), but this seems questionable.

Range. Occurs from southern Canada through the central and eastern United States (Solomon 1974). Common in the South, but populations vary greatly among localities.

Description. ***Adult.*** Robust longhorn beetle, ranging from 17 to 25 mm long and 5 to 8 mm wide with long antennae (figure 119A). Prominent spine midway along each side of pronotum. Body pale brown to grayish yellow ground color; elytra banded with darker brown across base and just beyond middle (Knull 1946, Dillon and Dillon 1941). ***Egg.*** Yellowish white, parchment-like, elongate, averages 4 mm long and 1 mm in diameter (figure 119D). ***Larva.*** Mature larva (figure 119B) slightly robust, fleshy, generally cylindrical, legless, and 18 to 28 mm long. White to yellowish except for prominent dark brown mandibles and amber spiracles. ***Pupa.*** White to greenish initially but becomes yellowish at maturity, with eyes, mandibles, and appendages darkening considerably before adult emergence (Solomon 1974).

Biology. Adults emerge in west-central Mississippi from early May to early June (Solomon 1974); in Ohio, adults have been observed on foliage in June and July (Knull 1946). After they feed on tender twigs, leaf petioles, and leaf midribs, adults begin

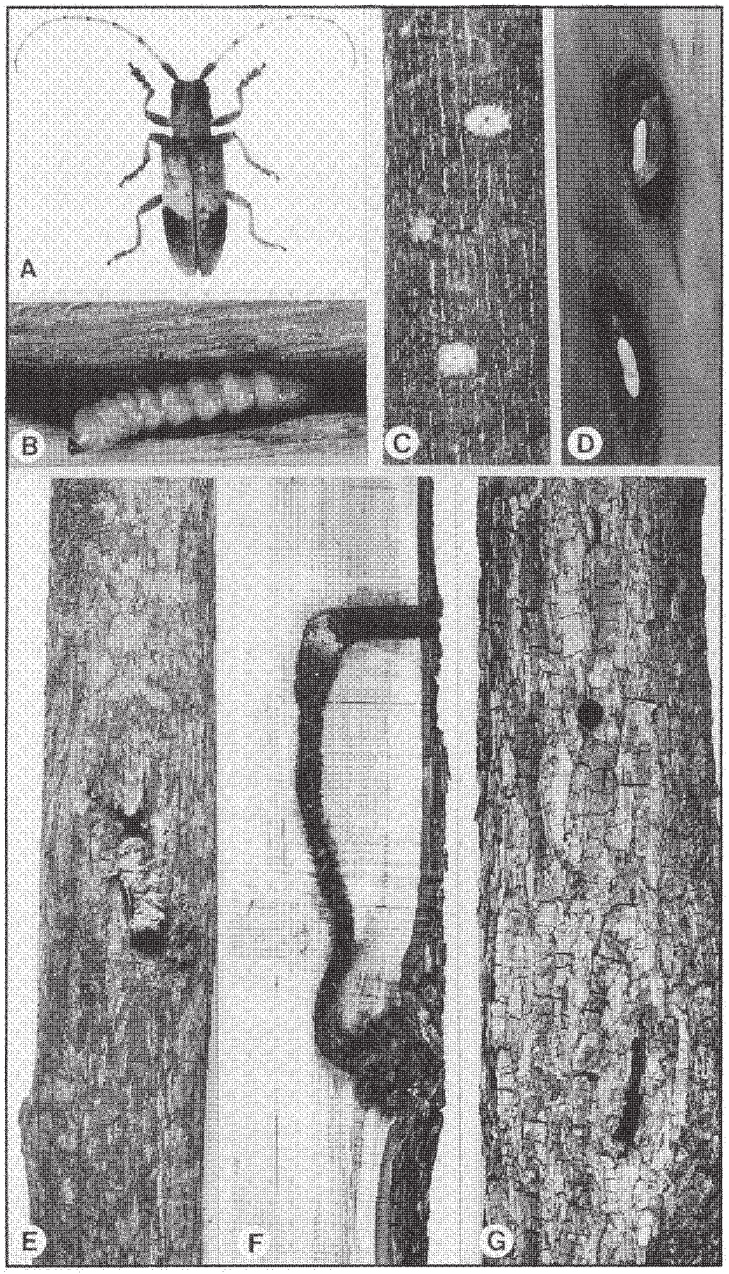

Figure 119—Goes pulcher, *[hickory borer]: A, adult; B, larva; C, egg niches; D, eggs beneath bark; E, frass extruded from elongate entrance; F, gallery—entrance below, exit above; G, entrance hole below, exit hole above.*

mating and egg laying. To oviposit, females chew oval niches in the bark, then force the ovipositor through the opening, downward between the bark and sapwood to deposit 1 egg per niche. Females are known to deposit up to 14 eggs each, but probably deposit many more. Eggs are usually deposited singly, but clusters of two to three niches may be found. Adults live 11 to 32 days. Newly hatched larvae produce small irregularly shaped mines of 1 to 2 cm in diameter under the bark before tunneling into the sapwood. This behavior differs from that of the closely related species *Goes tigrinus* and *G. pulverulentus*, whose larvae bore directly into the sapwood after eclosion. During late fall and early spring of the final year of development, mature larvae construct pupal chambers by closing the uppermost portion of galleries with plugs of long excelsior-like fibers. Pupation lasts 15 days during mid-April to early May. The new adults chew circular emergence holes through the bark. The life cycle is completed in 3 to 5 years.

Injury and damage. Earliest indications of attack are egg niches 4 to 8 mm in diameter (figure 119C) made by egg-laying females (Solomon 1974). Egg niches are most common on the sunny aspect of the trunk; they frequently occur in branch crotches (Craighead 1923). As young larvae begin to reach the outer sapwood, oozing sap from the point of attack darkens the bark. In succeeding years, the stain becomes slightly bleached or yellowish brown. Frass extrudes from the entrance hole (figure 119E) and falls to the ground. As larvae reach maturity, the frass changes to excelsior-like wood fibers 8 to 12 mm long. Larval galleries (figure 119F) extend horizontally or obliquely upward 2 to 5 cm from the point of entry into the wood, rise vertically another 6 to 12 cm, then turn horizontally back to the surface. Active galleries often are partially filled with frass, particularly along the innermost wall. Small diverticula tightly packed with frass sometimes occur at the junction of the horizontal and vertical tunnels of the gallery. Completed galleries are 9 to 16 cm long and 1.0 to 1.3 cm in diameter. Each borer leaves two holes, an elongate entrance hole and a 7-mm-diameter round exit hole (figure 119G). As these wounds heal, bark scars at entrance sites appear as slightly sunken slits, with a small bulge around the periphery. The exit holes heal to form circular scars resembling overgrown branch stubs and are visible for several years. Borer attacks are most common on main stems 7 to 11 cm in diameter. Trunk diameters at point of attack average less for pecan and water hickory than for mockernut and bitternut hickories. Tree trunks are most commonly attacked between 1.5 and 2.3 m above groundline, but occasionally attacks may occur from the tree base to heights of 4.8 m. Attacks on large trees are restricted usually to the upper trunk and branches. On trees of poor vigor, whose borer injuries are slow to heal, galleries serve as nesting sites for ants and also permit stain and decay fungi to be established. Trunks weakened by borer galleries and woodpecker excavations may be broken by wind. Borer holes, stain, and decay degrade the wood for handlestock, furniture, and other commer-

cial uses (Solomon 1974).

Control. Heavy sap-ooze at oviposition sites kills many eggs and early instar larvae (Solomon 1974). Woodpeckers are major predators of borers that survive beyond the first year; up to a third of the larvae have been destroyed by woodpeckers in some localities. No parasites have been reported. In forest stands and woodlots, the removal of brood trees during stand improvement operations is silviculturally plausible. In shade trees and other valuable trees, this pest can be controlled mechanically with knife and wire or by injecting commercial fumigants into galleries. Attacks can be prevented with trunk sprays of an insecticide during the oviposition period.

Plectrodera scalator (Fabricius)

cottonwood borer (figure 120)

Hosts. Poplar, willow. Eastern cottonwood is preferred host, followed by the other poplars; willows are only occasionally attacked (Solomon 1980).

Range. New York south to Georgia and west to Texas, New Mexico, and Montana (Linsley and Chemsak 1984, Solomon 1980). Most common through the Great Plains from Texas north to South Dakota and in the Mississippi River Valley from Mississippi north to Michigan.

Description. ***Adult.*** Elongate, somewhat cylindrical, very robust longhorn beetle (figure 120A) (Blatchley 1910, Milliken 1916). Measures 25 to 40 mm long and about 12 mm wide. One of largest and most strikingly colored longhorn beetles in North America. Ground color of body and appendages shiny black. White pubescence covers front of head and surrounds eyes. White pubescence on thorax arranged to form longitudinal, dorsal, bare black patch and similar black areas at base of large spines on sides of thorax. Each elytron with two irregular rows of rectangular, shiny black patches running longitudinally that are separated by irregular longitudinal and transverse bands of white pubescence, giving elytra checkered appearance. Long antennae black with first two segments rusty to gray. ***Egg.*** White to yellowish and elliptical; chorion tough and leathery; measures 3 to 4 mm long (figure 120B) (Milliken 1916, Solomon 1980). ***Larva.*** Mature larva robust and cylindrical in form, and about 55 mm long and 12 mm wide (figure 120C) (Milliken 1916). Integument very thin, shiny, and densely covered with short, golden brown hairs. Prothorax in front bears a continuous transverse row of short golden brown hairs; rear portion covered with velvety pubescence. ***Pupa.*** Similar in form to adult and averages about 35 mm long (figure 120D) (Milliken 1916).

Biology. Adults emerge late May to late June in Mississippi (Solomon 1980) and late June to mid-August in Kansas (Milliken 1916). Adults live about a month after emerging. After feeding on leaf petioles, new twig growth, and tender bark, females dig shallow pits 6 to 19 mm deep in the soil at the root collar, then shred the bark with their jaws to make oviposition sites. After depositing a single egg at each site, females partially fill the soil pits. Eggs hatch after incubating 13 to 18 days, and young larvae mine down-

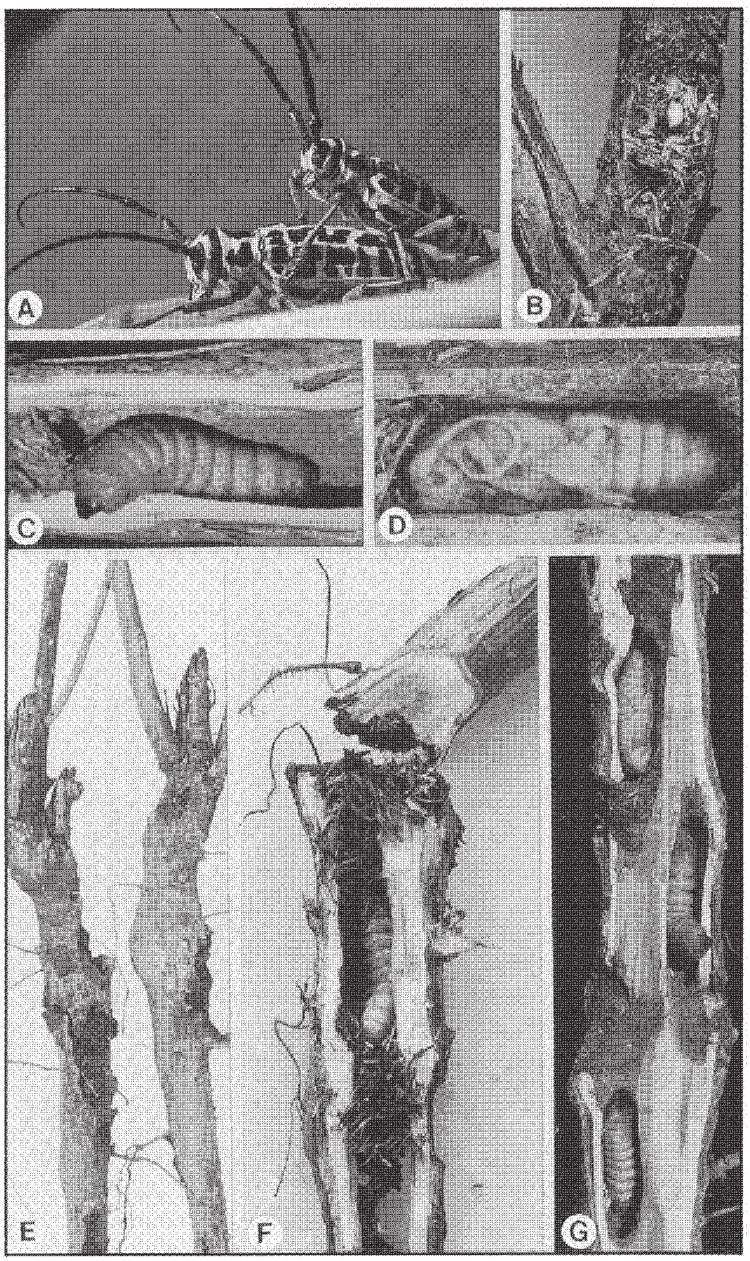

Figure 120—Plectrodera scalator, *cottonwood borer: A, adults mating; B, egg; C, larva; D, pupa; E, infested roots with swellings, openings, and frass; F, infested plant broken at root collar; G, multiple infested root.*

ward in the inner bark and soon begin to etch the wood. Galleries extend downward into the taproot of 1- and 2-year-old seedlings; however, galleries may extend slightly upward above ground when multiple larvae are present. In larger trees, larvae usually do not penetrate the wood deeper than 25 mm and often hollow out roughly oval areas 51 to 76 mm in diameter, a habit particularly common where larvae tunnel in large roots. Galleries in small lateral roots are narrow and range from 10 to 20 cm long. Portions of the galleries are typically packed with excelsior-like shredded wood, which is also used to plug any openings in the bark. One or two winters are spent in the larval stage. From late April to early July, mature larvae construct pupal cells by plugging the galleries with fibrous frass. New adults emerge by cutting exit holes 10 to 13 mm in diameter directly through the bark and to the soil surface; such holes are sometimes visible in the soil and on the bark near groundline. A 2-year life cycle has been reported (Milliken 1916) for cottonwood borers in large trees; however, in 1- and 2-year-old trees in Mississippi, most of a brood develops in 1 year, and the remainder develops in 2 years (Solomon 1980).

Injury and damage. Symptoms of cottonwood borer infestation in 1-year-old plants in nurseries are shriveled and dry terminals, twigs, and bark, and broken stems (Morris 1963, Solomon 1980). When plants are lifted for planting, infested roots appear swollen, or galled, and openings in the bark expose larval galleries packed with excelsior-like frass (figure 120E). Hollowed and weakened young plants often break at the root collar (figure 120F). Heavily infested plants may harbor three or more larvae in the main root (figure 120G). Similar injury occurs in 2-year-old plants. In addition, adults may partially or completely girdle the bark on twigs, causing them to break off or die; sever leaf petioles, resulting in a ragged defoliated appearance; and make numerous, deep, shredded, oviposition niches that can result in broken stems. Fibrous, reddish brown frass is sometimes ejected at the root collar, but because most attacks occur at groundline and larvae burrow downward, infestation often goes unnoticed unless breakage occurs. Injury to large trees is more difficult to detect unless the soil is removed to expose the root collar and upper roots. As high as 27% of 1- and 2-year-old stools were infested in one Mississippi nursery (Solomon 1980). Occasionally, adults become numerous in nurseries, causing bark wounds, broken terminals, breakage of stems near the ground, and partial defoliation when leaf petioles are severed. Extensive bark injury and broken terminals cause excessive branch forking and crooked sprouts, which reduce the quality of sprouts for vegetative cuttings. In plantations, the bases of young trees are sometimes riddled by the larvae, but trees seldom die from such injury. Natural and planted cottonwood stands on poor sites, such as sand flats and heavy clays, are more heavily infested than stands on good sites. Also, shelterbelt plantings on the Great Plains have been severely damaged by the cottonwood borer.

Control. The cottonwood borer has few parasites and predators because most of its life cycle is spent in the tree below ground level; however, in Kansas, beetles have been heavily parasitized by the fly *Sarcophaga vericanda* Coquillett (Hungerford 1915). Woodpeckers, raccoons, and skunks occasionally feed on larvae when they occur in stems and exposed roots (Solomon 1980). Extended flooding in lowlands sometimes kills many larvae. Cultural practices can help to minimize losses. New nursery sites should be selected that are isolated from infested natural or planted stands. Nurseries with a history of heavy damage should rogue, pile, and burn old stools to destroy the reservoir of infestation at 3-year intervals.

Neoptychodes trilineatus Linnaeus

[fig tree borer] (figure 121)

Hosts. Fig, alder, mulberry, willow, netleaf hackberry. Fig is the preferred host (Cope 1984, Craighead 1923, Linsley and Chemsak 1984).

Range. Throughout the southern United States from South Carolina to Florida along the Gulf Coast into Texas and west to Arizona and south to South America (Horton 1917, Linsley and Chemsak 1984). Also prevalent throughout Central America and occurs in some parts of South America.

Description. ***Adult.*** Robust and elongate longhorn beetle; female 21 to 35 mm long and male 19 to 31 mm long (figure 121A) (Horton 1917, LeBeau 1938, Linsley and Chemsak 1984). Average body width about 5 mm. Long antennae of males average 63 mm, or nearly 2.5 times body length; antennae of females markedly shorter. Head with deep narrow groove at middle and eyes nearly divided by bases of antennae. Legs slender with fore pair longest. Body broadest across base of elytra, which taper toward tips and end in short spine near dividing line between elytra. Two broad brown stripes, accented with minute orange tufts in longitudinal rows, extend from bases of antennae to tips of elytra. Medial white to yellow stripe with scalloped edges runs full length of abdomen and thorax, and two similar lateral stripes extend from near tips of elytra along margins to base of antennae. ***Egg.*** Elongate, nearly cylindrical, white to pale yellow or green, and averages 3.5 mm long and 0.9 mm wide. ***Larva.*** White to cream-colored, legless grub, varying in length from 3 mm just after hatching to 43 mm when fully grown (figure 121B) (Craighead 1923, LeBeau 1938). Larval body broadest across prothorax, gradually tapering toward tip of abdomen. Anterior borders and mandibles of head dark brown to black and posterior portion clear light amber. ***Pupa.*** Creamy white and averages 24 mm long and 5 mm wide across thorax.

Biology. Along the Gulf Coast, emergence of adults begins in March, accelerates in May, continues through summer, and reaches a peak in September. The last adults emerge as late as November or early December (Horton 1917). Adults feed on small succulent twigs, foliage, and immature or ripe figs. Females live 3 to 8 months and deposit from 130 to 260 eggs each. Females start ovipositing 8 to 16 days after they emerge and continue for 66 to 179 days, the

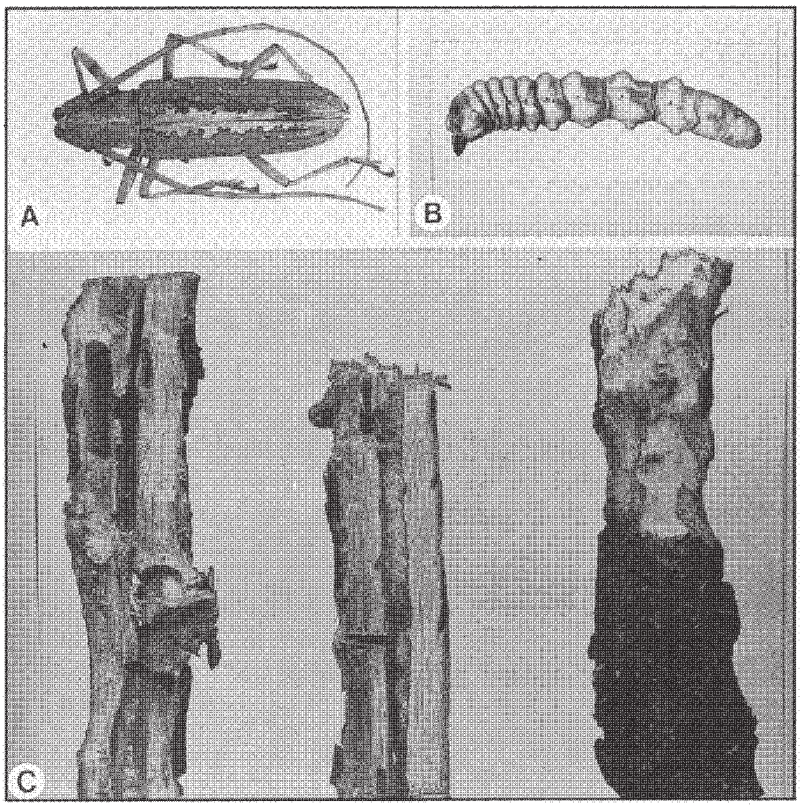

Figure 121—Neoptychodes trilineatus, *[fig tree borer]: A, adult; B, larva; C, infested stems with mines, galleries, and frass (A, specimen courtesy R. Hodges; B & C, reproduced from Horton [1917]).*

longer oviposition periods occurring during cooler months. Females chew two parallel transverse slits in the bark of trunks and branches with their mandibles and deposit eggs in them. Egg incubation averages 6.5 days in Louisiana. Newly hatched larvae feed in the inner bark or surface of the sapwood for 1 to 3 weeks, then gradually penetrate deep into the wood, packing galleries with sawdustlike frass. About two-thirds of the larvae complete development in an average of 3 months and emerge as adults in the same year that the eggs were laid; the remaining larvae generally require 9 to 11 months and emerge as adults the year after oviposition (Horton 1917, LeBeau 1938). Mature larvae pupate in their galleries in cells of tightly packed sawdustlike frass. Pupation varies greatly from 5 to 73 days and averages 24 days but is shorter during summer. Newly transformed adults chew circular holes through the bark to emerge.

Injury and damage. Dead or dying branches and a general decline in tree vigor may be the first noticeable indications of infestation (Horton 1917). Close inspection reveals the characteristic transverse, parallel oviposition slits in the bark made by the female. Very little frass is ejected to the outside except at cracks, crevices, and other broken places in the bark. Splitting infested stems reveals the white larvae and long frass-packed galleries (figure 121C). Feeding injury by the adults on the bark of tender twigs, leaves, and fruit is further evidence of infestation. This borer is very destructive where figs are grown commercially, damaging trees that are diseased and mechanically injured. After initial attacks, trees often are infested repeatedly in succeeding years until killed. Once infested, trees usually succumb within 2 to 3 years. Up to 1,700 borers have been found in one large fig tree in Louisiana. Trees in good health are seldom attacked.

Control. Natural enemies have not been reported in the literature. Preventive measures are far better than remedial ones. The insect rarely oviposits in vigorous hosts; therefore, the best control measure is keeping trees healthy (Gould 1935, Horton 1917, LeBeau 1938). Care should be taken to avoid bruising the bark or breaking limbs during cultivation and fruit harvest. Trees should be shaped through pruning for maximum strength against breaking and splitting by high winds. Infested branches should be pruned out immediately. Pruning wounds and mechanical injuries should be carefully cleaned, wound edges smoothed and painted with wound dressing. All prunings and infested branches should be promptly destroyed. Repeated insecticide applications may be needed to protect valuable trees in high-risk areas.

Synaphaeta guexi LeConte

[spotted tree borer] (figure 122)

Hosts. Willow, poplar, maple, California buckeye, California laurel, fig, walnut, chestnut, cherry, apple, pear, elm, oak. Although the insect has a wide host range, it seems to prefer willow and maple (Craighead 1923, Essig 1958, Linsley and Chemsak 1984).

Range. A Pacific Coast species ranging from southern California north to British

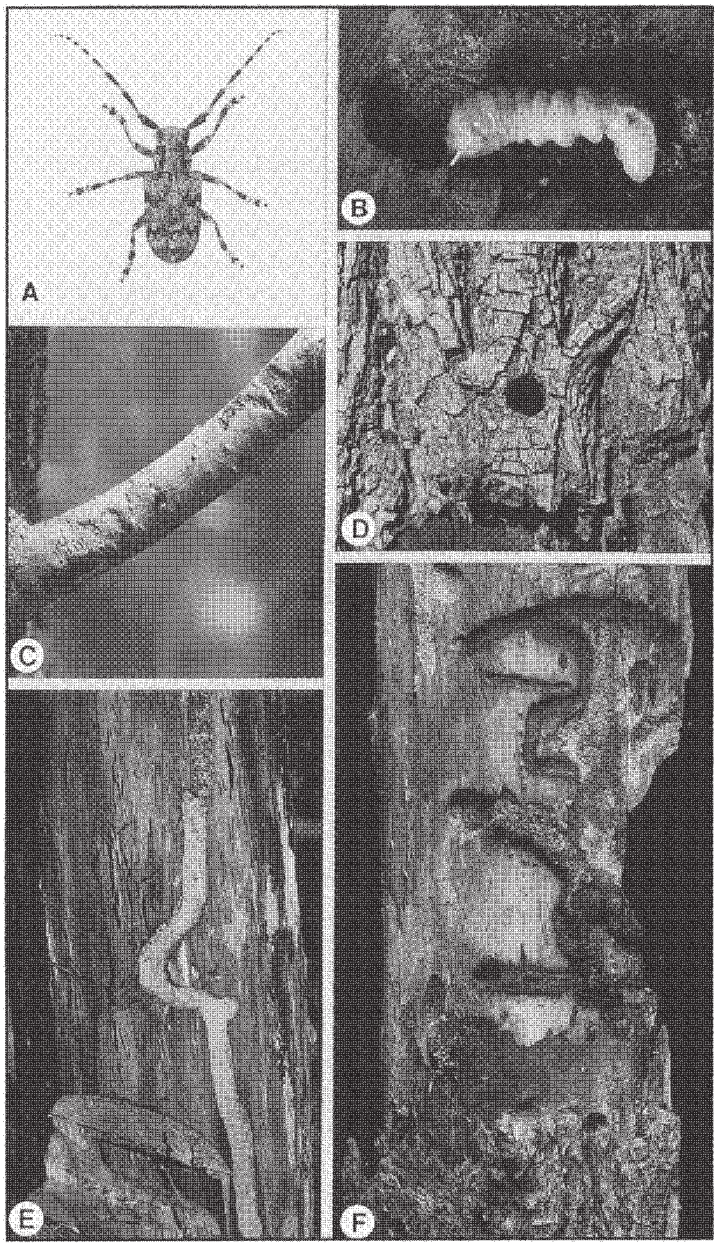

Figure 122—Synaphaeta guexi, *[spotted tree borer]: A, adult; B, larva; C, adult chew marks on green willow twigs; D, round emergence hole; E, early larval, frass-packed gallery on surface of sapwood; F, late larval galleries penetrating wood (specimens courtesy F. Hovore and R. Penrose).*

Columbia (Craighead 1923, Essig 1958, Linsley and Chemsak 1984).

Description. ***Adult.*** Rather short, broad, very robust longhorn beetle, rough, noticeably flattened across dorsum and from 12 to 23 mm long (figure 122A) (Essig 1958, Linsley and Chemsak 1984). Antennae slightly longer than body and joints tipped with bluish gray. Base of elytra markedly wider than pronotum, giving square-shouldered appearance. Beetles bluish gray, minutely punctured, mottled with white, black, and orange with two zigzag black stripes across elytra (Furniss and Carolin 1977). ***Larva.*** Robust, slightly depressed, white except for dark-brown head and mandibles, shiny, sparsely clothed with long, slender, golden hairs, 16 to 28 mm long (figure 122B) (Craighead 1923, Michelbacher and Ortega 1958).

Biology. Adults may be present year round, but most emergence occurs from April to July (Linsley and Chemsak 1984). New adults feed on the succulent bark of young twigs and branches before ovipositing. Females select trees that are weakened, injured, or recently dead, preferring to oviposit in wounds or injuries (Essig 1958, Michelbacher and Ortega 1958). Females cut niches in the bark to receive the eggs. Larval galleries often begin in small branches and extend through large branches and even the trunks. Larvae make extensive galleries and pack the frass within the burrows. Pupation occurs within a chamber in thick bark, just beneath the bark, or in the wood, and usually perpendicular to the surface. The duration of the life cycle is unknown.

Injury and damage. Chew marks made by feeding adults in the tender bark of young branches are evidence of the beetles (figure 122C). Examining the bark on trunks and large branches reveals egg niches in it. The emerging adults leave round holes 6 to 8 mm in diameter in the bark (figure 122D). Larval burrows are large, wide, somewhat flattened, and filled with frass. Galleries made during early development are long and meander mostly on the surface of the sapwood (figure 122E). Those made by older larvae extend through both the sapwood and heartwood, and the frass is coarse and fibrous (figure 122F).

Control. Natural controls have not been studied. Good maintenance that keeps orchard and ornamental trees in good health is the best protection.

Dorcaschema wildii Uhler

[mulberry borer] (figure 123)

Hosts. Mulberry, Osage-orange. Where the two hosts occur together, mulberry (especially red mulberry) is usually attacked and suffers larger infestations (Solomon 1968).

Range. Reported from Ohio (Knull 1946) south to Mississippi and west to Texas and Nebraska (Linsley and Chemsak 1984, Solomon 1968), but it probably occurs throughout the natural ranges of its two known hosts in the central and eastern United States.

Description. ***Adult.*** Typical longhorn beetle with antennae up to 50 mm long in male and 30 mm long in female; elongate and moderately robust and ranges from

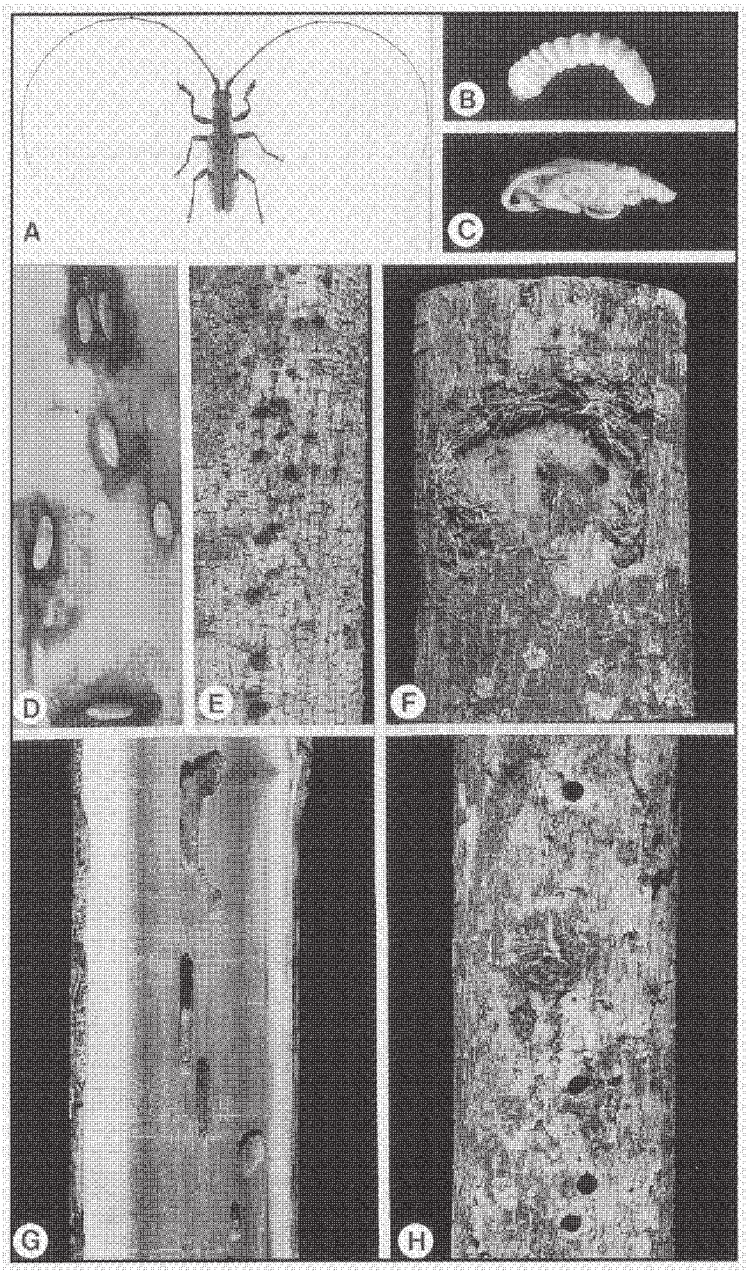

Figure 123—Dorcaschema wildii, *[mulberry borer]: A, adult; B, larva; C, pupa; D, eggs beneath bark; E, cluster of egg niches in bark; F, larval cavity partially filled with fibrous frass beneath the bark; G, galleries extending into wood; H, emergence holes.*

16 to 22 mm long and 3 to 5 mm wide (figure 123A) (Dillon and Dillon 1972, Knull 1946). Body dark brown with surface clothed in fine gray and light brown hairs. Elytra with numerous small round bare spots that make surface appear pitted, and a light brown stripe along outer margins. Pronotum noticeably elongate and cylindrical. ***Egg.*** Yellowish white, elongate, about 3 mm long and 1 mm wide (figure 123D). ***Larva.*** Shiny, legless, cylindrical, and white to cream colored, except for amber head with dark brown mandibles and 20 to 26 mm long at maturity (figure 123B). ***Pupa.*** Entirely white when first formed, 15 to 20 mm long (figure 123C).

Biology. Adults emerge from about mid-May to mid-June (Solomon 1968) and live for several weeks. They have been taken in light traps as late as July 18. New adults feed on the foliage for a few days before mating and laying eggs. Ovipositing females chew niches in the bark, deposit 1 to 2 eggs between the bark and wood, and seal the openings with a secretion that hardens as it dries. Females caged on mulberry trunks laid 5 to 21 eggs, but those in the wild probably lay many more. Oviposition occurs late May to early July. Sometimes 50 or more egg niches have been observed on a tree (Solomon 1968). Early-stage larvae feed between the inner bark and wood and mine irregular patches of inner bark 2.5 to 7.6 cm in diameter. When larvae are 1 to 3 months old, they begin constructing galleries in the wood. The oblong to oval galleries curve horizontally inward for about 2.5 cm, turn upward for another 2.5 cm, then curve back toward the surface. Diameters of completed galleries range from 3.2 to 6.3 mm. Only one grub occupies each gallery, but larvae feed so close together that their cavities often overlap. Larvae overwinter in their galleries, which they partially plug with loose fibrous frass in late fall. During spring, the larvae enclose themselves with excelsior-like wood fibers in pupal chambers at the innermost portion of the galleries. Pupation occurs from about mid-April to late May and lasts 19 to 22 days. Newly formed adults chew round exit holes through the wood and bark to emerge. The life cycle varies from 1 to 2 years, but most of a brood matures in 1 year (Solomon 1968).

Injury and damage. Egg niches (figure 123E) 2 to 3 mm in diameter cut in the bark are the first signs of attack (Solomon 1968). From 8 to 30 egg niches are commonly clustered on one or more areas of the trunk or branches. On vigorous trees, sap soon begins to ooze from the niches and runs down the trunk. After the eggs hatch and the larvae begin to feed, fine frass is ejected from the egg niches. As the larvae grow, the frass becomes coarse and fibrous. Frass protruding from numerous openings in the bark is a clear sign of an established infestation. Trees under 10 cm in diameter at breast height are most commonly attacked, but larger trees may be infested. On large trees, it usually first attacks branches and the upper trunk and may also attack large exposed roots. Dying branches and parts of the crown indicate attack. Repeated attacks during later years occur

lower on the trunk, often until the entire tree succumbs. Several months to a year later, the bark near a cluster of attacks loosens and breaks away, exposing larval mines etched in the wood surface (figure 123F). Dissection reveals the galleries extending through the wood (figure 123G). Round exit holes 4 to 5 mm in diameter are left in the bark by the emerging beetles (figure 123H). Trees that suffer from suppression, drought, or fire damage apparently are most attractive. Adults feed on mulberry foliage, devouring long narrow strips of leaf tissue along the midribs and major veins. Beetles rest on or under the leaves during daylight and can be easily beaten and dislodged from the foliage. Damage to mulberry trunks and branches is prevalent in the mid-South, where infestations are frequently so heavy that individual branches and even entire trees are girdled and killed. Trees are often attacked repeatedly in successive years until they succumb; lightly attacked trees that recover usually have large scars on their trunks (Solomon 1968). In the late 1800's, the borer was a destructive pest of Osage-orange hedgerows in the Philadelphia area (Laurent 1898).

Control. Woodpeckers are among the most important natural enemies of the mulberry borer. In one study area, woodpeckers worked 90% of trees infested (Solomon 1968). A braconid parasite—*Cencoelius* sp.—has been reared from infested bolts. One or two monthly applications of insecticide applied during the oviposition period may be needed to protect valuable trees.

Dorcaschema alternatum (Say)

[small mulberry borer] (figure 124)

Hosts. Mulberry, Osage-orange. In the South, red mulberry is more heavily infested than white mulberry or Osage-orange (Craighead 1923, Knull 1946, Gosling and Gosling 1977, Laurent 1898).

Range. New York south to Georgia and Alabama and west to South Dakota and Texas (Fattig 1947, Gosling and Gosling 1977, Leng and Hamilton 1896, Linsley and Chemsak 1984).

Description. ***Adult.*** Longhorn beetle with elongate, slender, cylindrical body, brown to dark brown, sparsely clothed with light gray to light brown pubescence and ranges from 7 to 16 mm long (figure 124A) (Dillon and Dillon 1972, Knull 1946, Linsley and Chemsak 1984). Thorax with four narrow stripes of clay-yellow pubescence. Elytra, with subparallel sides, covered with rows of irregular spots of dull yellowish to light brown pubescence. Antennae about three times body length in males and two times body length in females. ***Egg.*** Elongate, creamy white, and about 2 mm long (figure 124C). ***Larva.*** Shiny, legless, cylindrical, 16 to 20 mm long at maturity (figure 124B). Larva yellowish white except for amber spiracles and head with blackish mandibles. ***Pupa.*** Adultlike, remarkably smooth, and darkens with age (Craighead 1923).

Biology. In Mississippi, adults emerge and are present from May to July, but have been collected in other areas as late as September (Fattig 1947). Adults feed extensively on foliage of hosts and usually rest, feed, and mate on the undersides of

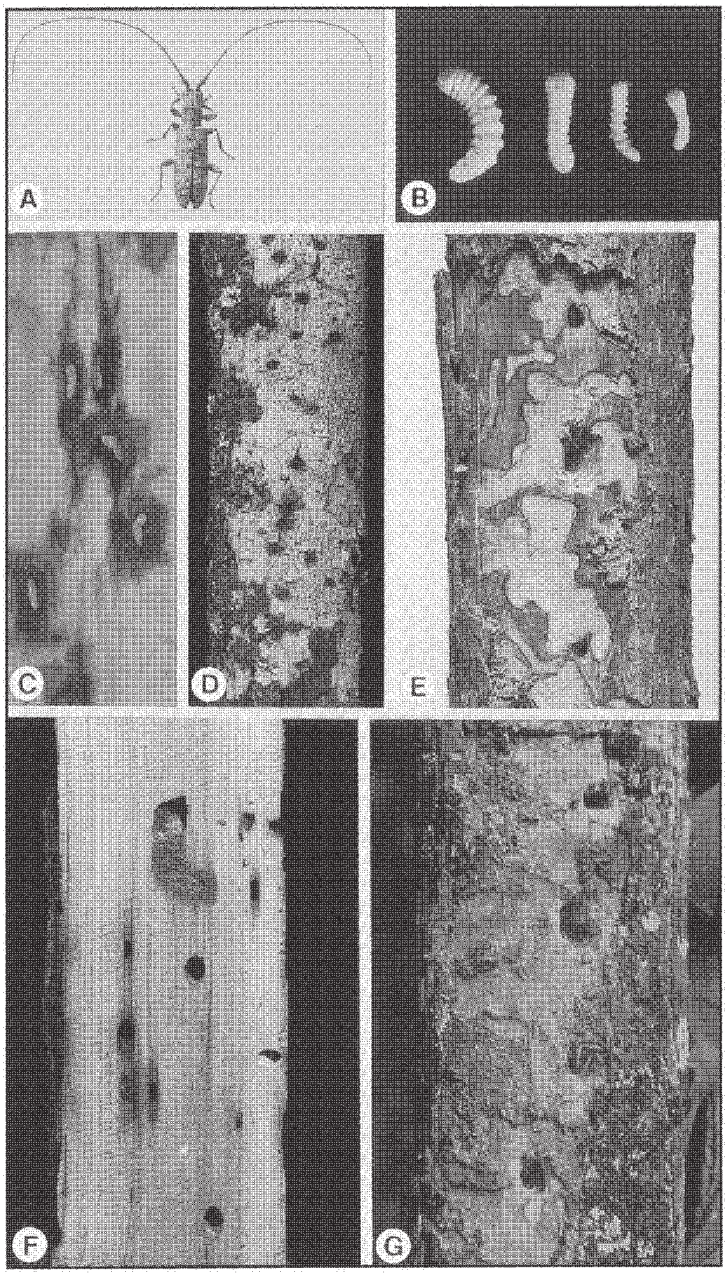

Figure 124—Dorcaschema alternatum, *[small mulberry borer]: A, adult; B, larvae; C, eggs under bark; D, cluster of egg niches in bark; E, larval mines beneath bark; F, galleries in the wood; G, pecked holes indicating woodpecker predation.*

leaves during the day. Females prefer weakened trees for oviposition—usually those stressed by drought, fire, or previous infestation by either *D. wildii* or this species. This borer may infest branches, trunks, and exposed roots (Riley 1880). Females deposit eggs in groups on portions of the tree but often adjacent to bark killed by previous broods. Larvae mine the cambium area extensively. The mines of several larvae often intersect and girdle the branch or trunk. The larvae later construct galleries that curve horizontally into the wood, then turn upward and outward. Larvae overwinter in their galleries and pupate in spring in pupal chambers formed by plugging the galleries with excelsior-like wood fibers. Pupation lasts about 3 weeks. New adults emerge by chewing round exit holes 2 to 3 mm in diameter through the wood and bark. A life cycle requires 1 to 2 years.

Injury and damage. Trees suffering top dieback should be inspected. Clusters of small egg niches cut in the bark usually occur on one side of the trunk (figure 124D). The bark of infested trees may crack and split and will have numerous tiny openings. Larvae eject yellow, short, fibrous frass in abundance during the fall; this frass may be present on the bark and around the base of the tree. Lifting the bark reveals extensive mines that etch the sapwood quite deeply in places (figure 124E) and numerous white larvae. Portions of the mines are tightly packed with both fine and fibrous frass. Galleries extend into the wood (figure 124F), frequently beside those of *D. wildii*, and are difficult to distinguish except that they are smaller than those of *D. wildii*. This borer attacks both vigorous and dying trees. In the mid-South, infestations often become heavy enough to girdle and kill trees in one season. Once infested, trees usually are attacked repeatedly until they succumb.

Control. Woodpeckers capture large numbers of larvae during winter and spring (figure 124G). A hymenopterous parasite—*Eurytoma dorcaschemae* Ashmead—has been recorded (Linsley and Chemsak 1984). An unidentified fungus disease has also been found, but incidence has been light. Insecticides may be needed to protect ornamentals.

Oncideres cingulata cingulata (Say)

twig girdler (figure 125)

Hosts. Hickory, pecan, persimmon, elm, sourwood, basswood, honeylocust, dogwood, eucalyptus, oak, hackberry, maple, fruit trees. Prefers the hickories, pecan, persimmon, elms, and hackberry, but attacks many species when its populations are high. Oaks (including water oak, post oak, live oak, and Nuttall oak) and fruit trees (including apple, pear, peach, plum, and citrus species) are attacked only occasionally (Bilsing 1916, Linsley and Chemsak 1984). Mesquite, acacia, and blackbead serve as hosts to the subspecies *O. c. texana* Horn (Hovore and others 1987, Linsley and Chemsak 1984).

Range. Most common in the South but known as far north as New England and westward to Kansas and Texas (Beal and

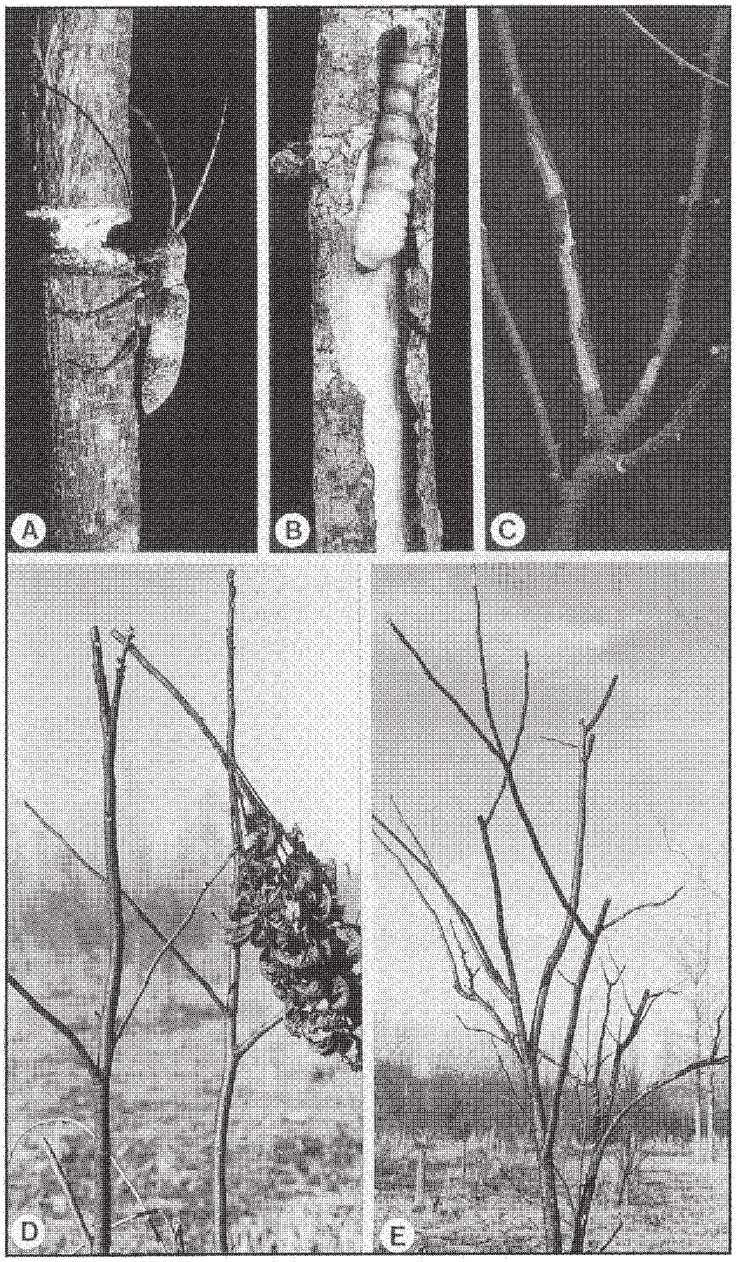

Figure 125—Oncideres cingulata cingulata, *twig girdler: A, adult girdling stem; B, larva in gallery; C, adult-feeding injury to bark; D, pecan terminal girdled; E, 4-year-old pecan with every major branch girdled.*

Massey 1942, Gill 1924, Herrick 1904). The subspecies *O. c. texana* has a range limited to south Texas and northeastern Mexico (Linsley and Chemsak 1984).

Description. ***Adult.*** Typical longhorn beetle from 11 to 20 mm long (figure 125A) (Bilsing 1916, Gill 1924, Herrick 1904). Body cylindrical and generally grayish brown with broad ash gray band across middle of elytra. ***Egg.*** White, elongate to oval, and about 2.5 mm long. ***Larva.*** Whitish, cylindrical, legless grub that reaches 16 to 25 mm at maturity (figure 125B). ***Pupa.*** White with short, dark spines on dorsal sides of segments.

Biology. Adults emerge late August to early October (Bilsing 1916, Gill 1924, Herrick 1904). They feed on tender bark near branch ends of host trees and mate before ovipositing and girdling twigs. Females girdle branches apparently to provide a suitable medium with a concentrated food resource (particularily nitrogen) to enhance larval survival (Forcella 1982). They lay eggs during or after girdling but never before making part of the cut. Females insert eggs singly beneath the bark, or slightly into the wood, usually near bud scars or adjacent to sideshoots. The number of eggs per twig usually varies from 3 to 8 but may range up to 40. Adults live 6 to 10 weeks, and females deposit 50 to 200 eggs each. Eggs hatch in about 3 weeks. Larvae grow very little in fall and winter but grow rapidly during spring. They usually tunnel toward the severed end of the twig, feeding only on the woody part and leaving the bark intact. Feeding larvae make a few small circular holes in the bark to eject pellets of frass. Mature larvae close off the galleries with shredded fibers to form pupation chambers and pupate in August and September for 12 to 14 days. Adults chew circular holes in the bark to emerge. This girdler has one generation per year.

Injury and damage. Feeding adults sometimes remove large patches of bark from twigs and small branches (figure 125C). Severed twigs on the ground, hanging, loosely attached (figure 125D) or lodged in the canopy during late summer and fall are good evidence of infestation (Gill 1924, Herrick 1904). Most girdled twigs are from 6 to 12 mm in diameter, occasionally up to 18 mm in diameter, and 30 to 60 cm long. The girdle distinguishes injury by the twig girdler from that of branch pruners. The cut is made from the outside by the adult beetle and has been described as a uniform V-shape encircling the twig (figure 125A). The cut is seldom complete, having a small center with a jagged surface caused by the break. Close inspection of severed twigs reveals tiny egg niches and many mandible marks or grooves made in the bark by the female beetles. Because twigs are girdled while leaves are present, the severed twigs retain their brown leaves for some time. Severed twigs lodged in the canopy or on the ground often retain their leaves even after the tree sheds its leaves at frost. Trees in young pecan plantations close to wooded tracts occasionally suffer heavy damage; the terminal and all major laterals may be girdled (figure 125E) (Kennedy and others 1981).

Severed twigs commonly cover the ground under infested trees. Fruiting of heavily infested pecan trees is often greatly reduced, resulting in low nut yields the following year and sometimes longer. This injury causes the development of many sideshoots that adversely affect tree symmetry. Nurseries producing pecan and other susceptible hosts near heavily infested woodlots occasionally suffer loss of many girdled seedlings. Repeated girdles of terminals in young timber plantations and in natural reproduction causes forks, crooks, and other stem deformities (Kennedy and others 1981).

Control. Natural controls are important in keeping twig girdler populations low. Desiccation of the eggs is the greatest decimating factor. Hymenopterous parasites—including *Eurytoma magdalidis* Ashmead, *Heterospilus* sp., *Horismenus* sp., *Iphiaulax* sp. and *I. agrili* (Ashmead)—help to reduce populations (Beal and Massey 1942). A predator—*Cymatodera undulata* Say—has also been reared. In orchards, nurseries, and ornamental plantings, severed twigs on the ground and those lodged in the trees should be gathered and burned during fall, winter, and spring to destroy the eggs and grubs (Gill 1924, Moznette and others 1931). The same practice should be followed in woodlots when plantings in the vicinity have a history of serious damage. Insecticides may be necessary to prevent damage from heavy infestations.

Oncideres pustulatus LeConte

[huisache girdler] (figure 126)

Hosts. Huisache, guajilla, honey mesquite, western honey mesquite, Jerusalem-thorn, lindheimer mimosa, ebony blackbead, great leucaena (Craighead 1923, Duffy 1960, Hovore and Penrose 1982). Prefers huisache and great leucaena, but most leguminous trees within the range seem to be susceptible (Rice 1989).

Range. Temperate south central Texas to tropical southern Tamaulipas in Mexico (Linsley and Chemsak 1984, Rice 1986).

Description. ***Adult.*** Robust, longhorn beetle varying from 17 to 27 mm in length (figure 126A) (High 1915). Antennae extend slightly beyond ends of elytra, with distal joint of male antennae about twice as long as that of female. Beetles covered with heavy vestiture of brownish gray hair but become darker to nearly black as gray hairs rub off. Basal third of elytra lighter gray than remainder, creating banded appearance. Pronotum with pair of lateral and three median dorsal calluses. ***Egg.*** Elliptical to oval, measuring 2.5 to 3.0 mm long and about 1 mm wide; one end slightly more pointed than other. Eggs white when deposited but become yellowish before eclosion. ***Larva.*** Newly hatched larva about 2.8 mm long with pale white body, light brown head, and dark mandibles. Mature larvae (figure 126B) whitish, cylindrical, legless, 22 to 30 mm. ***Pupa.*** Pronounced dark brown spines on dorsum of each abdominal segment, 18 to 22 mm long.

Biology. Adults emerge from July to late November (High 1915). They mate within several days after emergence; it is not unusual to observe congregations upward of 24 females in a tree crown visited by one or

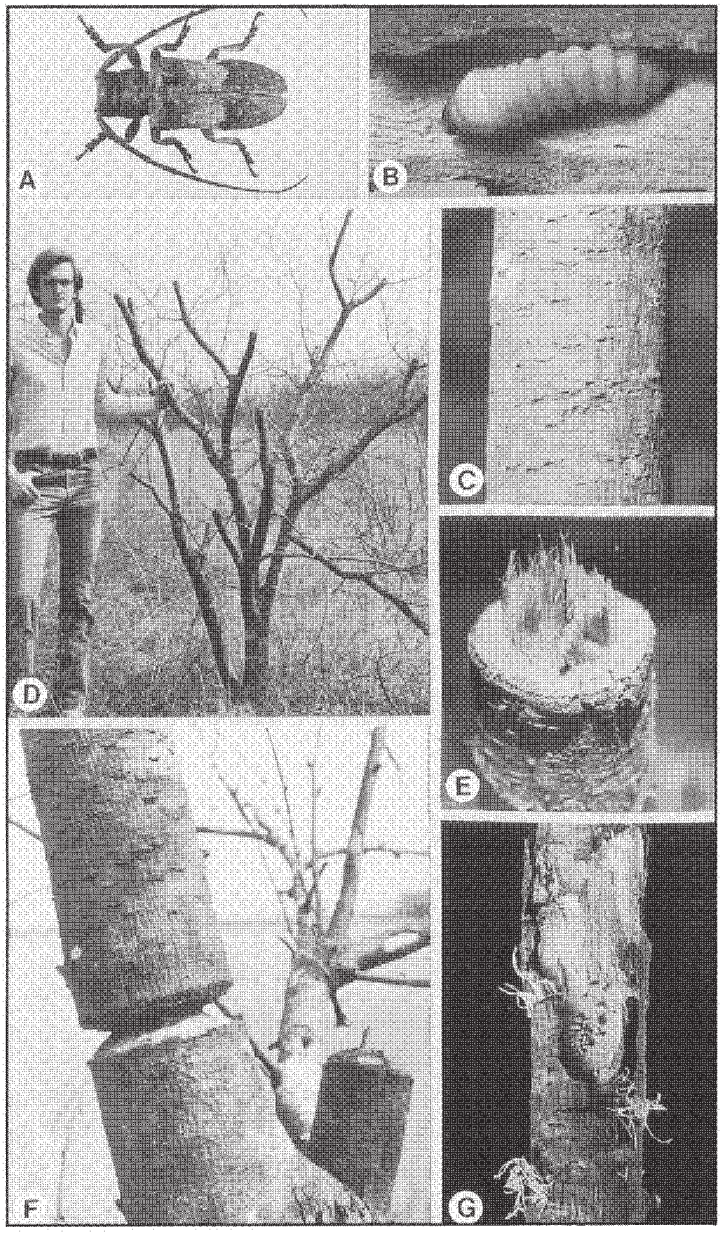

Figure 126—Oncideres pustulatus, *[huisache girdler]: A, adult; B, larva; C, mandible marks and egg niches; D, huisache plant with major branches girdled; E, end of girdled stem; F, branch girdled but not yet broken; G, burrow beneath bark with fibrous frass (specimens and/or photographs courtesy M. Rice).*

two males. Before oviposition, females chew tiny niches in the bark (figure 126C) with their powerful jaws, then deposit single eggs into the cavities and cover them slightly with gluelike secretions. Females may deposit eggs anywhere along the branch to be girdled, not necessarily near the bases of buds and smaller twigs as do some *Oncideres* species (High 1915). After oviposition, females girdle the branches, usually near their bases. After eggs hatch, larvae tunnel in the pith and xylem, packing the frass tightly behind in the galleries. Larvae require 40 to 42 weeks to mature depending on moisture. Before pupation, larvae construct slightly enlarged cells at the ends of the galleries, cut holes through the bark to facilitate adult emergence, then plug themselves off in frass-lined cells. The pupal stage lasts about 4 weeks. The insect generally has a 1-year life cycle (High 1915), but a 2-year cycle has been reported in the lower Rio Grande Valley of Texas (Vogt 1949b). Nineteen species of cerambycid beetles and 14 species of other insects coinhabit the girdled branches of great leucaena in Texas (Hovore and Penrose 1982, Linsley and Chemsak 1984).

Injury and damage. The first evidence of infestation is wilting and dead foliage on branches scattered throughout the crowns of affected trees (High 1915). Girdled branches readily break off (figure 126D) in high winds and litter the ground under the trees. Closer inspection reveals that the branches were cleanly and deeply grooved (girdled) (figure 126E and F) around their circumference. Removing the bark from girdled branches will reveal extensive galleries and fibrous frass (figure 126G). Branches of huisache 13 to 55 mm in diameter—occasionally up to 65 mm in diameter in great leucaena (Vogt 1949b)—and 1.8 to 4.0 m long may be girdled (Rice 1989). No other North American species of *Oncideres* is known to girdle such large branches. Girdling typically occurs a few centimeters from the base of a larger branch or just above where the branch joins the main stem. This insect so severely prunes the branches, particularly on young trees, that they become badly deformed; injury to older trees hinders seed production. Trunks of younger trees may be girdled near the ground, resulting in the death of the entire aboveground portion. This beetle has been so destructive to the valuable shade and ornamental huisache in the arid Southwest that some fear the extinction of the tree (High 1915).

Control. Natural enemies include the hymenopterous parasites *Caenophanes* sp., *Chryseida inopinota* Brues, *Eurytoma* sp., and *Meteorus* sp. (High 1915). The downy woodpecker, Texas woodpecker, and ants are important predators. Dessication or excessive moisture during larval development causes high mortality, and winter temperatures of −5 to −7 °C have caused mortality rates exceeding 90% (Rice 1986). Since girdlers spend at least 10 months in the girdled branches on the ground, collecting and burning them between January 1 and August 1 reduces populations (High 1915).

Oncideres rhodosticta Bates

[mesquite girdler] (figure 127)

Hosts. Mesquite, acacia, mimosa, parkinsonia, ebony blackbead. Honey mesquite appears to be the major host; other species are attacked to a lesser degree (Linsley and Chemsak 1984, Ueckert and others 1971).

Range. The southwestern United States and northern Mexico (Linsley 1940). Particularly prevalent in southwestern Texas.

Description. ***Adult.*** Robust longhorn beetle with cylindrical body with noticeably long antennae; 12 to 19 mm long (figure 127A) (Essig 1958, Polk and Ueckert 1973). Beetles brownish black with gray pubescence on pronotum and across middle and tips of elytra (Essig 1958, Linsley 1940). Surface of each elytron dotted with about 35 to 40 small, yellowish to rusty orange patches of pubescence (Polk and Ueckert 1973). Transverse row of three small swollen spots on pronotum helps to distinguish this species (Linsley 1940). ***Egg.*** Elliptically ovate, creamy white, and slightly pointed at one end, averaging 4.3 mm long and 1.1 mm in diameter (Polk and Ueckert 1973). ***Larva.*** Newly hatched larva yellowish white with light brown head and black mandibles and about 3.2 mm long. Mature larvae (figure 127B) about 25 mm long. ***Pupa.*** About 20 mm long, white when first formed but gradually becoming dark brown (Polk and Ueckert 1973).

Biology. Adults emerge late August to late November from branches girdled the previous year. Adults feed on tender bark around buds, thorns, and small limbs for several days before ovipositing. Females chew deep circumferential grooves that cut through the bark and cambium, and sufficiently deep into the xylem to prevent upward movement of water and nutrients (figure 127C and D). Girdling takes about 2 days; girdled branches are from 5 to 20 mm in diameter (Linsley and others 1961). It is not unusual for a pair to mate while the female girdles a branch (figure 127E). Females oviposit on the branch distal to the point of girdling. To oviposit, the females cut incisions through the bark with their mandibles while facing toward the base of the tree, reverse their position, and insert an egg into each slit with their ovipositors and finally seal the openings with amber secretions (Polk and Ueckert 1973). Up to 10 eggs are deposited on a branch, but the number varies with branch size (Linsley and others 1961). Girdled branches usually break soon after oviposition (figure 127F). Newly hatched larvae feed just under the bark, weakening the branch, which may enhance breakage. Larvae gradually enlarge the oviposition slits and eject frass from their galleries through these openings (Polk and Ueckert 1973). Branches may be partially to completely hollowed by the developing larvae (figure 127G and H). Pupation occurs within the galleries in late August and early September the year after oviposition; thus, this girdler has a 1-year life cycle.

Injury and damage. The first sign of attack is dead and dying branches throughout the crowns of mesquite. The branches die beyond the point of girdling and readily break off in the wind. From August through

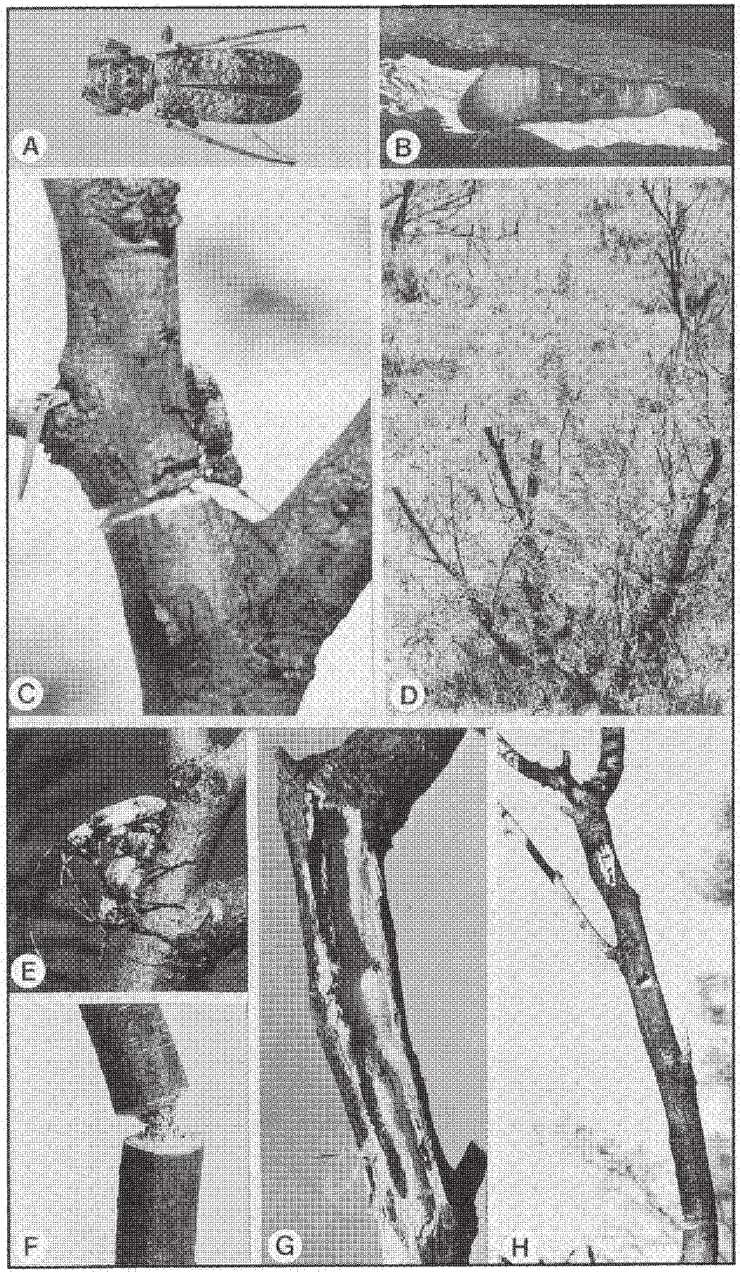

Figure 127—Oncideres rhodosticta, *[mesquite girdler]: A, adult; B, larva; C, adult girdling stem; D, severe pruning of mesquite; E, mating adults; F, completed girdle; G, gallery; H, exit holes chewed in girdled stem (courtesy D. Ueckert).*

November, the beetles mate, feed on tender twigs, girdle, and oviposit. When disturbed, they drop to the ground and play dead (Polk and Ueckert 1973). Foliage may remain on girdled branches for long periods. In a southwestern Texas survey, 90% of the honey mesquite trees had been attacked, and about 40% of all susceptible branches had been girdled (Ueckert and others 1971). From these preliminary observations, those authors suggested that the girdler might be used for the biological control of mesquite, which is considered a noxious plant on the range lands of the Southwest. In controlled tests with girdlers caged on mesquite in Texas, up to 75% of the crown volume has been destroyed (Polk and Ueckert 1973). However, study results from New Mexico showed that even though 45% of the mesquite trees had two to six branches girdled, the percentage of the total stems killed was negligible (Whitford and others 1978).

Control. Larval mortality from parasites, predators, and unknown causes ranges from 22 to 76% (Polk and Ueckert 1973). Ten species of hymenopterous parasites and one clerid predator have been found in galleries in Texas. Brood mortality is higher in branches that fall to the ground than in those that hang on the tree, probably because of high soil temperatures. Many other phytophagus insects co-inhabit girdled branches and compete for food and living space.

Oncideres quercus Skinner

[Arizona oak girdler]

Hosts. Oak. Oak generally (and not specifically) has been listed as the host (Linsley and Chemsak 1984).

Range. A southwestern species known only from southern Arizona and northern Mexico (Linsley and Chemsak 1984). Particularly common in mountains at elevations of 1,500 to 1,800 m.

Description. ***Adult.*** Moderately slender, cylindrical, elongate, convex longhorn beetle measuring 11 to 16 mm long and 3.4 to 4.2 mm wide (Casey 1913, Essig 1958). Elytra densely clothed with light gray pubescence becoming abruptly bright, rusty red brown with patches of dark yellowish brown hairs toward base (Casey 1913, Linsley and Chemsak 1984). Beetles sometimes with indistinct markings of red, brown, or yellow (Essig 1958). Head and legs densely covered with brownish yellow pubescence.

Biology. Adults emerge and are present from July through September (Beyer 1908). They feed on the bark at tips of shoots and particularly around leaf buds (Brisley and Channel 1914, Essig 1958, Linsley and others 1961). After feeding and mating, females begin girdling terminal shoots and twigs of host trees (Beyer 1908). Before the twigs fall to the ground, females begin ovipositing by cutting niches through the bark and depositing single eggs between the bark and wood. Secretions by females at egg sites cause the bark to form small blisters that protect the eggs as the bark and twig dry. Females make six or more egg niches 32 to 76 mm apart on each girdled twig, but only about half of the egg niches contain eggs. Larvae develop within the girdled twigs

where they feed on woody tissue, leaving the bark intact. Pupation occurs in cells within twig galleries. Although the insect reportedly requires 2 years for development (Beyer 1908), a 1-year life cycle seems more likely.

Injury and damage. Girdled twigs on the ground and partially girdled branches hanging loosely in the crown during late summer and fall are good evidence of infestation (Essig 1958, Linsley and Chemsak 1984, Linsley and others 1961). Girdled branches average about 13 mm in diameter and range from 30 to 90 cm long (Brisley and Channel 1914). Examination of girdled twigs can help distinguish this species from other pruning insects. The girdling cut is made from the outside of the twig inward toward the twig center and resembles a V-shaped cut around the circumference of the stem. The cut is seldom complete, leaving a jagged center caused by the break (Beyer 1908). Examination of girdled twigs reveals numerous mandible marks and tiny egg niches along the bark surface. Bare areas with bark chewed away near the tips of tender terminals and branch ends of both girdled and nongirdled stems are further evidence of infestation by this borer. Seedlings to mature trees may be injured. In heavily infested areas, trees may be so badly pruned that shape and symmetry are ruined. Cleanup under ornamentals becomes necessary, and the fruiting area can be so reduced that mast crops for wildlife are seriously diminished.

Control. The insect spends most of its 2-year life cycle in the larval stage in girdled twigs, offering an extended opportunity to collect and burn fallen twigs before adults emerge. This type of cultural control can be effective with ornamentals, especially when practiced on a neighborhood basis.

Aegomorphus morrisi (Uhler)

[tupelo borer] (figure 128)

Hosts. Tupelo. Has been found in water tupelo and blackgum (Craighead 1923, Lugger 1884). Yellow-poplar has been mentioned as a host, but this report seems questionable (Beutenmuller 1896).

Range. Reported only from a few widely scattered areas in eastern North America including South Carolina, Missouri, Pennsylvania, and Canada (Blatchley 1910, Craighead 1923). More recently, it has been observed in the Ozark Mountains of Arkansas, loessal bluffs of Mississippi, and river bottomlands of Florida.

Description. ***Adult.*** Rather robust, somewhat flattened longhorn beetle of medium size, measuring 20 to 26 mm long (figure 128A) (Blatchley 1910). Antennae about body length to slightly longer. Thorax tuberculate above and on sides. Femora swollen apically. Each elytron with indistinct M-shaped black mark behind middle. ***Larva.*** Robust and white with short dark mandibles (figure 128B) (Craighead 1923). Ampullar tubercles very large, spiracles large and strongly chitinized, and body sparsely covered with coarse to velvety pubescence.

Biology. Adults emerge in June (Craighead 1923). Females deposit eggs on the lower trunks of small living host trees,

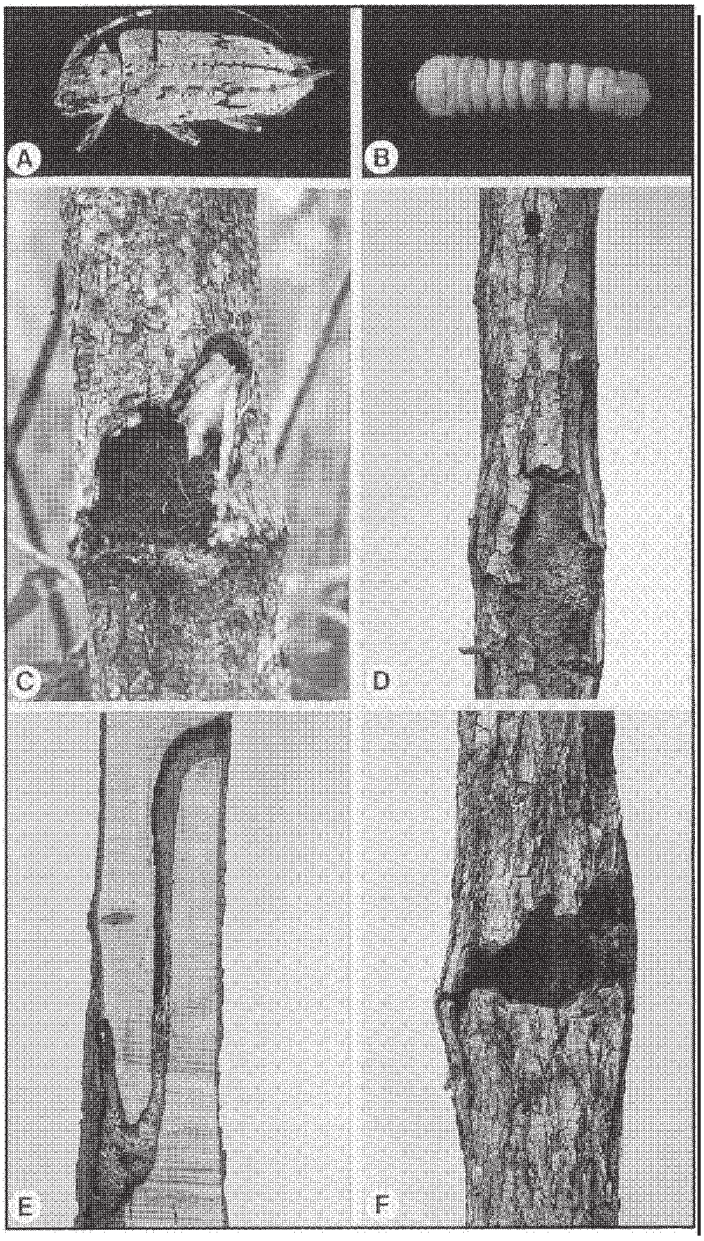

Figure 128.—Aegomorphus morrisi, *[tupelo borer]: A, adult; B, larva; C, bark removed to expose cavity and fibrous frass; D, old attack showing frass-packed mine below and round exit hole above; E, gallery entrance below, exit above; F, patch-type scar in bark (A, specimen courtesy J. Chemsak).*

especially saplings. Larval habits are somewhat similar to those of the *Goes* borers. The larvae feed in the phloem and cambium, hollowing out cavelike cavities, then construct galleries into the sapwood and heartwood. Galleries extend 26 to 64 mm inward, 8 to 13 cm upward, then turn back to the bark surface. The new adults emerge through round exit holes. Thus, each insect leaves two holes—a large entrance and a small exit. The life cycle likely requires 2 years or longer.

Injury and damage. Small to large areas of loosened bark, sometimes with coarse frass protruding from bark openings provide good evidence of infestation (figure 128C and D). Removing the bark reveals a large irregular cavity 5 to 8 cm in diameter packed with fibrous frass. Splitting an infested stem reveals the entrance and cavity under the bark, gallery, and exit (figure 128E). Bark scars resulting from previously healed attacks consist of rather large patchy scars with small round scars directly above (figure 128F). Attacks have been found on saplings from about 5 to 12 cm in diameter and at heights from slightly above ground to about 1.8 m. Populations are small and widely scattered; thus, overall damage has been minor.

Control. Woodpeckers sometimes capture the larvae. Direct control with chemicals applied as a spray or injected into galleries should be effective on high-value trees.

Saperda calcarata Say

poplar borer (figures 129 and 130)

Hosts. Poplars. Quaking aspen is favored in the northern range (Peterson 1947), whereas eastern cottonwood is the major host in its southern range (Morris 1963). Balsam poplar is moderately attacked (Drouin and Wong 1975). Other poplar species and cultivars are attacked to varying degrees (Peterson 1947).

Range. A serious pest of poplars throughout most of the United States and Canada; restricted in distribution and abundance in its western range (Morris and others 1975).

Description. ***Adult.*** Moderately robust, elongate, longhorn beetle ranging from 20 to 30 mm long (figure 129A) (Morris and others 1975). Females slightly more robust and stouter than males. Body color grayish blue and heavily striped with fine brown dots that overlay a faint yellow pattern. Antennae about as long as body. ***Egg.*** Slender, creamy white, and about 3 to 4 mm long (figure 129B) (Peterson 1947). ***Larva.*** Legless, elongate, cylindrical, yellowish white, and 30 to 38 mm long (figure 129C). ***Pupa.*** Yellow white; 20 to 35 mm long (figure 129D).

Biology. Adults emerge from infested trees in May and June in the South and as late as July and August in the North (Hofer 1920, Morris and others 1975) and feed on foliage and bark of tender shoots of host trees. About a week after emergence, mating begins. Oviposition starts a few days later with single eggs (occasionally two or three) being deposited in niches cut into the bark of the trunk. After the eggs have incubated about 2 weeks, the eggs hatch, and larvae begin feeding on the bark tissue and later

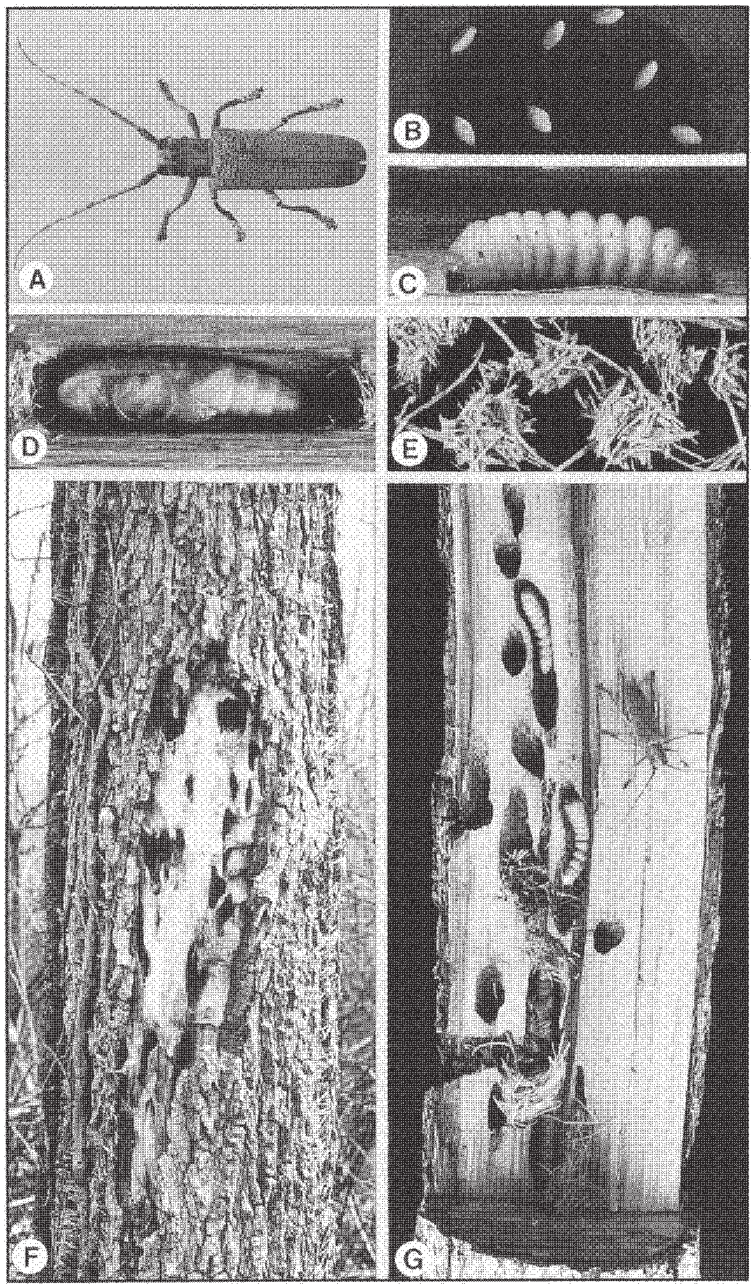

Figure 129—Saperda calcarata, *poplar borer: A, adult; B, eggs; C, larva; D, pupa; E, coarse, fibrous frass; F, active cluster of attacks; G, multiple galleries and insect stages.*

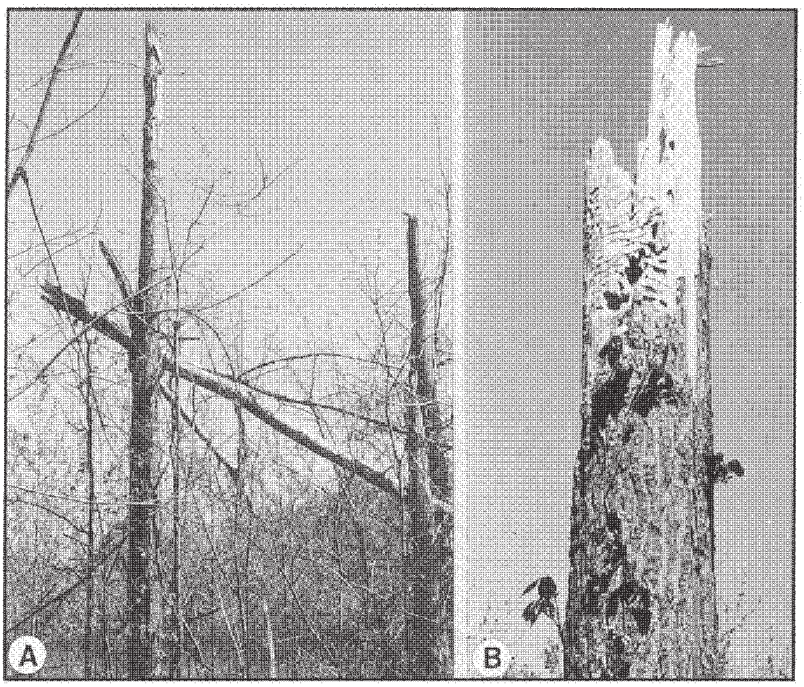

Figure 130—Saperda calcarata, *poplar borer: A, trees in cottonwood plantation broken at borer-weakened sites; B, closeup showing cluster of larval tunnels at point of break.*

move into the sapwood. After overwintering behind frass plugs in the galleries, the larvae resume activity in spring, enlarging and extending their tunnels (Drouin and Wong 1975). The life cycle varies from 2 years in Mississippi (Morris and others 1975) to 3 to 5 years in the borer's northern range (Drouin and Wong 1975, Peterson 1947). Pupation occurs from April to July, depending on location, and lasts 2 to 3 weeks. The adults emerge from the entrance sites. Although trees as small as 4 cm in diameter may be attacked, most infestations occur in stems 8 cm in diameter and larger. Open-grown trees and those growing in sparse understocked stands with unshaded or partially shaded trunks are most attractive to females for oviposition (Graham and Mason 1958).

Injury and damage. Wet spots with oozing sap mixed with fine frass on the trunk are the earliest signs of the presence of poplar borers. Although attacks may occur singly, they are generally clustered, especially in the southern range. Frass becomes fibrous and excelsior-like as the larvae develop, and large amounts of coarse frass may by seen at tunnel entrances, in bark crevices, and in piles around the base of trees (figure 129E). Feeding by a cluster of larvae results in the bark splitting and breaking away irregularly (figure 129F). Completed galleries 10 to 20 mm in diameter typically extend obliquely upward into the sapwood for 5 to 8 cm, then straight upward for another 10 to 18 cm for a total length of 15 to 25 cm (figure 129G). However, galleries are often crooked because they intersect or avoid galleries of other larvae (Peterson 1947). Tree injury may be characterized by woodpecker excavations in the vicinity of larval feeding. Scar tissue may be evident for many years when injured areas are overgrown (Morris and others 1975). Small trees are occasionally killed by larvae girdling beneath their bark. Large trees are seldom killed outright, but clusters of larvae tunneling close together may riddle portions of trunks, seriously weakening them structurally. Woodpecker excavations and decay fungi further weaken trees so that serious wind breakage occurs (figure 130A and B). Surveys of quaking aspen showed that 64% of the trees in southern Michigan and 53% of the trees at five locations in British Columbia had been attacked by poplar borers (Cottrell 1962, Graham and Mason 1958). In a survey of 10 commercial cottonwood plantations in the lower Mississippi River Valley, infestation rates ranged from 2 to 45% and averaged 20% (Nebeker and others 1985). In timber stands, the value of infested trees sawn for lumber may be greatly reduced by defect and degrade (Morris and others 1975). Moreover, the egg niches provide favorable infection courts for the hypoxylon canker disease.

Control. Natural mortality of the poplar borer is frequently high. Two species of hymenopterous parasites—*Dolichomomitus irritator* (Fabricius) and *Habrolepoidea depressa* Girault—and one dipterous parasite *Ptilodexia canescens* (Walker) have been recorded (Arnaud 1978, Carlson 1979,

Gordh 1979). In Colorado, egg and larval parasites, predators, and fungus disease account for annual mortalities of 30 to 38% (Hofer 1920). In Mississippi, up to 65% of the larvae in young plantations are excavated by woodpeckers. Studies in Canada revealed that natural controls—including egg infertility, climate, excessive sap flow, and six species of parasites, predators, and disease—destroyed 81% of the population of this borer (Peterson 1947). Ten other species of parasites have been reported in western Canada (Drouin and Wong 1975). Cultural practices such as avoiding poor planting sites and maintaining healthy trees can markedly reduce incidence of the poplar borer. Borer infestations vary directly with stem diameter and inversely with stocking (Ewan 1960). But in aspen stands, periodic removal of infested trees proved worse than no cutting because the reduction in stand density resulted in higher infestations (Peterson 1947). In managing aspen, therefore, the recommended practice is to maintain well-stocked stands and clearcut at maturity (Ewan 1960). Insecticides may be necessary for protecting trees in parks and urban areas. Systemic insecticides have shown some promise for controlling damage when regenerating balsam poplar in Canada (Drouin and Wong 1975).

Saperda concolor LeConte

[willow gall saperda]

Hosts. Willow, poplar. Willows appear to be the major hosts, based on the meager literature available (Felt and Joutel 1904).

Range. The taxonomic position of this species is vague and it has been confused with *S. inornata* Say and *S. populnea tulari* Felt and Joutel in much of the literature (Felt and Joutel 1904, Nord and Knight 1971). *Saperda concolor* is a southwestern species reported from New Mexico, Arizona, and Texas (Felt and Joutel 1904, LeConte 1852).

Description. ***Adult.*** Black, finely punctate longhorn beetle, entirely covered by dense gray or yellowish gray pubescence, which is less dense at top of thorax, thus giving a darker appearance and increasing effect of a lateral band. Beetles with median line on thorax, black antennae, annulated with gray and measuring about 12 mm long (Felt and Joutel 1904, LeConte 1852). ***Larva.*** White, slender, elongate, and about 14 mm long.

Biology. Adults emerge in May and June (Felt and Joutel 1904). Females gnaw egg niches in the bark and deposit one or two eggs per niche. The young larvae mine under the bark and later into the wood. Galleries may extend in either direction along the stem, but in larger stems, the larvae take a transverse direction, sometimes girdling stems. Some larvae feed mainly around the stem, especially in the callus tissue of the gall, which causes the rough annular swelling to develop and enlarge. The larvae maintain openings in the gall toward which they push small amounts of frass. A generation requires 1 to 2 years.

Injury and damage. Egg niches cut in the bark soon begin oozing sap, providing the earliest evidence of infestation (Felt and Joutel 1904). Warty, gnarly, gall-like swellings typically form at sites of infestations. Galls may be twice the size of infested stems.

Small branches 6 to 18 mm in diameter are most likely to be attacked, but saplings and sprouts up to 50 mm in diameter may be infested. Infested trees are often girdled and killed or may break at the galled sites.

Control. Infested branches should be pruned during winter. Nothing is known of natural controls and direct controls have not been needed.

Saperda inornata Say

[poplar-gall saperda] (figure 131)

Hosts. Poplars and willows. Quaking aspen, bigtooth aspen, balsam poplar, meadow willow, and sandbar willow have been recorded as hosts (Nord and others 1972b). Although the willows are reportedly preferred in Canada (McLeod and Wong 1967), quaking aspen appears to be a favored host in the north central United States (Nord and others 1972b).

Range. North America from northern Minnesota, southeastern Ontario, and southern Quebec to southern Illinois east to Pennsylvania and in the West from northern Manitoba and Saskatchewan to southern Colorado (Wilson and Ostry 1980).

Description. ***Adult.*** Uniformly dark gray, pubescent longhorn beetle that ranges from 8 to 13 mm long (figure 131A) (Nord and Knight 1971, Wilson and Ostry 1980). Body black, but short erect cinereous hairs give gray appearance. Antennae slightly shorter than body and annulated with cinereous and black hairs. ***Egg.*** Creamy white, elongate, sometimes flattened on one end averaging about 2.5 mm long (Grimble and others 1969). ***Larva.*** Mature larva legless, slender, elongate, white, smooth, shiny, sparsely covered with fine whitish hair, and about 10 to 16 mm long (figure 131B). ***Pupa.*** Adultlike in form, white, and 8 to 13 mm long.

Biology. Adults emerge mid-May to late June; feed on the edges of leaves, along the midribs, and on the outer tissues of new shoots and older twigs; and may live for 2 months or more (Nord and others 1972b). Oviposition begins soon after emergence and continues until August. Eggs hatch in 12 to 15 days. Young larvae feed in the xylem adjacent to the necrotic tissue around the eggs. Subsequently, the larvae feed just under the bark, tunneling in one direction perpendicular to the stem axis and around the periphery of the stem. The peripheral tunnels may extend halfway around large stems, further in small ones. A central tunnel up to 25 mm long is extended either upward or downward parallel to the stem axis. Before pupation, larvae usually pack the peripheral tunnels and a third of the central tunnels with frass. Pupation then takes place in the central tunnels just above the packed frass. Adults emerge through 3- to 4-mm diameter round holes gnawed in one side of the galls (Nord and others 1972b). The duration of the life cycle is related to the time of oviposition and summer temperatures. Larvae from eggs laid early in the oviposition period appear to complete development the first summer and pupate the next spring. Larvae that develop from eggs laid late in the oviposition period overwinter, resume feeding the following spring, and complete development the

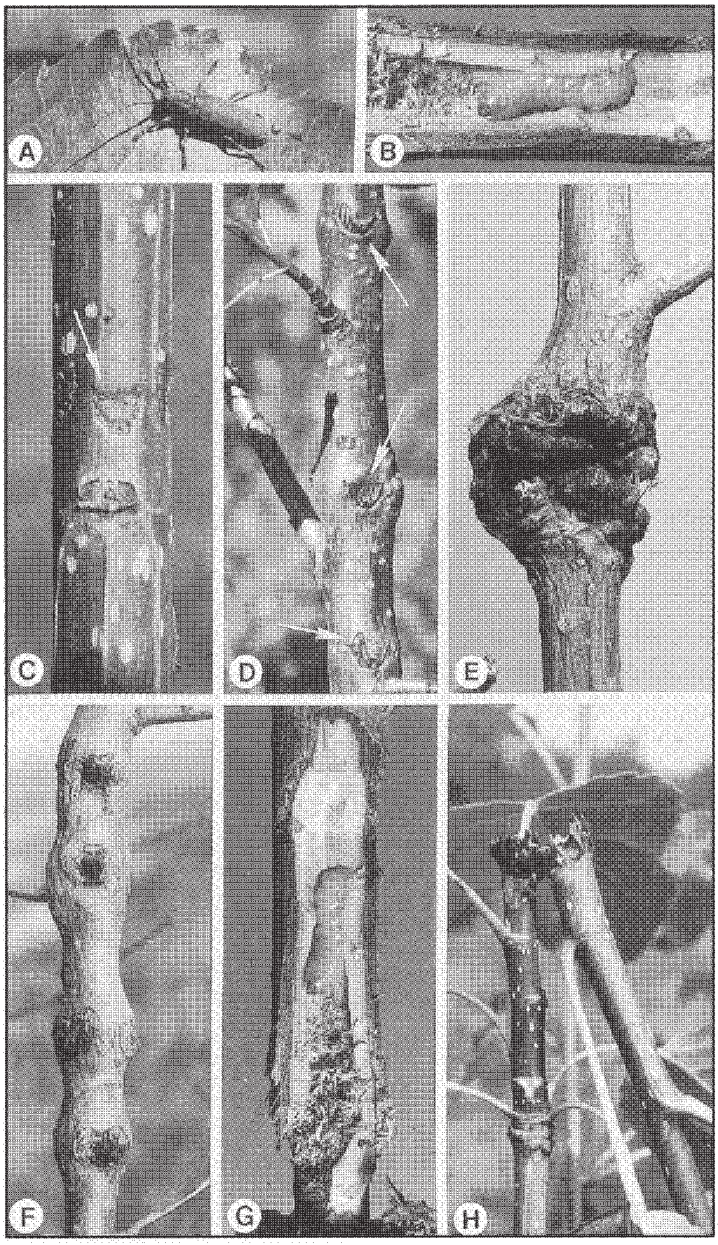

Figure 131—Saperda inornata, *[poplar-gall saperda]: A, adult; B, larva; C, fresh egg niche; D, U-shaped egg niches beginning to heal; E, gall-like swelling; F, multiple gall-like swellings; G, gallery with larva and frass; H, stem broken at galled site (courtesy M. Ostry).*

second summer after hatching (Nord and others 1972b). In its northern range, the pest's life cycle is generally 2 years, but 3 years may sometimes be necessary (McLeod and Wong 1967).

Injury and damage. Evidence of early injury is one or more brownish, horseshoe- or shield-shaped egg niches (figure 131C), often in a ring around the stem, that later become scars on the outer bark (figure 131D) (Grimble and others 1969). Stems 3 to 15 mm in diameter are most generally attacked. Larval feeding results in callus tissue accumulating around the area injured by the feeding and causes a thickening in the stem. A swollen area or globose gall is formed a few weeks after the eggs are laid (figure 131E). The degree of swelling and the shape of galls depend on the activity of the larvae, but galls may be twice the size of the stem. Callus tissue may form only around egg niches when eggs do not hatch or when larvae are short lived. The outer bark over the egg niches usually sloughs off and exposes the rough black scars at swollen sites (figure 131F). Larvae cut holes in the oviposition scars to eject frass. Near the end of the feeding period, larvae tunnel toward the center of the gall and upward or downward parallel to the stem axis for 20 to 40 mm (figure 131G) (Nord and others 1972b). Stems often break at the galls (figure 131H). When the main stem is girdled and growth stops or when the stem breaks, growth is lost, and crooks, forks, and abnormal branching develop. Injuries are generally most prevalent in small stands of suckers in old fields, along roadsides, and along the edges of larger stands (Nord and others 1972b). Damage to young trees in well-stocked natural stands seldom reduces natural reproduction below tolerable levels. The potential for economic loss is greatest in new outplantings. Young plantations of aspen or hybrid poplars in the Great Lakes region have suffered, especially when the young trees are stressed on poor sites, or from dry weather and competing vegetation. Outplantings of clonal or progeny tests in some localities must be protected to keep stunting, abnormal branching, and mortality from confounding the genetic effects. Although 60% of the whips in a new commercial hybrid poplar plantation in Michigan were attacked and significantly reduced in height growth, the trees grew rapidly and recovered most of the loss by the fourth year, and only 4% of the trees were killed (Moore and Wilson 1986). *Saperda* wounds provide entryways for *Hypoxylon* and *Cytospora* canker fungi that can increase economic losses (Anderson and others 1976, Nord and Knight 1972).

Control. Natural controls include the failure of eggs to hatch, desiccation of eggs and larvae, disease, parasitism, and predation. Estimates of eggs that fail to hatch range from 17 to 45% (Grimble and others 1969, McLeod and Wong 1967). Desiccation of eggs and larvae results from the death of part or all of the host tree because of disease, wind breakage, or injuries caused by other insects and rodents (Grimble and Knight 1970). In Canada, disease caused larval mortality of 13 to 17% (McLeod and Wong 1967), but in Michigan,

such mortality was estimated at less than 5% (Grimble and Knight 1970). Ten species of hymenopterous parasites and three species of dipterous parasites play major roles in population regulation, killing an estimated 14 to 22% of the population (Grimble and Knight 1970, McLeod and Wong 1967). Predation by birds, particularly woodpeckers, has varied greatly among areas from 3 to 74% and has been restricted mostly to 2-year-old galls (McLeod and Wong 1967, Grimble and Knight 1970). Cultural controls include planting only on good sites away from naturally infested trees and removing and destroying infested branches (Wilson and Ostry 1980). Chemical controls, found to be effective in test plantings in Wisconsin, may be needed to protect young plantations (Nord and others 1972b).

Saperda populnea moesta LeConte

[eastern gall saperda] (figure 132)

Hosts. Poplar, willow. Balsam poplar is the major host; quaking aspen and other poplars and willows are attacked to varying degrees (MacAloney and Ewan 1964, Wong and McLeod 1965).

Range. Across southern Canada and the northern tier of the United States from the Atlantic Coast to the Rocky Mountains (Chemsak and Linsley 1982, Felt and Joutel 1904).

Description. ***Adult.*** Slender, elongate longhorn beetle measuring about 9.5 mm long and 2.7 mm wide (figure 132A) (Knull 1946). Background color of body black but clothed with uniform gray pubescence concentrated mostly in gray patches on each side of pronotum. Antennae of males extend beyond tips of elytra; in females, they do not reach ends of elytra. Head, pronotum, and elytra densely and coarsely punctured. Elytra taper slightly caudally and apices rounded. ***Larva.*** Mature larva (figure 132B) measuring 11 to 14 mm long, legless, cylindrical in cross section, and body tapers slightly toward rear (Saunders 1874). Head small, reddish brown in front and pale behind, with pale streak along middorsal line. Integument smooth, yellow, shiny, and sparsely clothed with fine, long, whitish hairs. Pronotum about as wide as long, slightly thicker, and more hardened than other body segments. ***Pupa.*** About 12.5 mm long and pale yellow with few short spines on dorsum of abdomen (figure 132C).

Biology. Adults emerge in June and July in Michigan (Gosling and Gosling 1977). Females deposit eggs singly in slits cut in the bark. Larvae mine under the bark around the twig when they are young; later, they bore into the wood, forming short galleries parallel to the twig axis (MacAloney and Ewan 1964). Living tissues at the larval feeding sites swell into ovoid galls that are relatively smooth in appearance, about 30 mm long, and up to 19 mm wide (Wong and McLeod 1965). Larvae pupate in their galleries during May of the year following oviposition. The insect has a 1-year life cycle.

Injury and damage. Infestations are readily detected by ovoid swellings, or galls, on living twigs (figure 132D) (Felt and Joutel 1904, MacAloney and Ewan 1964,

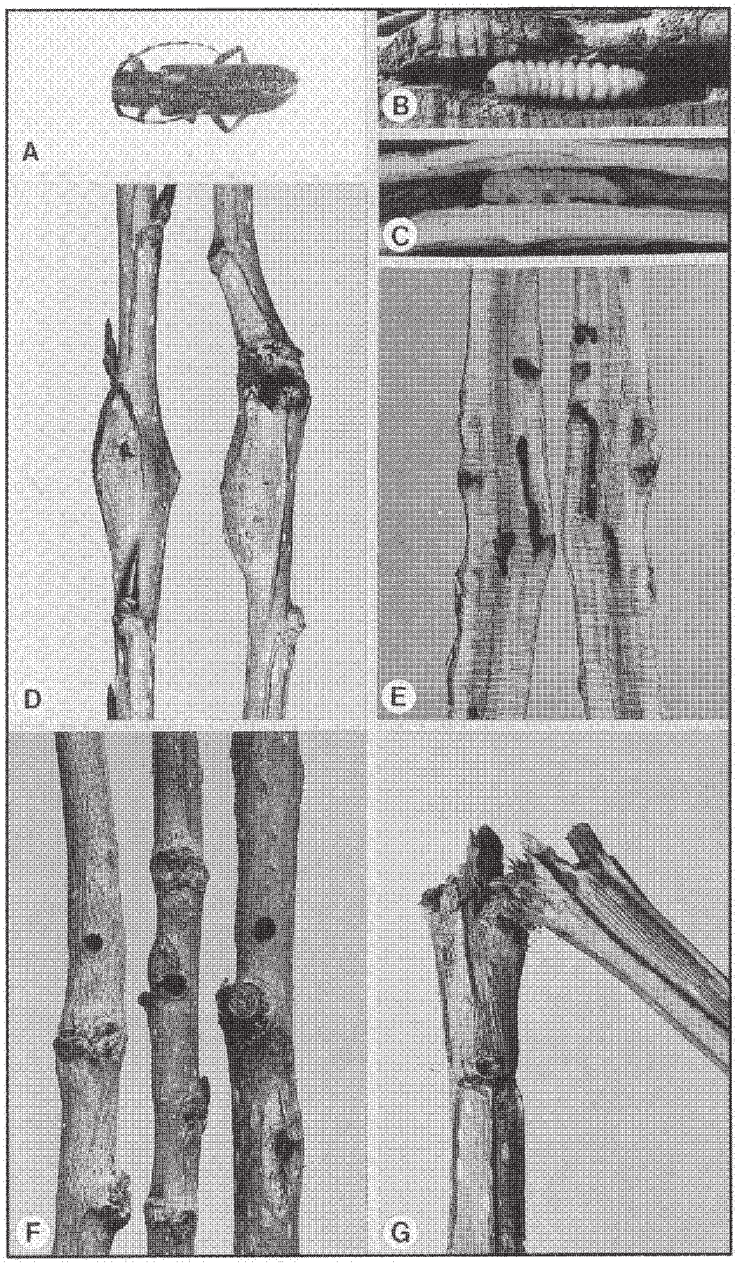

Figure 132—Saperda populnea moesta, *[eastern gall saperda]: A, adult; B, larva; C, pupa; D, swollen, infested stems; E, galleries; F, emergence holes; G, stem broken at infested site (specimens courtesy C. Palm).*

Wong and McLeod 1965). Galls occur on trees of all ages and on stems of suckers and seedlings but mostly on twigs, branches, and main stems 3 years old or younger. Characteristic U-shaped oviposition scars or callus tissue is found on or near the galls where females have oviposited. *Hypoxylon* sp. often infects the infested twigs. Dissecting infested branches reveals galleries up to 25 mm long and mostly filled with yellowish orange frass (figure 132E). Emerging adults leave round exit holes about 3 mm in diameter (figure 132F). Stems weakened at galled sites often break (figure 132G); the ground under infested trees may be strewn with galled twigs broken off by the wind. The insect has been reported killing aspen seedlings and suckers (MacAloney and Ewan 1964) but generally is mostly a nuisance, producing numerous galls on twigs, often causing twig growth to stop and making twigs susceptible to wind breakage. It has damaged some hybrid poplars in the Great Lakes region.

Control. Only one hymenopterous parasite—*Xylophrurus bicolor* Townes—has been reared in the United States (Carlson and Knight 1969). In Europe, as much as 100% of eggs and young larvae of *S. populnea* have died in vigorous trees (Anonymous 1979). Cultural control includes planting on good sites and proper tree maintenance. Galled twigs should be removed and destroyed during winter. Chemical control can be obtained with two or three well-timed applications of insecticide at 15- to 20-day intervals.

Saperda populnea tulari Felt and Joutel

[western gall saperda] (figure 133)

Hosts. Poplar. Black cottonwood has been mentioned specifically, but other poplars are undoubtedly attacked as well (Craighead 1923).

Range. Along the Pacific Coast from California north through Washington and into British Columbia and east to Arizona and Nevada (Chemsak and Lindsey 1982, Craighead 1923, Felt and Joutel 1904, Furniss and Carolin 1977).

Description. ***Adult.*** Resembles *S. p. moesta*; slender, elongate longhorn beetle about 9.5 mm long (figure 133A) (Felt and Joutel 1904). Beetle black but densely covered with grayish red or fulvous hair. Thorax with stripe on each side and median band on top. Head, pronotum, and elytra densely and coarsely punctured. Distinguished from *S. p. moesta* by its larger and deeper punctures, which are more scattered and less numerous. ***Larva.*** Narrow, cylindrical, white except for dark brown mouthparts and reaches about 12.5 mm when mature (figure 133B).

Biology. Adults emerge from spring to early summer and deposit eggs in small niches cut in the bark of young stems. Larvae burrow mostly in the swollen portion of the stems, but some make short tunnels beyond the galls. The life cycle requires 1 or 2 years (Craighead 1923, Felt and Joutel 1904, Furniss and Carolin 1977).

Injury and damage. Irregular to globose stem swellings that become gall-like are evidence of infestation (figure 133C).

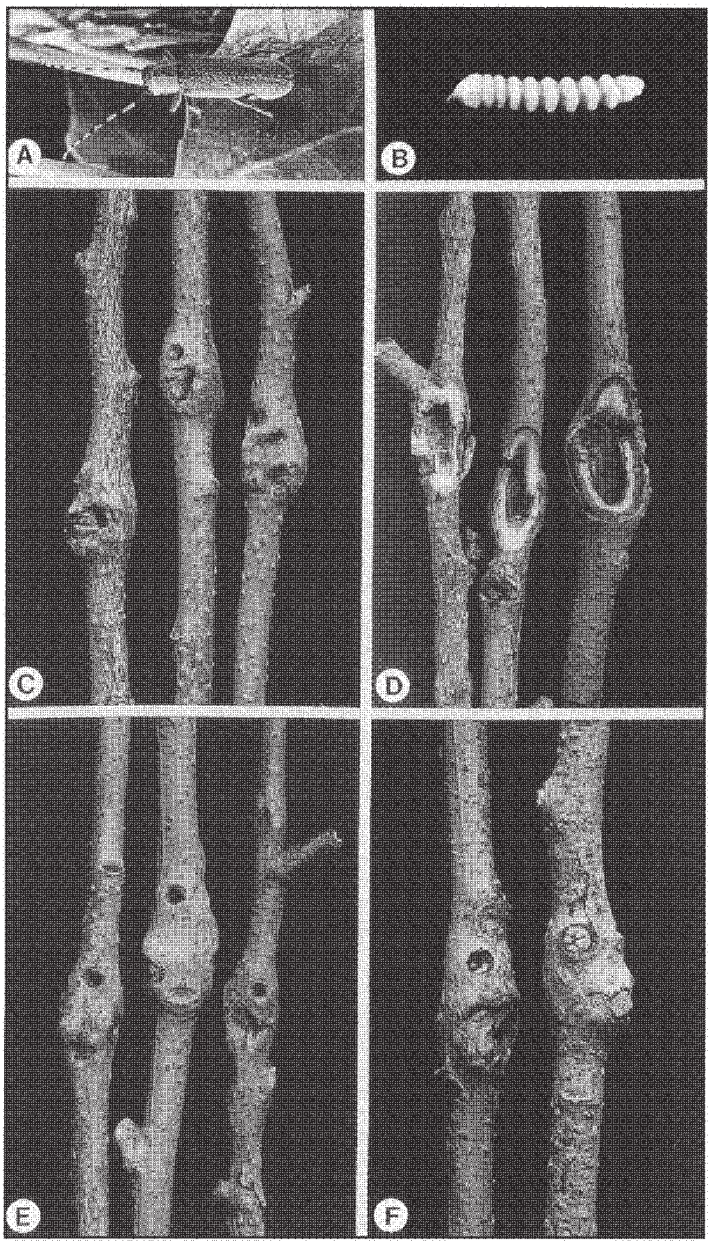

Figure 133—Saperda populnea tulari, *[western gall saperda]: A, adult; B, larva; C, gall-like swellings on small stems; D, burrows in swollen stems; E, round emergence holes; F, healed emergence hole scars on swollen stems (specimens courtesy F. Hovore and R. Penrose).*

Branches and terminals of 6 to 12 mm in diameter on trees of all sizes may be attacked. Dissecting the swollen stems reveals the larval burrows partially filled with fibrous frass (figure 133D). Emerging adults leave round holes about 3 mm in diameter in the swollen stem (figure 133E). These openings heal to form round puckered scars (figure 133F) that resemble healed branch stubs. It is recorded as attacking and killing young black cottonwood (Craighead 1923).

Control. Woodpeckers prey upon the larvae. Unidentified parasites have been reared (Craighead 1923).

Saperda candida Fabricius

roundheaded appletree borer (figure 134)

Hosts. Quince, apple, pear, crabapple, serviceberry, hawthorn, mountain-ash, chokecherry, cotoneaster. Hosts are limited almost entirely to the family Rosaceae (Brooks 1919b, Haseman 1936, Johnson and Lyon 1988). Quince, apple, and pear, preferred in this order, are the most important cultivated hosts. Serviceberry and hawthorn are the most important native wild hosts. A few other species—including peach, cherry, and plum—have been casually mentioned as hosts.

Range. Found generally throughout the eastern United States and southeastern Canada. The westward limits are the Dakotas and Texas (Brooks 1919b, Hess 1940).

Description. ***Adult.*** Longhorn beetle, varies in length from 13 to 25 mm with prominent antennae about as long as body (figure 134A) (Haseman 1936). Beetles light brown on upper surface with two white longitudinal dorsal stripes extending full length of body and joined at head (Brooks 1919b). Lower surface of body and front of head white (USDA ARS 1965). Legs and antennae grayish. ***Egg.*** Pale, rust brown, elongate, slightly flattened, and about 8 mm long (Felt and Joutel 1904). ***Larva.*** White to yellowish white, legless with brown head and black jaws; reaches length of about 38 mm (figure 134B).

Biology. Adults emerge as early as April in the South and as late as June in the North; specimens have been collected as late as August (Felt and Joutel 1904, Slingerland and Crosby 1919). Most beetles in an area emerge within 2 to 3 weeks. After about 10 days of feeding and mating, females deposit 15 to 30 eggs and may live up to 75 days. Eggs are inserted singly into slits in the bark within 25 cm of ground level (USDA ARS 1965, Felt and Joutel 1904). One to several eggs may be laid on the same tree. Incubation takes 15 to 20 days (Brooks 1919b). During their first feeding season, larvae grow to about 13 mm and burrow in the bark and surface sapwood. They winter in the surface sapwood, at or slightly below ground level. During the second and/or subsequent summers, the larvae enlarge their burrows and extend narrow elongate galleries into the wood. Pupation occurs at the upper ends of the tunnels in chambers that curve out to the inner bark. The pupal stage requires about 3 weeks; beetles remain in the pupal chambers about 2 weeks before gnawing through the bark (Brooks 1919b). The insect usually completes a

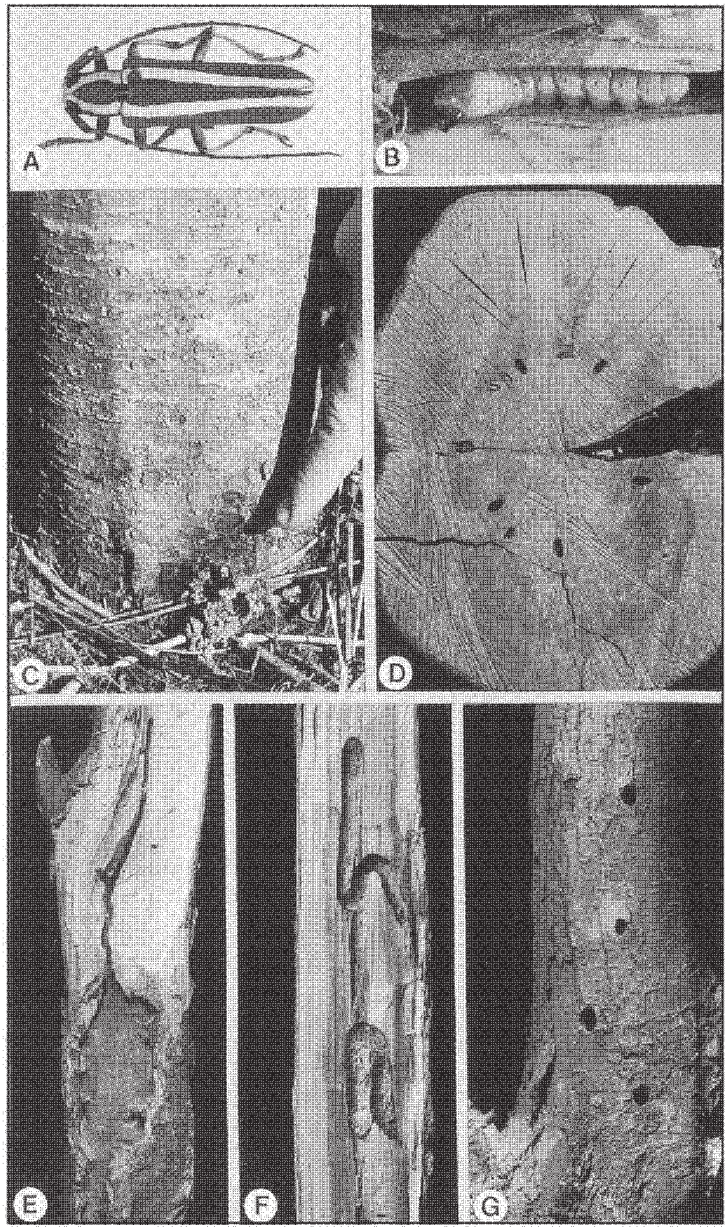

Figure 134—Saperda candida, *roundheaded appletree borer: A, adult; B, larva; C, frass at base of young apple tree; D, cross section with oval galleries; E, cavity under bark with long narrow gallery; F, galleries in small stems; G, round exit holes near base of tree (D-G, specimens courtesy J. Simeone).*

generation in 2 years in the South but requires 3 to 4 years in the North (USDA ARS 1965).

Injury and damage. Close inspection reveals one or more curved to longitudinal oviposition slits in the bark around the base of trees (Brooks 1919b, Haseman 1936). Brown to dark brown sap stains appear, and soon afterward, fine frass is extruded through openings in the bark. In a few weeks, small piles of reddish, fibrous frass appear around the base of the tree (figure 134C). Narrow galleries in the wood are oval in cross section (figure 134D), may extend in either direction, and sometimes reverse directions. Removing the bark reveals broad, irregular burrows in the outer sapwood, often extending as narrow galleries deeper into the wood (figure 134E and F). Burrows in the bark and surface sapwood vary from 2 to 5 cm across, and narrow galleries within the wood range from 6 to 15 mm long. Galleries may extend both above and below ground level and sometimes into the roots. Portions of burrows may be packed with frass. Bark over the burrowed sites may become noticeably depressed, especially on young, smooth-barked trees. Round holes 5 to 6 mm in diameter are left in the bark by emerging beetles (figure 134G). Adults can sometimes be found feeding on the bark of twigs, midribs of leaves, and even on fruits (Brooks 1919b). Trees that break at the groundline should be examined for evidence of borer tunnels, frass, and larvae. This insect is the most destructive borer attacking apple trees. Trees of all ages are susceptible to attack, but those 3 to 10 years old are most affected (USDA ARS 1965). A young tree may be killed as the result of the feeding of only one or two larvae, and trees under 10 years of age may suddenly break near the ground from earlier borer injury (Haseman 1936). Without protection, young orchards can be ruined in a few years when borers are abundant (Brooks 1919b). Older trees may be attacked throughout their growth, but infestations are most destructive during drought, disease, and poor maintenance. Ornamentals are seriously damaged in some localities.

Control. The hairy, downy, and golden woodpeckers and the northern flicker are the most important natural controls (Felt and Joutel 1904, Hess 1940). Woodpeckers prey upon all stages, preferring the mature larvae and pupae; from 50 to 90% of the borers have been captured in some orchards. Other predators include spiders, carpenter ants, click beetles, and carabid beetles. Five species of hymenopterous parasites—*Cenocoelius saperdae* (Ashmead), *Echthrus niger* Cresson, *Microbracon* sp., *Monogonogastra agrili* (Ashmead), and *Xylophrurus nubilipennis luctuosus* (Provancher)—and one dipterous parasite (*Sarcophaga* sp.) have been reported (Hess 1940, Carlson 1979, Marsh 1979). Cultural practices designed to keep trees healthy and vigorous help to reduce borer damage (USDA ARS 1965). Infestations can be reduced by locating and destroying undesirable wild hosts in nearby woodlots, roadsides, and ditchbanks. Current pest management programs, including the use of pesticides to

control other insect pests, help to reduce losses caused by this borer. Chemical controls properly timed and directed can help in minimizing losses.

Saperda cretata Newman

[spotted appletree borer] (figure 135)

Hosts. Apple, crabapple, hawthorn, serviceberry. Apple is the preferred host, but crabapple is commonly attacked. Hawthorn and serviceberry have been mentioned occasionally as wild hosts (Felt and Joutel 1904).

Range. Ontario and throughout the northeastern United States west to Iowa, Wisconsin, and Texas (Chittenden 1898, Felt and Joutel 1904).

Description. ***Adult.*** Typical longhorn beetle, cinnamon brown with white markings, and ranging in length from 10 to 20 mm (figure 135A) (Felt and Joutel 1904, Milne and Milne 1980). Antennae extend nearly to tips of elytra. Pronotum narrower than elytra with white band along sides; sometimes with minute white spot at middle base of pronotum. Oblong white spot, twice as long as wide, at middle of each elytron and another small white spot near tip. Elytra rounded at tips. Sides of abdomen white and underside brown. ***Larva.*** Mature larva (figure 135B) fleshy, legless, white, cylindrical in cross section and about 28 mm long. Head brown, oblong, rectangular, usually partly concealed by prothorax, which is slightly wider than head. Each successive thoracic and abdominal segment behind prothorax gradually narrows in width toward last abdominal segment. Intersegmental areas of abdomen deeply creased, or folded inward, giving an annular or ringed appearance.

Biology. Adults emerge late May to mid-August in Michigan (Gosling and Gosling 1977). Before mating and ovipositing, adults feed on the foliage and bark of new twigs (Mutchler and Weiss 1923). Females lay eggs singly in the bark in paired slits about 12 mm apart (Felt and Joutel 1904). Young larvae that hatch from each pair of eggs burrow in opposite directions under the bark of large limbs and sometimes into the trunk (Slingerland and Crosby 1919). During the first year of development, larvae make tortuous galleries beneath the bark, then gradually bore deep into the wood. Galleries of large larvae generally follow the grain of the wood (Mutchler and Weiss 1923). To pupate, larvae enclose themselves within cells of excelsior-like wood fibers; pupation lasts 4 to 6 weeks. Completed larval burrows may reach 20 cm or more with pupal cells near the ends of galleries and usually close to the bark (Mutchler and Weiss 1923). New adults chew circular holes directly to the surface to emerge. Two or more years are required for the life cycle.

Injury and damage. This borer confines attacks to the upper trunk and large limbs (McDaniel 1936, Mutchler and Weiss 1923). Foliage of infested limbs eventually wilts and dies from the extensive burrowing of the larvae in the bark and wood. Entrance openings in the bark, often with yellowish to reddish frass protruding, can be found along both the trunk and large

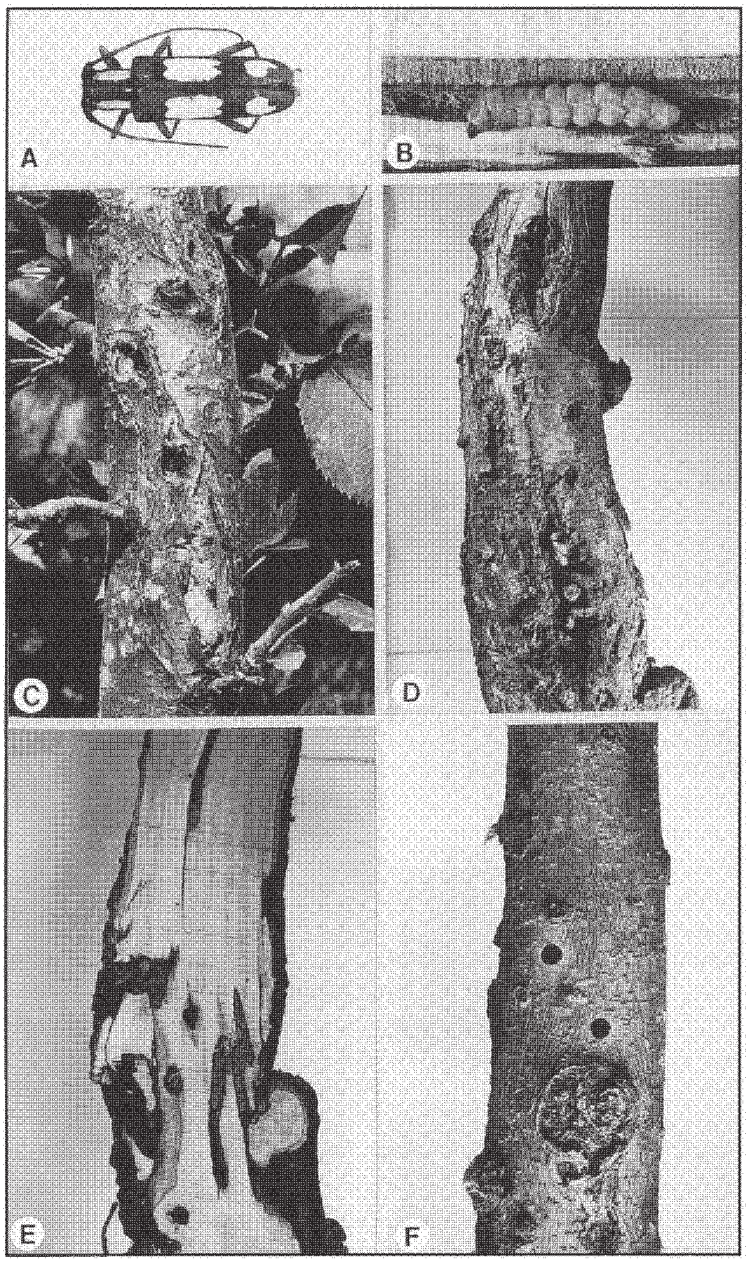

Figure 135—Saperda cretata, *[spotted appletree borer]: A, adult; B, larva; C, attack sites on apple branch; D, trunk scarred from repeated attacks; E, galleries; F, emergence holes in apple branch (A, specimen courtesy D. Whitehead).*

branches (figure 135C). Stems attacked repeatedly become heavily scarred with openings, depressions, and gall-like swellings on the bark (figure 135D). Dissection of dead and dying stems reveals larval burrows and galleries and sometimes the larvae in the bark and wood (figure 135E). Pupation chambers constructed of compacted, shredded, excelsior-like fibers may be exposed in the burrows. Emerging beetles leave round exit holes 4 to 6 mm in diameter in the bark on infested stems (figure 135F) (Knull 1946). This borer has been most damaging to apple trees in the Lake States, especially Michigan (Doane and others 1936, Slingerland and Crosby 1919). Although this borer is not as destructive as *S. candida*, it may tunnel the upper trunk and destroy many of the branches, eventually weakening or killing the tree. Both orchard and ornamental trees may be damaged, but economic infestations occur on a local basis.

Control. Woodpeckers destroy many larvae, but no other predators or parasites have been reported. Maintaining tree vigor helps to minimize infestation. Also, removing and destroying heavily infested limbs and trees will help to prevent population buildup. Removing wild hosts in the immediate vicinity of orchards helps to prevent infestation. Chemical controls developed for the roundheaded appletree borer may be needed occasionally to control this borer.

Saperda fayi Bland

[thorn limb borer] (figure 136)

Hosts. Hawthorn. Cockspur hawthorn and pear hawthorn have been mentioned specifically as hosts, but other species of hawthorn are probably susceptible (Felt and Joutel 1904, Zimmerman 1878).

Range. Most prevalent in New York and Pennsylvania but may be found throughout the northeastern United States west to Michigan and south to Illinois and Iowa and in Ontario (Felt and Joutel 1904, Gosling and Gosling 1977).

Description. ***Adult.*** Longhorn beetle with short, slender body about 12.5 mm long and 3.4 mm wide (figure 136A) (Knull 1946). Antennae extend beyond ends of elytra in male but do not reach apex in female. Body clothed with chocolate brown pubescence. White stripe of pubescence on sides of prothorax from head to base of elytra. Each elytron with elongate white patch in middle and smaller patch on apical quarter along line separating elytra. Two smaller white spots near elytral apices barely visible in males (Felt and Joutel 1904). Sides of elytra subparallel basally and taper gradually toward rounded apices. Head and elytra densely and coarsely pitted. ***Larva.*** Mature larva (figure 136B) about 20 mm long and body whitish, fleshy, legless, and more or less cylindrical. Prothorax slightly wider than head, which it partially conceals. Intersegmental folds deeply indented or creased, accordian-like, giving appearance of raised fleshy rings around body.

Biology. Adults emerge in late May and early June in Pennsylvania (Hamilton 1888). However, beetles are present from late May to mid-July in Michigan (Gosling and Gosling 1977) and have been collected as late as

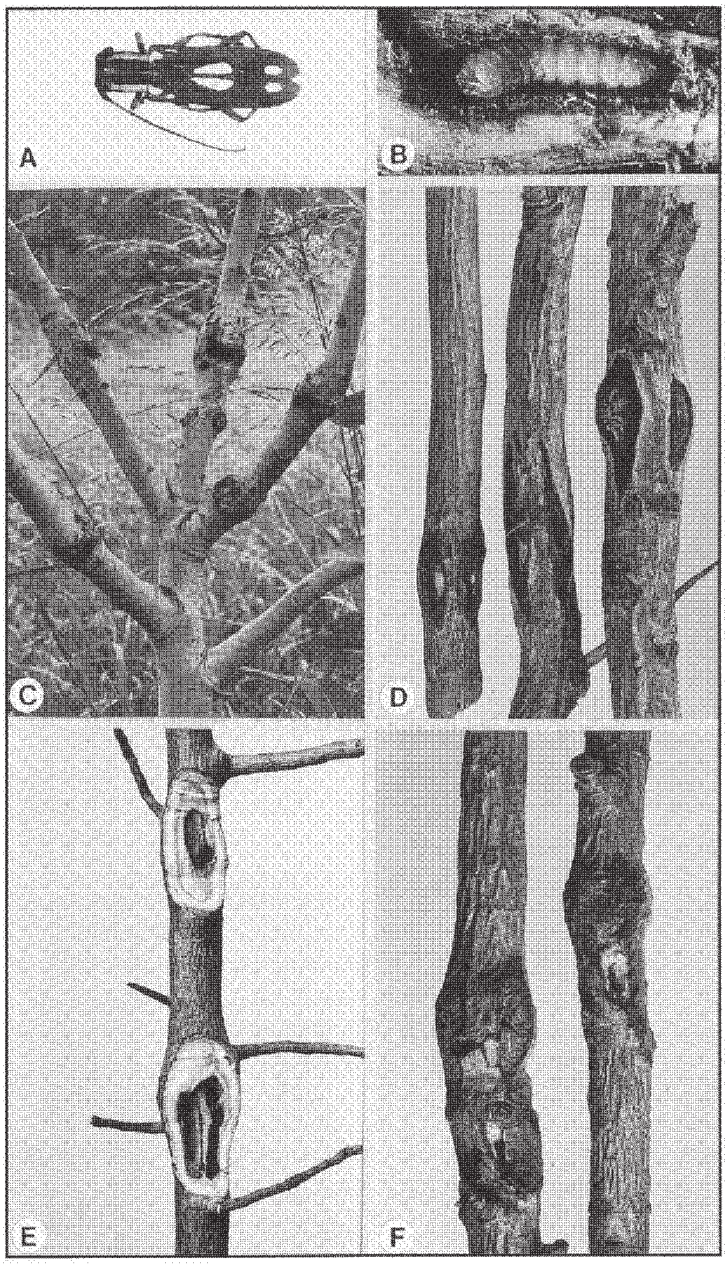

Figure 136—Saperda fayi, *[thorn limb borer]: A, adult; B, larva; C, limbs with galls; D, entrance holes in small limbs; E, burrows; F, woodpecker excavations at infested sites (A & B, specimens courtesy D. Whitehead; D-F, specimens courtesy J. Nord).*

August 15 in New York (Zimmerman 1878). Adults have not been observed to feed, and the life span is short, lasting about 2 weeks (Felt and Joutel 1904). Mating and oviposition occur soon after emergence. Small branches 6 to 37 mm in diameter are selected for oviposition. Females make longitudinal slits approximately 19 mm long in the bark with their jaws and deposit single eggs in each. The slits typically are parallel to each other and spaced about equally around the branch. During the first year, larvae construct galleries 1 to 5 cm long in the outer sapwood, returning periodically to feed in the bark near the entrance holes. In spring of the second year, some larvae continue to feed in the decaying wood near the entrance holes and by autumn are nearly fully grown. Other larvae, during their second year after hatching, construct parallel galleries up or down the branch for distances of 6 to 10 cm. Pupation is in cells prepared by plugging the galleries with excelsior-like wood fibers. Adults may either emerge from the original larval entrance holes or cut separate circular exit holes through the wood and bark to the surface. This borer requires 2 years to complete the life cycle.

Injury and damage. The insect limits its attacks almost entirely to small branches less than 37 mm in diameter (Zimmerman 1878). Trees with branches broken or dying back should be examined for infestation. Infested trees will have gall-like, gnarly swellings on the branches (figure 136C). Elongate entrance holes (figure 136D), often packed with frass, may be evident on the bark. Dissection of infested branches reveals mostly short irregular galleries (figure 136E) and sometimes white larvae. Although a branch may contain one larva, three to six in separate galleries within a branch are common (Hamilton 1888). Adults leave circular exit holes 4 to 5 mm in diameter on or near the galls. Badly tunneled branches are often broken by wind. Weakened branches gradually die back and detract from the appearance of the tree (Hamilton 1888). Serious damage is seldom widespread; most infestations are limited to small localities, sometimes to one tree or a few trees. The symmetry of ornamentals is occasionally ruined by weakened and killed branches.

Control. Woodpeckers are the only natural enemies reported (figure 136F) (Felt and Joutel 1904). Pruning and burning infested branches will destroy the larvae and reduce the infestation.

Saperda vestita Say

linden borer (figure 137)

Hosts. Basswood. European basswood (or linden) is particularly susceptible to attack, but American basswood is also commonly infested in some areas. Poplar, elm, and apple also listed as food plants (Felt and Joutel 1904), but these hosts seem questionable.

Range. Canada and throughout the eastern United States as far west as Missouri and Iowa, closely approximating the natural range of its host, basswood (Felt and Joutel 1904). Most common in the northeastern United States.

Description. ***Adult.*** Robust, elongate longhorn beetle, ranging from 12 to

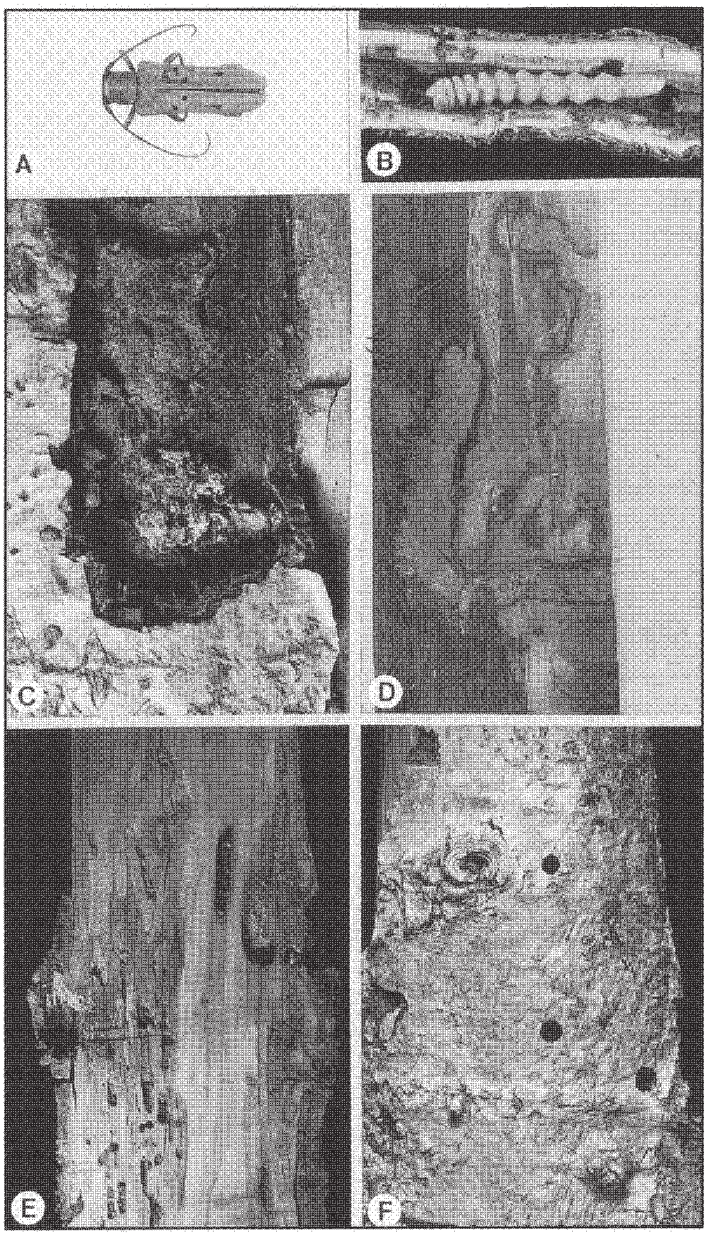

Figure 137—Saperda vestita, *linden borer: A, adult; B, larva; C, mines beneath bark partially packed with frass; D, mines etched in sapwood surface; E, galleries extending into wood; F, round emergence holes (A & B, specimens courtesy D. Whitehead; C-F, specimens courtesy W. Johnson).*

21 mm long and 4.5 to 5.5 mm wide (figure 137A) (Blatchley 1910, Knull 1946). Underlying body color dark reddish brown but largely hidden by dense covering of olive-yellow to gray prostrate pubescence. Three small, dark, denuded spots on each elytron; two situated obliquely before middle and one more distant behind middle. Antennae extend slightly beyond elytra in males but do not reach elytral apices in females. Pronotum broader than long, with wavy sides with coarsely and densely punctate surface. Tips of elytra rounded. ***Larva.*** Robust, fleshy, legless, somewhat cylindrical and from 22 to 25 mm long (figure 137B) (Craighead 1923, Peterson 1960). Head partly concealed by prothorax, oblong-rectangular with sides nearly parallel. Dorsum of prothorax consists of heavily chitinized, somewhat rectangular plate, with very roughened surface over three-fourths of length. Spiracles along sides of body narrowly oval and strongly chitinized.

Biology. Adults emerge and are present from early May to mid-September in Michigan (Gosling and Gosling 1977). Prior to mating and ovipositing, adults feed on the bark of new shoots, leaf petioles, and leaf veins (Kotinsky 1921). Females deposit two or three eggs in niches that they cut into the bark. Females may deposit up to 90 eggs each (Felt and Joutel 1904). Newly hatched larvae burrow under the bark for 15 cm or more and then turn into the wood for about the same distance (Webster 1900b). Most eggs are near the base of the tree, mostly in the lower 30 cm of the trunk; less frequently, eggs are laid higher on the trunk and lower limbs. Many larvae eventually bore downward into the larger surface roots. In young trees, the larvae sometimes gouge two parallel rings that form annular swellings around the trunks. Most pupation occurs at about ground level. The linden borer appears to require 3 years to complete its life cycle (Harris 1844).

Injury and damage. Infested trees weaken; lower limbs begin dying back, and eventually, the entire tree may succumb. Most attacks occur in the lower limbs, lower trunk, and surface roots (Harris 1844). Bark over the attack site may swell or become depressed and often cracks and loosens. Removing the bark reveals large mines and cavities partially packed with frass (figure 137C). Broad irregular mines meander and etch the surface of the sapwood (figure 137D). Galleries penetrate the wood sometimes for 15 to 20 cm (figure 137E). Emerging adults leave round exit holes 5 to 6 mm in diameter in the bark (figure 137F). In late summer, because of feeding by the adults, shoots and leaves may die and drop prematurely, and trees are sometimes almost denuded (Kotinsky 1921). This borer was very destructive to European linden shade trees in the Boston and Philadelphia areas in the mid-1800's, attacking the bases of larger limbs and the lower trunks and surface roots of large trees and nursery stock (Webster 1900b). In nurseries in Connecticut, infestations in the bases of young trees have resulted in serious stem breakage during high winds (Britton and Zappe 1927). Newly emerged adults also feed on the bark and leaf petioles

on shoots, causing excessive green leaf drop, sometimes to the extent of nearly denuding the tops of trees (Webster 1900b).

Control. Little is known of natural controls of the linden borer; only one hymenopterous parasite—*Atanycolus charus* (Riley)—has been mentioned (Felt and Joutel 1904). Heavily infested trees should be cut and burned during winter to destroy the larvae (Kotinsky 1921). Chemical controls may be needed to protect valuable trees.

Saperda tridentata Olivier

elm borer (figure 138)

Hosts. Elm. American elm, slippery elm, and cedar elm are hosts, with American elm the favored species. The elm borer probably attacks other native elms, but has not attacked English elm, an introduced species (Felt and Joutel 1904).

Range. Southeastern Canada and generally throughout the eastern United States west to Texas (Felt and Joutel 1904, Pechuman 1940, USDA FS 1985). Particularly common in the northeastern United States, especially New York and Massachusetts.

Description. ***Adult.*** Moderately elongate, slightly robust longhorn beetle, 9 to 17 mm long (figure 138A) (USDA FS 1985). Densely clothed with gray pubescence with three orangish red oblique crossbars on elytra and narrow stripe on ridges of pronotum and elytra. Two small black spots on each side of pronotum. Each elytron with two black spots near base and similar one near apex. Antennae nearly as long as body. ***Egg.*** White, elongate, 2.5 by 1 mm. ***Larva.*** Long, moderately slender, slightly flattened, and 12 to 25 mm long when mature (figure 139B) (MacAloney and Ewan 1964, USDA FS 1985). Legless larvae reddish white at first but later yellowish white with brown head. ***Pupa.*** Newly formed pupa yellowish and measures about 12 mm long.

Biology. Adults appear in spring with males emerging slightly before females (Pechuman 1940). Emergence occurs mostly in May and June but may continue into summer. Adults have been taken as early as April in Mississippi and as late as August 24 in New York. Most active at night; both sexes are often taken in light traps. The beetles mate soon after emerging and feed extensively on leaves, petioles, and young twigs; egg laying begins 3 or 4 days after emergence. Fresh sappy wood of trees weakened from drought, disease, or other causes is most attractive to ovipositing beetles. Females usually oviposit at night, laying single eggs in niches cut in bark crevices. They lay 50 to 60 eggs during their 1-month lifetimes. After hatching, larvae bore into the bark and feed initially on the outer corky layer. They later move to the inner bark, where they feed on the cambium and inner phloem (Haseman 1936). Young larvae tunnel transversely across the grain of the wood between the bark and wood. As larvae grow, they often meander in all directions, reducing the inner bark and sapwood surface to granular frass. They commonly girdle large branches in this manner (Pechuman 1940). In early August to mid-October, the larvae begin forming pupal cells about 4 to 8 mm deep in the sapwood,

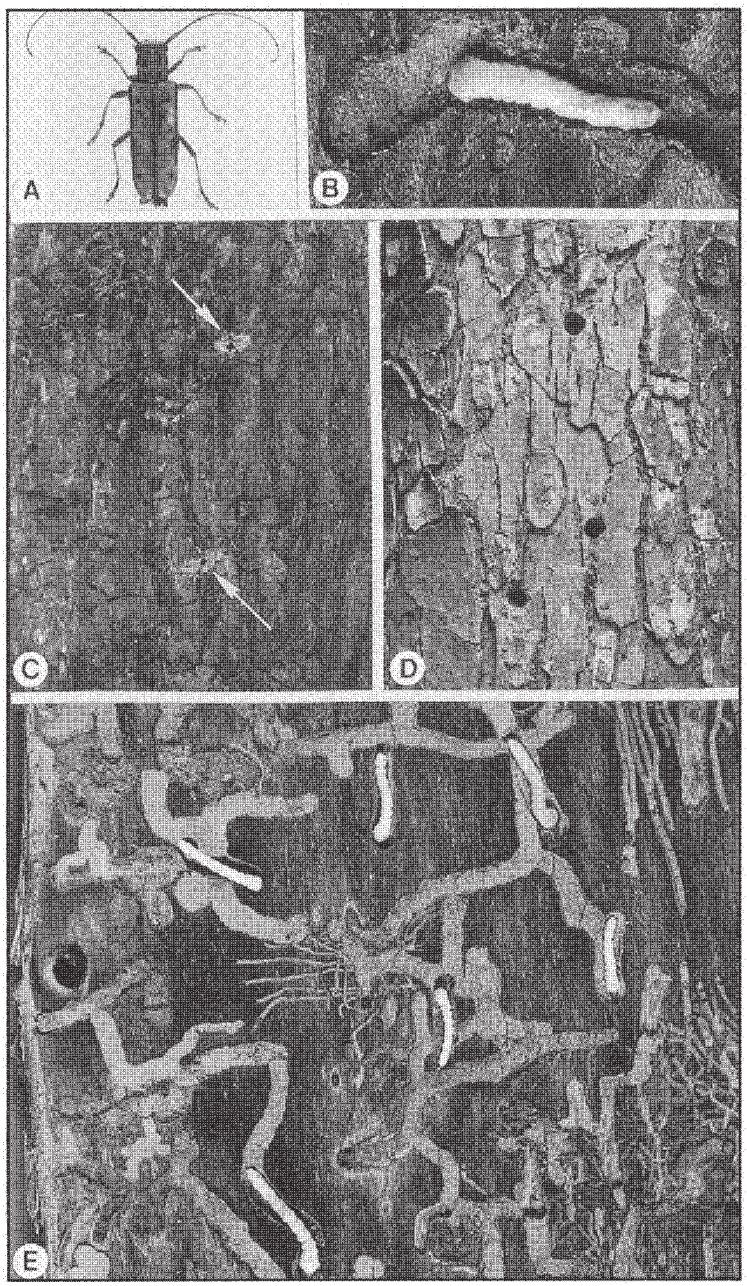

Figure 138—Saperda tridentata, *elm borer: A, adult; B, larva; C, egg niches; D, round emergence holes; E, frass-packed mines (with larvae) meandering beneath bark.*

where they overwinter. Pupation begins in March and April, lasting 22 to 33 days during early season but only 15 to 18 days late in the season. Adults chew round holes in the wood and bark to emerge. Under most conditions, one generation a year occurs, but when trees succumb quickly and the wood dries rapidly, 2 or even 3 years may be required to complete the life cycle (Pechuman 1940).

Injury and damage. During early stages of its attack, this borer is easily overlooked, but symptoms become more prominent as the larvae develop. Frequently, the first signs of attack consist of thin, light-colored foliage followed by scattered dying branches (Felt and Joutel 1904). Inspection of the trunk and branches reveals small egg niches in the bark (figure 138C), and within a few days, small pieces or ribbons of reddish frass are extruded from tiny openings in bark crevices. Under dry conditions, the frass may resemble dark sawdust in crotches and crevices. Much of the frass is packed in mines instead of being ejected to the outside. After the attack has progressed, patches of the bark may be easily pulled from the tree. After a brood completes development, numerous round holes 4 mm in diameter are present in the bark (figure 138D). Removing the bark reveals a mass of mines or burrows and numerous larvae in the inner bark and cambium (figure 138E). The mines are narrow initially but become wider as larvae develop. Larvae penetrate the wood only to pupate. The mines are generally packed with fibrous frass except near feeding larvae. When an attack is heavy, individual branches or even the entire tree may be girdled and killed. However, unless the tree is diseased, its death is generally slow. The insect is an important pest of park and shade elms, especially old and weak trees. Trees weakened by repeated defoliation or disease are particularly susceptible. Feeding by the adult beetles on leaves, leaf petioles, and young twigs may be extensive enough to affect the appearance of the foliage. Such feeding may also transmit the Dutch elm disease fungus, *Ceratocystis ulmi* (Buisman) C. Moreau. Trees gradually decline, and their value as park and shade trees is diminished. Over several generations, infested trees may be killed. Attacks on shade and ornamental trees are most important; infestations in forests are generally less damaging.

Control. Six species of hymenopterous parasites—*Atanycolus simplex* (Cresson), *A. ulmicola* (Viereck), *Cenocoelius saperdae* (Ashmead), *Heterospilus* sp., *Spathius benefactor* Matthews, and *Xorides albopictus* (Cresson)—help to reduce infestations but often do not prevent economic damage (Carlson 1979, Kaston 1937, Marsh 1979). Because trees weakened by drought, mechanical damage, air pollution, disease, and insect defoliators are especially susceptible to attack, practices should be followed to keep trees vigorous. In valuable trees, young larvae can be removed mechanically (Haseman 1936). Heavily infested trees, especially those dying from heavy broods, should be removed and destroyed to reduce the borer population (Felt 1905).

Saperda horni (Joutel)

[willow saperda] (figure 139)

Host. Willow. Host is restricted to willows, but species have not been recorded (Craighead 1923).

Range. A western species occurring along the Pacific Coast from Washington to California (Chemsak and Linsley 1982, Felt and Joutel 1904).

Description. ***Adult.*** Shiny black longhorn beetle, densely covered with gray pubescence in male, and light, yellowish gray pubescence in female; 16 to 20 mm long (figure 139A) (Essig 1929). In female, pubescence lighter on underside of body but occurs in dark yellow blotches and irregular streaks on dorsum. Dark yellow line along outer margins of elytra. Cylindrical thorax with longitudinal, dorsal, dark yellow stripe along each side and one on median line. Head covered with yellow hairs changing to gray around mouthparts. Elytra obliquely narrowed at apices (Joutel 1902). ***Larva.*** Smooth with shiny integument, thickly covered with fine white pubescence (figure 139B). Transverse, raised, fleshy ampullae on abdominal segments coarsely roughened (Craighead 1923).

Biology. Adults emerge and oviposit in June and July. During oviposition, females chew irregular holes through the bark and deposit three to four eggs in each at equal angles to each other. Cannibalism among the hatching larvae leaves only one or two to make long, slender galleries in the heartwood. Pupation occurs at the inner, uppermost portions of the larval galleries (Craighead 1923). Habits of this borer are similar to those of *S. calcarata* Say (Craighead 1923). It appears that 2 years are required to complete the life cycle.

Injury and damage. Attacked trees usually have numerous oviposition niches, entrance scars, and exit holes on the stems and larger branches (figure 139 C, D, and E). Galleries extend obliquely into the wood, then longitudinally (figure 139C and F), and are partially filled with fibrous frass. Emerging beetles leave round exit holes 3 to 4 mm in diameter (figure 139D). Trees stressed, weakened, and in poor vigor are most apt to be attacked. This borer infests suitable trees heavily and leaves the bark badly scarred. Young trees have been killed in California (Craighead 1923). Infested trees often die by fall the same year in which oviposition occurs (Craighead 1923).

Control. Woodpeckers capture many larvae in small diameter stems (figure 139G). Little else is known of controls.

Saperda obliqua Say

[alder borer] (figure 140)

Hosts. Alder, hazel, birch. Favored host is black alder (Felt and Joutel 1904, McDaniel 1936).

Range. Throughout the eastern half of the United States and Canada (McDaniel 1936).

Description. ***Adult.*** Robust, elongate, longhorn beetle measuring about 20 mm long and 5.4 mm wide (figure 140A) (Felt and Joutel 1904, Knull 1946). Body light reddish brown with dark brown markings. Pronotum narrowed in front with two sub-

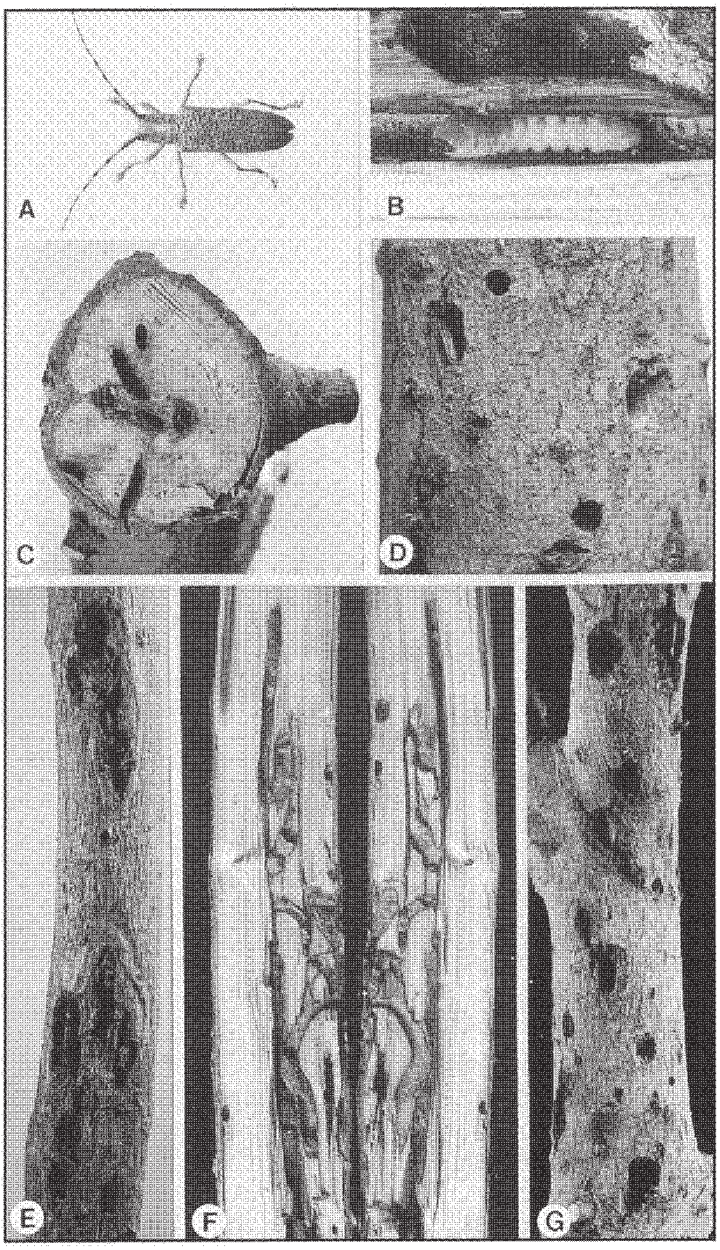

Figure 139—Saperda horni, *[willow saperda]: A, adult; B, larva; C, cross section of galleries; D, round exit holes; E, entrance holes and old scars; F, galleries partially packed with frass; G, numerous woodpecker excavations in stem (specimens courtesy F. Hovore).*

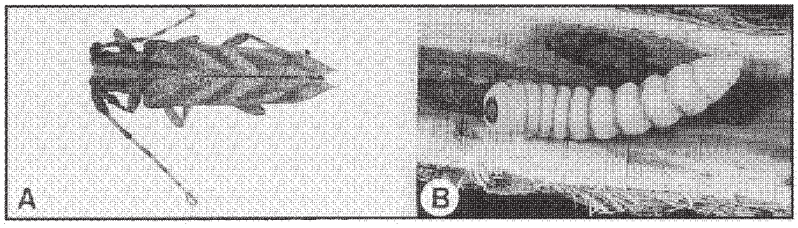

Figure 140—Saperda obliqua, *[alder borer]: A, adult; B, larva (specimens courtesy D. Whitehead).*

dorsal stripes converging at scutellum. Dorsum of elytra with four dark oblique bands and surface unevenly, densely, and coarsely punctured. Sides of elytra gradually narrow toward tips, and each elytron ends with an acute spine. ***Larva.*** Mature larva (figure 140B) robust, elongate, fleshy, legless, whitish, and about 20 mm long. Head partly concealed by prothorax, which is slightly wider than long and roughened over three-fourths of length (Craighead 1923). Integument very finely wrinkled and clothed with fine, whitish hairs.

Biology. Adults emerge and fly from late June to mid-August in Michigan (Gosling and Gosling 1977), June and July in Ohio (Knull 1946), and in May and June in northern Georgia (Fattig 1947). Beetles can often be found on tips of alder branches, and their coloration gives them the appearance of withered leaves. Females deposit eggs in the bark around the base of trees and bushes. Initially, larvae work in and under the bark, causing mines and irregular gall-like swellings on the stems. As the larvae mature, they bore downward in the wood, sometimes into the roots, whereas other *Saperda* larvae burrow upwards (Felt and Joutel 1904). Mature larvae construct longitudinal burrows deep in the wood where they pupate (Beal and others 1952). Adult behavior differs from that of other *Saperda* species; instead of dropping to the ground and feigning death or hiding when disturbed, they remain motionless and cling tightly to the twig with their antennae directed forward. The life cycle is not known, but based on the insect's habits, is presumed to require 2 years.

Injury and damage. Attacks are most common on the lower trunk but occasionally occur in the lower branches (Beal and others 1952, Felt and Joutel 1904). The injury caused by this borer is readily recognized by the conspicuous, irregular, gall-like growths on the stems near the groundline. Cutting into the stem swellings reveals galleries in the bark and wood, more or less following the wood grain. Galleries sometimes extend 7 to 10 cm below ground level in the roots, particularly in the surface roots. Round exit holes 5 to 6 mm in diameter can be found, usually above swellings. The riddling of the bases of stems near groundline often causes them to break in the wind (McDaniel 1936). In heavily infested alder swamps, large numbers of prostrate stems in all stages of attack and decay have been observed (Felt and Joutel 1904). However, because neither alder nor hazel are important commercial timber species and the incidence in birch is low, the borer is of minor economic importance in forest settings.

Control. Woodpeckers are reportedly effective in reducing populations (Felt and Joutel 1904). An unidentified tachinid parasite was found destroying about 50% of the larvae in a Pennsylvania study (Craighead 1923). Also, a hymenopterous parasite—*Xylophrurus luctuosus* (Provancher)—has been recorded (Linsley 1961). Cutting and burning badly infested trees have been suggested to control infestations (McDaniel 1936). Chemicals may be required to protect ornamentals.

Saperda lateralis (Fabricius)

[red-edged saperda] (figure 141)

Hosts. Hickory, elm, basswood, ash, oak, maple, poison ivy, witch hazel. Hickory and elm seem to be favored (Craighead 1923, Dillon and Dillon 1972, Knull 1946). Virginia pine has been listed as a host (Stein and Tagestad 1976), but this seems questionable.

Range. Throughout the eastern United States and eastern Canada west to Nebraska (Craighead 1923).

Description. ***Adult.*** Moderately short, rather robust, longhorn beetle measuring 9 to 15 mm long and about 4 mm wide (figure 141A) (Dillon and Dillon 1972, Knull 1946). Body lightly clothed with dark gray pubescence. Head and pronotum with orangish red stripe on each side, which is continuous with narrow, lateral, submarginal stripe of same color along each elytron. Antennae black, reaching elytral tips in females and extending slightly beyond elytral tips in males. ***Larva.*** Finely wrinkled integument clothed with fine, whitish, silky hairs, prominent fleshy ampullae on dorsal and ventral abdominal segments, and heavily chitinized spiracles (figure 141B) (Craighead 1923).

Biology. Adults emerge from mid-May through July and are attracted to light (Gosling and Gosling 1977). After emergence, adults feed on the tender bark and leaf petioles at the ends of current shoot growth (Felt and Joutel 1904). Females lay their eggs on stressed and dying trees and around dead and wounded areas on living trees. Very moist wood at the bases of trees is preferred for oviposition. One year is required to complete the life cycle (Craighead 1923).

Injury and damage. Attack sites are most common in moist wood at the bases of trees, near injuries just above the root-collar area, and at the bases of sprouts on recently cleared forest land (Craighead 1923, Felt and Joutel 1904). Removing bark from old wounds with dead areas on living trees and from weakened and dying trees reveals galleries and white larvae. This borer is of little economic importance because it primarily attacks trees that are severely weakened and dying.

Control. Nothing is known of the natural enemies, and direct controls are not needed.

Saperda discoidea (Fabricius)

[hickory saperda] (figure 142)

Hosts. Hickory, butternut, walnut. Hickory is preferred host; found only occasionally in the other hosts (Craighead 1923, Felt and Joutel 1904).

Range. Throughout the eastern half of Canada and the United States west to Nebraska (Craighead 1923).

Description. ***Adult.*** Elongate, moderately robust, cylindrical longhorn beetle; male 10 to 11 mm long and female 14 to 16 mm long (figure 142A) (Dillon and Dillon 1972, Knull 1946, Mutchler and Weiss 1923). In female, head, thorax, and scutellum densely clothed with yellow hairs; elytra reddish brown, each with small spot on basal third and somewhat broad, crescent-shaped, transverse band at middle composed of yellow hairs. Male uniformly brown or black partially covered with

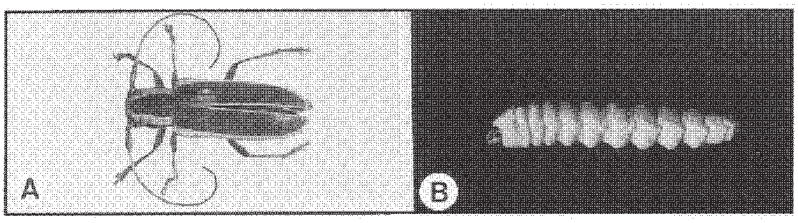

Figure 141—Saperda lateralis, *[red-edged saperda]: A, adult; B, larva.*

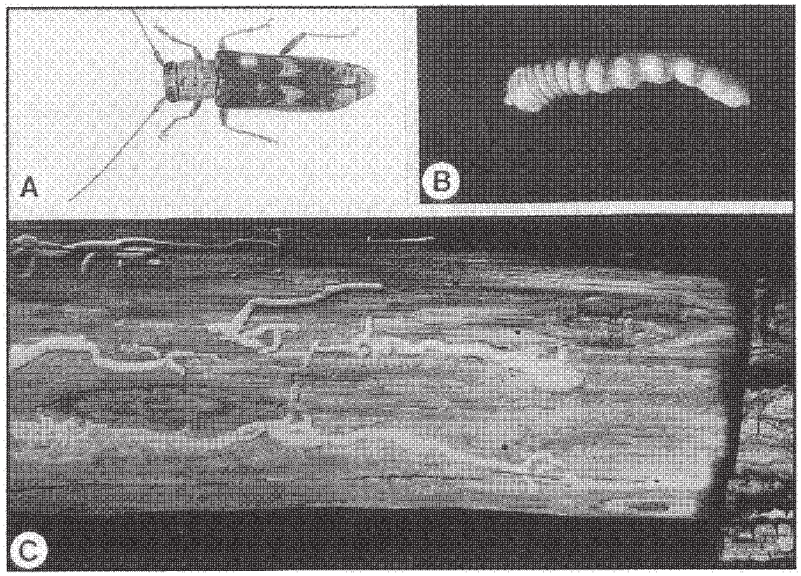

Figure 142—Saperda discoidea, *[hickory saperda]: A, adult; B, larva; C, galleries on surface of sapwood (C, specimen courtesy J. Simeone).*

sparse gray pubescence, which forms light gray lines on sides and disk of pronotum. ***Larva.*** Smooth, shiny integument clothed quite densely with fine, whitish, silky hairs; labrum more densely hairy in front (figure 142B) (Craighead 1923). ***Pupa.*** Slender, setaelike spines in V-shaped group on thorax and in transverse band on dorsum of abdominal segments.

Biology. Adults emerge and are in flight from April to September (Craighead 1923). Light attracts the adults, and they can readily be collected at night from the bark of dying and recently dead hickories. Females deposit eggs in bark crevices and in small holes made by hickory bark beetles (USDA FS 1985). Developing larvae feed gregariously, almost exclusively between the bark and wood, where they make extensive mines that etch the sapwood. Pupation occurs in cells either in the bark or surface sapwood (Felt and Joutel 1904). Adults cut circular holes 4 to 5 mm in diameter in the bark to emerge (Knull 1946). Most larvae complete development in 1 year, but overlapping broods may occur (USDA FS 1985).

Injury and damage. Injury is difficult to identify based on external symptoms because this borer commonly attacks severely stressed and dying trees, especially those weakened by the hickory bark beetle (Craighead 1923, Felt and Joutel 1904). Peeling the bark reveals numerous, meandering, intertwined larval galleries, packed with fibrous frass (figure 142C). The larvae are gregarious; as many as a dozen have been found together in 15- by 15-cm areas under the bark.

Control. Six species of insect parasites have been recorded, but little is known of their effectiveness (Linsley 1961). Direct controls have not been needed.

Saperda puncticollis Say

[woodbine borer] (figure 143)

Hosts. Virginia creeper, poison ivy, poison oak. Virginia creeper (woodbine) appears to be favored (Craighead 1923, Felt and Joutel 1904). Grape has been casually mentioned, but this observation needs to be confirmed (Gosling and Gosling 1977).

Range. Southern Canada and through the eastern United States south to Georgia and west to Louisiana and Michigan (Craighead 1923, Felt and Joutel 1904, Turnbow and Franklin 1980a).

Description. ***Adult.*** Short, slender longhorn beetle ranging in length from 9 to 11.5 mm (figure 143A) (Dillon and Dillon 1972). Body sparsely covered with black pubescence above and densely covered with gray hairs underneath. Head yellow with black spot on front and vertex and black antennae (Felt and Joutel 1904). Pronotum yellow with four round black dots on upper surface and lateral spot on each side (Knull 1946). Elytra have broad, yellow marginal and sutural bands (Felt and Joutel 1904). ***Larva.*** Slender, with integument finely wrinkled, white and covered densely with light, chestnut brown hairs (figure 143B) (Craighead 1923). Pronotum distinctly wider than long.

Biology. In Michigan, adults appear from late May to early July (Gosling and Gos-

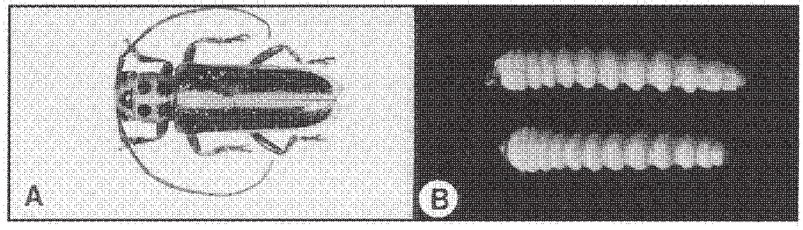

Figure 143—Saperda puncticollis, *[woodbine borer]: A, adult; B, larvae (specimens courtesy D. Whitehead).*

ling 1977) and are commonly found on the foliage of hosts. Little is known about the biology of this borer other than that the larvae mine under the bark of vines and pupate in xylem cells closed off from the larval mines by plugs of frass (Craighead 1923). This borer presumably has a 1-year life cycle.

Injury and damage. Larvae tunnel in the host vines, often killing them. The larval galleries can be exposed by peeling the bark of dead or dying vines. This borer is currently of no economic importance but may offer potential for biocontrol of noxious host plants.

Control. Woodpeckers are important enemies of the larvae (Felt and Joutel 1904). A single hymenopterous parasite—*Labena grallator* (Say)—has been recorded (Carlson 1979).

Oberea schaumii LeConte

[poplar branch borer] (figure 144)

Host. Poplar. Quaking aspen, bigtooth aspen, Lombardy poplar, Carolina poplar, eastern cottonwood, and plains cottonwood have been listed (Nord and others 1972a). Eastern cottonwood is preferred in the South, and quaking aspen has been mentioned most often in the North.

Range. Southern Canada and southward throughout much of the United States south to Mississippi (Morris and others 1975).

Description. ***Adult.*** Slender, elongate longhorn beetle ranging in length from 12 to 16 mm (figure 144A). Coloration quite variable, ranging from mostly black to brownish yellow or yellowish orange, causing some authors to describe color forms and even subspecies (Allen and Knight 1976, Breuning 1960, Nord and others 1972a). Males mostly black; females generally lighter. ***Egg.*** Yellowish white, elongate, occasionally flattened on one end and about 2.5 mm long. ***Larva.*** Legless, narrow, very slender, yellowish white except for dark mandibles, develops to 12 to 25 mm long (figure 144B). ***Pupa.*** Yellowish white (Morris and others 1975).

Biology. Adults emerge April to June and are sometimes present until early August (Morris and others 1975, Nord and others 1972a). After a few days of feeding and mating, females begin laying eggs in niches gnawed in the bark (Grimble and others 1969). They select stems for ovipositing sites that are mostly 5 to 15 mm in diameter and 1 to 6 years old (Nord and others 1972a) but may be up to 38 mm in diameter (Morris and others 1975). Usually eggs are deposited singly between the wood and bark below the egg niches and hatch in about 2 weeks. Young larvae bore toward the center of the stem and then downward, ejecting frass the first summer through a split in the bark along one side of the egg niches and in subsequent years through circular holes cut to the outside from the central tunnel. The life cycle may be 1 to 2 years in the South (Cook and Solomon 1976) to 2 to 4 years in the North (Nord and others 1972a). Thus, the length of the central tunnel and the number of ejection ports will also vary, as activity is greater when the life cycle is longer. Near the end of the larval stage, larvae tunnel upward above their egg niches and outward to just under the outer layers of bark. Fully developed larvae

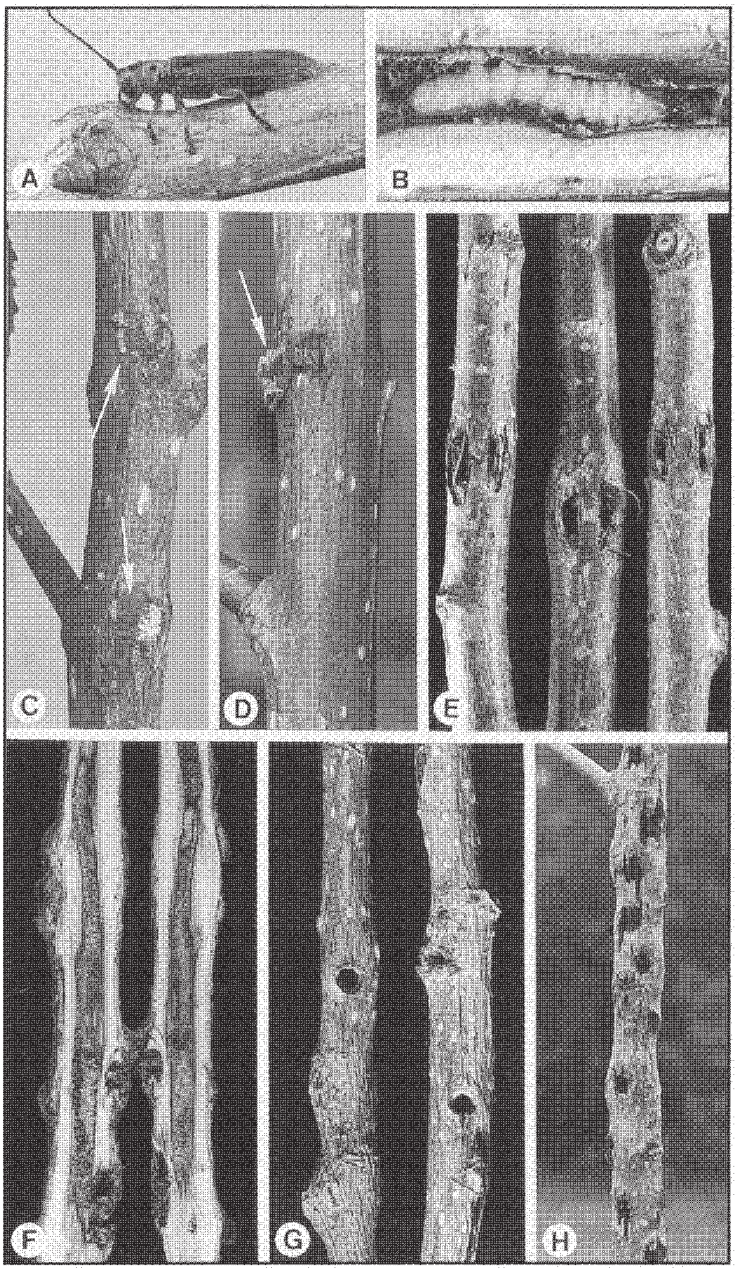

Figure 144—Oberea schaumii, *[poplar branch borer]: A, adult; B, larva; C, egg niches chewed in bark; D, fine frass extruded from egg niche; E, egg niches—a few weeks old; F, gallery with packed frass; G, round emergence holes; H, woodpecker excavations.*

pack the lower end of the tunnels with granular frass and fashion loose plugs of long, fibrous frass in the upper part of their tunnels. Pupation occurs behind frass plugs in the upper portion of the tunnels. New adults chew through the bark covering the tunnels to exit. There is a positive relation between this borer and canker fungi. At least a third of the cankers in quaking aspen have occurred at borer-infested sites (Nord and Knight 1972).

Injury and damage. Egg niches gnawed in the bark are early signs of infestation. Egg niches (figure 144C) are elongate, rectangular, and 5 to 11 mm long, about 3 mm wide, and usually parallel to the stem axis. Feeding by newly hatched larvae begins beneath the cambium tissue and is evidenced by fine frass in and around splits in the bark at the site of the egg niche (figure 144D). After a few weeks of stem growth, the egg niches become more prominent, appearing as two parallel splits in the bark (figure 144E). After the young larvae bore into the stem, they tunnel downward parallel to the stem axis. During the first summer, the larvae make tunnels about 25 mm long. In subsequent years, they lengthen and widen the tunnels so that the final dimensions may be as much as 16 cm by 4 mm (figure 144F). Although a moderate amount of frass is packed within the gallery, they eject some through the oviposition slit during the first year and some through secondary and tertiary ports made along the stem. During development, some of the external openings may become closed by callus or scar tissue (Nord and others 1972a). Callus growth sometimes causes the affected area to appear swollen. Emerging adults leave round, 4-mm diameter exit holes in the branches (figure 144G). When adults emerge, they conspicuously feed on the midribs and branch veins of the leaves (Morris and others 1975). Terminal breakage may result in crooked trunks, forking, and heavy branching in individual trees (Cook and Solomon 1976). Breakage, however, is uncommon except when multiple infestation occurs within the stem. Economic loss in stands of large trees and in well-stocked sucker stands is usually light to negligible (Nord and others 1972a). Infestations in aspen sucker stands in Michigan have ranged to 17% without serious impact. However, infestations appear to be greater in planted or open-grown trees. Therefore, impact is apt to be greatest in young monoculture plantings under intensive management.

Control. Natural controls are very important, destroying up to 98% of some populations (Grimble and Knight 1971). Egg non-viability has been estimated at 21%. Dessication of young larvae accounts for some mortality. Five hymenopterous parasites—including *Cenocoelius sanquineiventris* (Ashmead), *Cremastus nordi* Townes, *Dolichomitus messor perlongus* (Cresson), *Iphiaula eurygaster* (Brulle), and *Xylophrurus bicolor* (Cushman)—and three dipterous parasites—*Lixophaga* n. sp., *Megaselia* n. sp., and *Odinia* sp. near *xanthocera* Collin—have been reared. Parasitism rates have ranged up to 63% for some collections. Predation by woodpeckers has ranged from 5 to 25% in Michigan and up to 40% in Mississippi (figure 144H). Unidentified diseases are also important natural controls. In Mississippi, woodpecker predation and disease appear to be the major

natural controls (Cook and Solomon 1976).

Oberea quadricallosa LeConte

[western poplar branch borer] (figure 145)

Hosts. Poplar, willow. Specimens have been reared from arroyo willow and Fremont cottonwood, and adults have been collected from the foliage of black cottonwood (Hicks 1962, Hovore 1988, Milne and Milne 1980).

Range. West of the Rocky Mountains, recorded specifically in California, Oregon, Washington, and British Columbia (Hicks 1962, Milne and Milne 1980, Mutchler and Weiss 1923).

Description. ***Adult.*** Slender, cylindrical longhorn beetle ranges from 8 to 14 mm long (figure 145A) (Milne and Milne 1980, Mutchler and Weiss 1923). Head, antennae, elytra, and undersurface of thorax typically black to grayish. Pronotum yellow to orange with four black spots. Adults separated from those of closely related *O. schaumii* LeConte by having fuscous elytra with only narrow, yellow, basal markings and by larger basal spots on sides of pronotum (Hicks 1962, Mutchler and Weiss 1923). ***Larva.*** Long, slender, nearly cylindrical, legless, yellowish and 10 to 20 mm long (figure 145B).

Biology. Adults emerge during May and June and probably later in its northern range (Milne and Milne 1980). Beetles are commonly found on willow foliage in California (Hovore 1988). Females oviposit mostly on branches 8 to 16 mm in diameter. Based on larval sizes and gallery lengths in limited samplings, the insect appears to have a 2-year generation.

Injury and damage. Egg niches in the bark provide earliest evidence of infestation. In a few weeks, as the branch stem expands, the egg scars become more noticeable as two, vertical bark splits side by side (figure 145C). Sometimes, only one bark split becomes noticeable (figure 145D). Splitting the infested stems reveals galleries up to 12 cm long and 4 mm in diameter (figure 145E). The emerging adults leave round to oval holes 3 to 4 mm in diameter in the bark (figure 145F). Terminals and branches are tunneled, sometimes resulting in dieback and breakage. Slow-growing trees in open settings on poor sites have suffered most.

Control. Woodpecker excavation sites have been found, but actual predation has not been observed. No other natural or direct controls have been reported.

Oberea delongi Knull

[poplar twig borer] (figure 146)

Hosts. Poplar. Eastern cottonwood is preferred (Hicks 1962, Morris and others 1975). The insect has been observed less frequently in swamp cottonwood and occasionally in hybrid poplars. It probably occurs in other poplar species.

Range. Eastern United States from Michigan and Massachusetts south to the Gulf Coast and west to Kansas, from Ontario and Quebec in southeastern Canada (Hicks 1962, Morris and others 1975).

Description. ***Adult.*** Slender, elongate longhorn beetle measures 10 to 14 mm long and 2.5 mm wide (figure 146A) (Knull 1946). Antennae of male extend to apical fourth of elytra; female antennae slightly

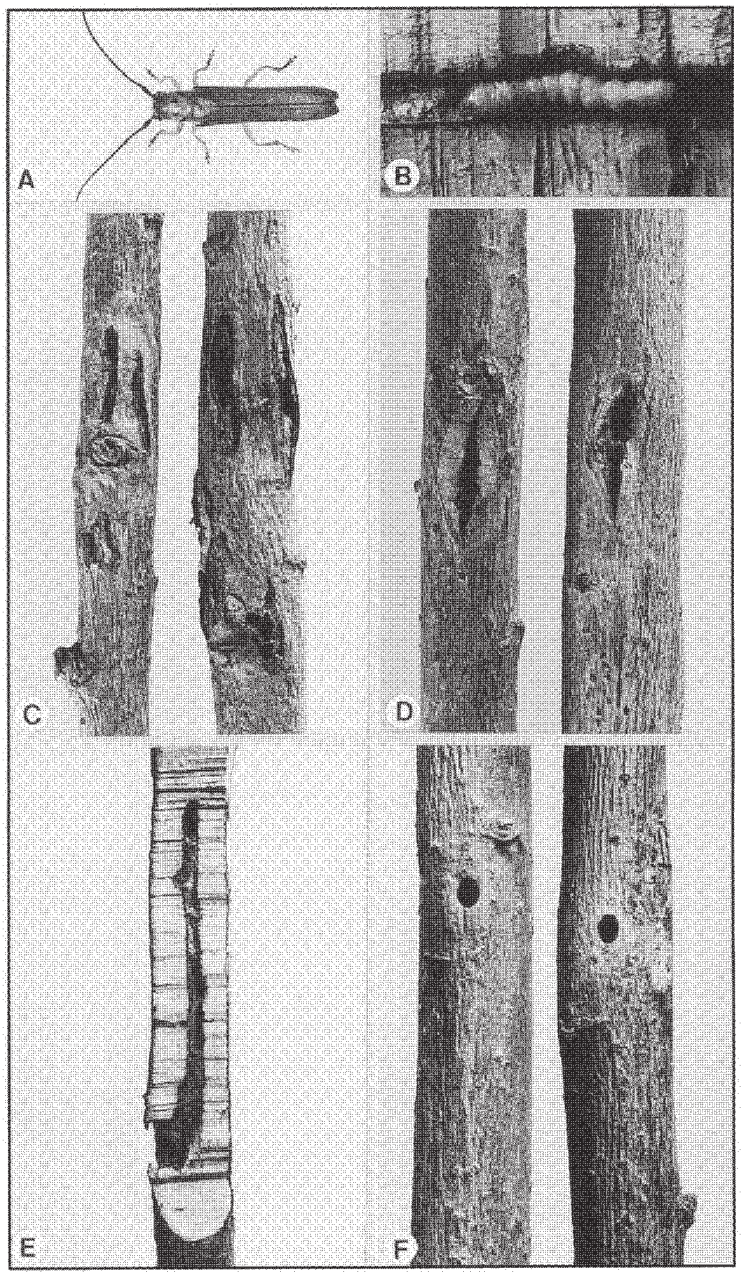

Figure 145—Oberea quadricallosa, *[western poplar branch borer]: A, adult; B, larva; C, egg niche scars; D, larval entrances; E, larval gallery; F, oval emergence holes (specimens courtesy F. Hovore and R. Penrose).*

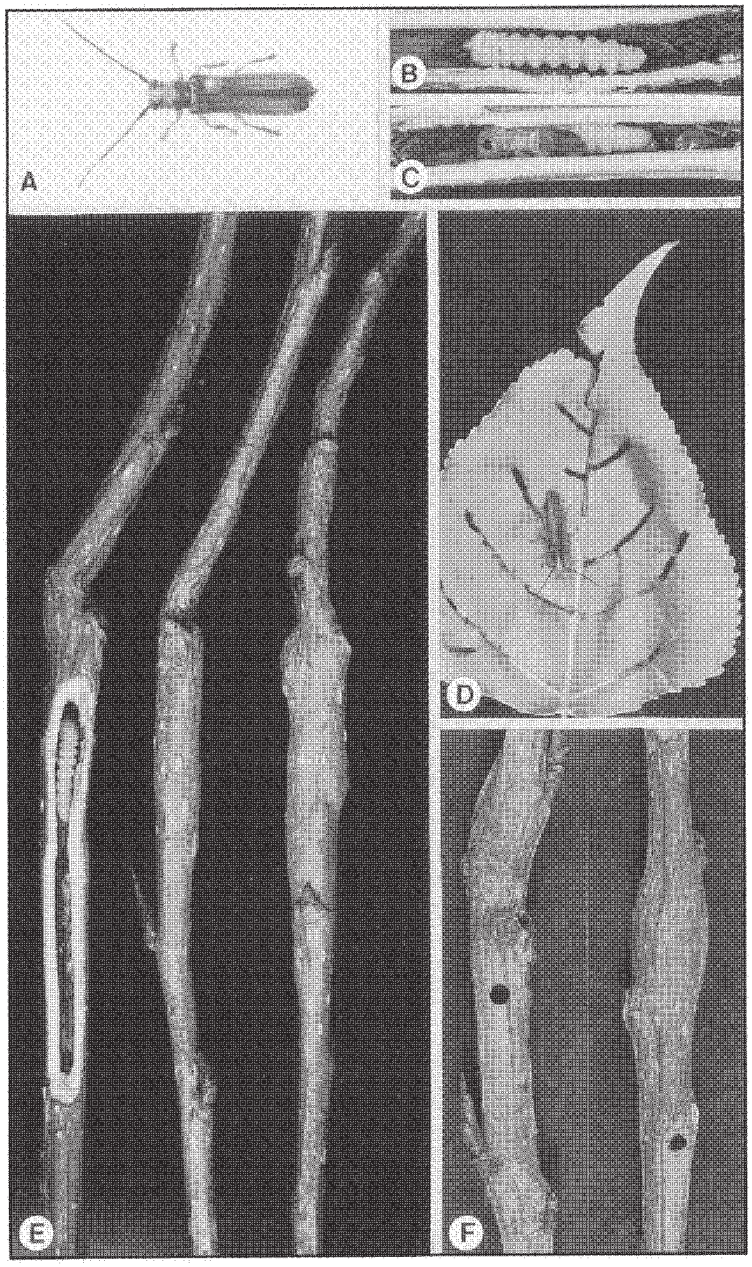

Figure 146—Oberea delongi, *[poplar twig borer]: A, adult; B, larva; C, pupa; D, leaf vein-feeding injury by adults; E, twig swellings, slight crooks, and exposed gallery; F, round emergence holes in twigs.*

shorter. Coloration of head, prothorax, and ventral surfaces somewhat variable, ranging from yellow to black; legs yellow; and elytra usually black with outer margins yellow. Surfaces of elytra faintly ridged, with coarse punctures between ridges. ***Egg.*** Creamy white, cylindrical, about 3 mm long and 0.5 mm in diameter. ***Larva.*** Greatly elongate, slender, and nearly cylindrical except body segments, which gradually decrease in width toward rear (figure 146B). Body smooth, shiny, and pale yellow except for brown head, dark brown mandibles, and light brown thoracic shield. Mature larvae about 19 mm long. ***Pupa.*** White and delicate and 8 to 12 mm long (figure 146C).

Biology. Adults emerge from April to June in the Deep South (Cook and Solomon 1976) and from mid-June through July in Michigan (Gosling and Gosling 1977). Adults feed extensively on the leaf midribs and large lateral veins after they emerge and mate. Females deposit eggs singly in niches chewed in the bark with their mandibles, typically selecting green shoots 5 to 13 mm in diameter. The niches remain visible for weeks after oviposition has ended. Eggs hatch in about 2 weeks, and larvae tunnel down the center of the stem, expelling little or no frass from the entrance holes. Larvae continue to feed into fall and overwinter in the shoots, feed briefly the following spring, and pupate within shoot galleries in March. Completed galleries range from 63 to 76 mm long and 3 to 5 mm in diameter. This twig borer completes a life cycle in 1 year (Cook and Solomon 1976, Morris and others 1975).

Injury and damage. The beetles injure foliage by feeding on the leaf midribs and, primarily, lateral veins (figure 146D), indicating that females are ovipositing in nearby twigs (Morris and others 1975). Egg niches are most common on twigs 6 to 10 mm in diameter, but larvae may be found in stems up to 13 mm in diameter. Infested branches usually become enlarged and appear swollen or even gall-like and frequently become slightly crooked at the point of attack (figure 146E). Larvae of this borer do not make a series of holes at regular intervals through which to eject frass as do many other species of *Oberea*. Infested twigs and terminals may be stunted or die back and occasionally break, especially when worked by woodpeckers. Dissection of infested twigs reveals dark galleries, partially filled with frass and the yellowish, elongate larvae (figure 146E). Round, exit holes about 2.5 mm in diameter are left in the swollen portion of the stem, or slightly below, by the emerging beetles (figure 146F). Damage is most destructive when terminals are attacked, often producing crooked, deformed, or excessively branched trees. Infestations have been observed in nurseries, plantations, natural stands, and ornamentals, but damage has been greatest in young plantations, adversely affecting tree form in crop trees. Damage has been greatest in the lower Mississippi River Valley (Cook and Solomon 1976).

Control. Woodpeckers, especially the downy woodpecker, are among the most important natural controls (Cook and Solomon 1976). Local counts have estimated predation rates up to 60% during some

years. Unidentified diseases kill sizeable numbers of larvae, especially during wet springs. Direct controls have rarely been needed.

Oberea tripunctata (Swederus)

dogwood twig borer (figure 147)

Hosts. Dogwood, viburnum, elm, sourwood, blueberry, rhododendron, azalea, laurel, poplar, willow, mulberry. Dogwood is preferred, but elm is commonly attacked (Beal and others 1952, Dillon and Dillon 1972, Johnson and Lyon 1988). It occasionally infests fruit trees in the genera *Malus* and *Prunus* as well as many shrubs.

Range. Distribution corresponds closely with that of flowering dogwood in eastern and central North America; recorded from Maine south to Florida and west to Texas, Kansas, and North Dakota (Craighead 1923, Johnson and Lyon 1988).

Description. ***Adult.*** Elongate, slender longhorn beetle measuring about 14 mm long and 2.4 mm wide (figure 147A) (Knull 1946). Head black, but prothorax, greater part of underside of body, and legs yellow. Pronotum with two smooth, black dorsal bumps, and another black spot in front of scutellum. Pronotum broader than long and cylindrical, with convex upper surface. Elytra variable in color but generally yellowish tan with narrow, black line on inner margins and broader black line on lateral margins. ***Egg.*** Yellowish, cylindrical, and slightly curved; measures 3 to 4 mm long and about 0.5 mm in diameter (Driggers 1929). ***Larva.*** Mature larva pale yellow except for dark brown head; measures 19 to 25 mm long with head capsule width of 1.2 mm (figure 147B) (Craighead 1923, Ruggles 1915). Larvae smooth, shiny, legless, and cylindrical; body segments gradually decrease in width toward rear. ***Pupa.*** Yellowish white, measuring about 13 mm long.

Biology. Adults emerge in April and May in north Georgia (Fattig 1947); common from May through July in Pennsylvania (Kirk and Knull 1926) and from late May to early August in Michigan (Gosling and Gosling 1977). Peak oviposition on blueberries in New Jersey is late June and early July; oviposition apparently occurs at night (Driggers 1929). Before ovipositing, females make two rings of punctures, 13 to 25 mm apart, and from 7 to 15 cm from the tips of current shoots (figure 147C). They slit the bark between the girdling wounds lengthwise and insert eggs singly under one of the bark flaps (figure 147D). Newly hatched larvae bore into the stem between the two girdles, tunnel short distances toward the twig tip, then reverse direction and bore down the center of the stem. At regular intervals along the stem, larvae make small holes to the bark surface through which they expel frass. Larvae overwinter between two, fibrous frass plugs within the galleries. Galleries in elm twigs measure up to 15 cm long (Ruggles 1915). Mature larvae girdle the woody part of the stem, causing many stems to break. The larvae quickly plug the girdled openings. Pupation begins in April and May and occurs in small chambers behind fibrous frass plugs. The insect completes its life cycle in 1 year in the South and over much of its range (Forbes 1911, Johnson and Lyon 1988). However, it

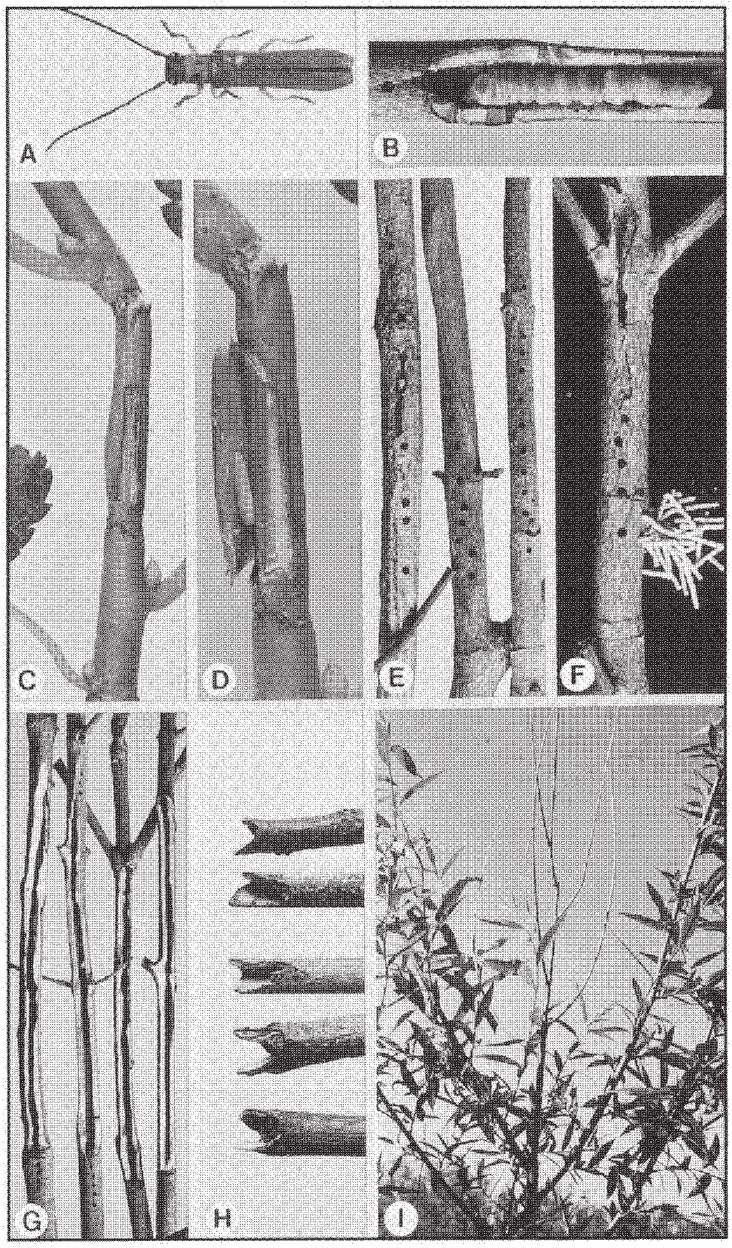

Figure 147—Oberea tripunctata, *dogwood twig borer: A, adult; B, larva; C, two oviposition girdles and egg site; D, bark flap pulled back to expose egg; E, linear rows of holes in twigs; F, pile of excrement pellet chains; G, long galleries; H, V-shaped stem girdles; I, willow terminal killed.*

requires a 2-year life cycle in Minnesota (Ruggles 1915) and a 3-year one is implied on blueberries in New Jersey (Driggers 1929).

Injury and damage. Wilting and dying of leaves on the tips of terminals and twigs during summer are usually the first signs of infestation (Driggers 1929, Forbes 1911, Johnson and Lyon 1988). Adults also feed on the leaves, making elongate elliptical holes along veins. As the season progresses, larvae bore down the centers of twigs toward the main stem, making rows of small holes at regular intervals in the bark along the twigs (figure 147E). Frass, in the form of excrement pellets adhering in long chains, is ejected from the small holes (figure 147F). Splitting the infested twigs reveals long narrow galleries in the stem centers (figure 147G). Stems are partially to completely girdled at one or more places by the larvae. Examining severed ends reveals characteristic V-shaped cuts (figure 147H). Terminals of young trees may be killed back for distances of several centimeters to 1 m (figure 147I). In seedlings, sprouts, and small shrublike plants (such as sourwood, blueberry, rhododendron, azalea, and laurel) larvae, in addition to killing the shoot tips, continue to burrow downward to the root crown or below until the entire aboveground plant is killed. Injury by this borer in the 1900's occasionally caused premature dropping of leaves and twigs of street elms in Minneapolis to such an extent that it appeared as if an early fall had arrived (Ruggles 1915). The insect has been very injurious to red-osier dogwood in Chicago parks (Forbes 1911). Cultivated blueberries in New Jersey are sometimes heavily damaged (Driggers 1929). Injury is much more important to ornamentals than in forests.

Control. Two species of hymenopterous parasites—*Bracon cerambycidiphagus* (Muesebeck) and *Cremastus orbus* (Davis)—have been reared (Carlson 1979, Marsh 1979). Rates of parasitism have varied from 50 to 80% (Driggers 1929, Ruggles 1915). Woodpeckers prey on the larvae. In ornamental plantings, the infested twigs should be pruned and destroyed before the adults begin emerging during spring. Ornamentals and nurseries can be protected with insecticides applied to the foliage and twigs during emergence and oviposition.

Oberea bimaculata (Olivier)

raspberry cane borer (figure 148)

Hosts. Raspberry, blackberry, poplar, persimmon, elm, dogwood, peach, plum, rose, apple, witch-hazel. Raspberry is preferred, but blackberry and other *Rubus* spp. are commonly attacked (Craighead 1923, Lintner 1889, Webster 1900b). Other species are attacked less often and more or less regionally.

Range. Throughout the eastern United States and southern Canada west to the Rocky Mountains (Chemsak and Linsley 1982).

Description. ***Adult.*** Slender, elongate, mostly black longhorn beetle about 13 mm long and 2.4 mm wide (figure 148A) (Knull 1946). Pronotum yellow with two smooth, black, raised bumps on middle upper surface and sometimes another black spot

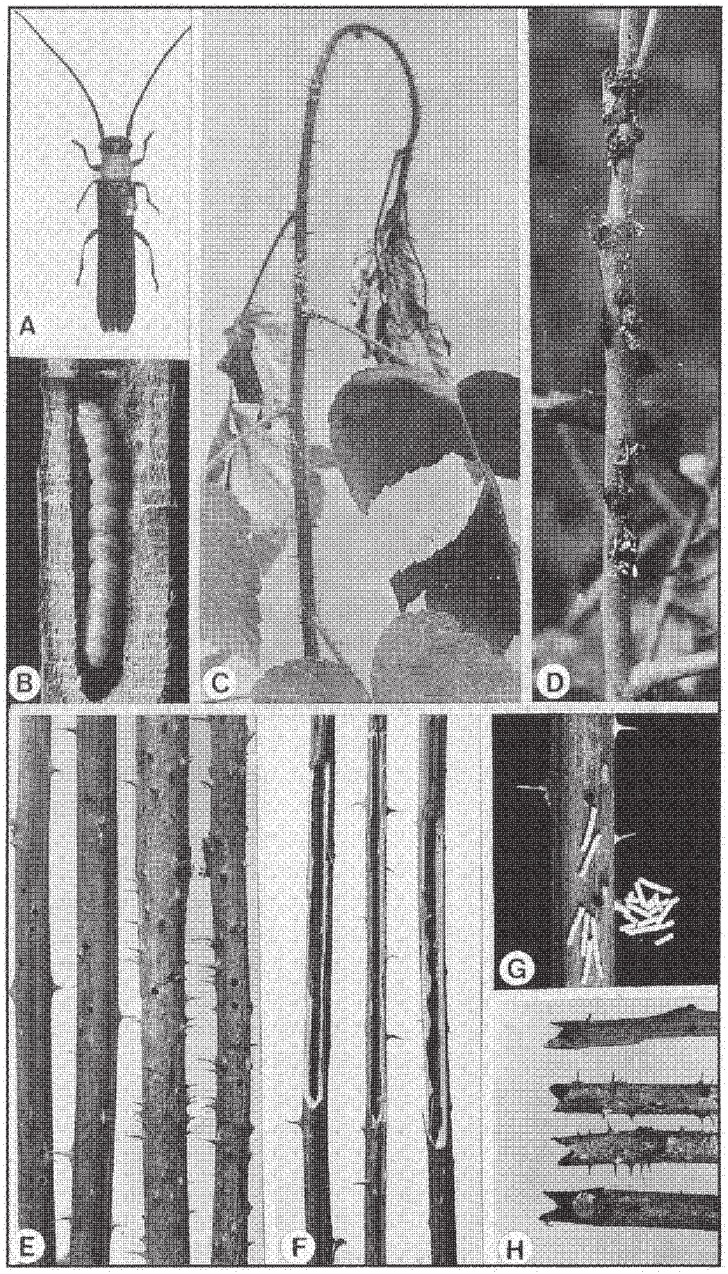

Figure 148—Oberea bimaculata, *raspberry cane borer: A, adult; B, larva; C, wilting, drooping raspberry cane; D, black exudate with frass on persimmon terminal; E, series of holes in canes; F, long galleries; G, excrement pellet chains; H, canes with V-shaped girdle.*

in front of base of elytra. Male antennae extend to apical fourth of elytra; female antennae somewhat shorter. Elytra elongate and truncate at apices; upper surfaces with longitudinal ridges and densely and coarsely punctured. ***Egg.*** Yellowish white, elongate, nearly cylindrical, slightly curved, rounded at both ends, and about 2.5 mm long (Slingerland and Crosby 1919). ***Larva.*** Mature larva (figure 148B) 20 mm to 22 mm long, with elongate, slender, cylindrical, dull yellow body. Body clothed sparsely with yellowish, stiff, short hairs. Head much smaller than the first thoracic segment and dark brown; mandibles much darker than head (Lugger 1899, Webster 1904). Abdominal segments decrease in width posteriorly. ***Pupa.*** Uniformly light yellow and about 13 mm long (Webster 1904).

Biology. Adults emerge late May to early August in Michigan (Gosling and Gosling 1977), late June to late July in South Dakota (Stein and Tagestad 1976), and somewhat earlier, during May and June, in warmer latitudes of Illinois southward (Webster 1904). Females make two rings of punctures about 13 mm apart, circling the stems 15 to 20 cm from the tips, and then insert single eggs through the bark between the two rings of punctures. Larvae tunnel downward in the pith 3 to 5 cm below the puncture wounds during the first summer, wintering in the shoots or canes (Slingerland and Crosby 1919). In the North, larvae continue to bore downward during the second year after eclosion, making numerous holes to the bark surface to expel frass; such injuries usually kill bearing canes before fruit matures. Larvae pass the second winter in their galleries at or near ground level. Pupation occurs in the tunnels during the second spring after oviposition; thus, the raspberry cane borer has a 2-year life cycle in its northern range. However, in its southern range north to the central United States, there is one generation per year.

Injury and damage. Wilting and drooping tender cane shoots (figure 148C) become noticeable soon after emerging adults make girdling punctures for oviposition. Later, injury becomes more conspicuous by the presence of dead leaves and tips of infested branches or canes in midsummer. Often, the dead tips break off in the wind (Lintner 1889), but those that do not break off remain attached to the canes long after the tops of the plants are dead, providing good evidence of infestation (McDaniel 1936). On persimmon, black gummy exudate mixed with frass can be found along infested stems (figure 148D). Larvae tunnel downward in the pith, periodically cutting small holes, often in straight rows to the surface of the bark to eject frass (figure 148E). Galleries and sometimes larvae can be found by slicing the stem longitudinally with a knife (figure 148F). Excrement pellets adhering end to end in long strands are ejected from the small holes (figure 148G). Larvae sometimes girdle the canes, with the severed ends exhibiting a V-shaped cut (figure 148H). Damage is worst where raspberry is produced commercially. Heavy borer populations may seriously prune growing shoots of both red and black raspberry plantings and in turn reduce fruit

production. Trees with branches killed repeatedly may gradually assume a scraggy, stunted, and misshapen appearance, with foliage growing in tufts.

Control. One dipterous parasite—*Lixophaga variabilis* (Coquillett)—has been reared (Arnaud 1978). Evidence of bird predation has been found on shoots and canes, but actual predation has not been observed. Wilting and drooping shoots should be pruned below the points of girdle as soon as observed (Slingerland and Crosby 1919). Later, when entire canes die, they should be cut close to the ground and burned to destroy the developing larvae (McDaniel 1936). Chemical controls may be needed in commercial and ornamental plantings.

Oberea ruficollis (Fabricius)

[sassafras borer] (figure 149)

Hosts. Sassafras, spicebush. Sassafras is preferred (Champlain and others 1925). Adults have been collected on sumac, but this is not likely a larval host (Mutchler and Weiss 1923).

Range. Throughout the eastern United States, from Pennsylvania south to Georgia and west to Arkansas and Michigan, and in Ontario (Champlain and others 1925, Fattig 1947, Gosling and Gosling 1977, Hicks 1962).

Description. ***Adult.*** Large, elongate, slender longhorn beetle measuring about 17 mm long and 3.8 mm wide (figure 149A) (Beal and others 1952, Knull 1946). Dark brown antennae extend beyond tips of elytra in males but do not reach tips in females. Head, prothorax, ventral surfaces, and legs brownish yellow (Knull 1946) to brick red (Beal and others 1952). Elytra covered with gray pubescence on black ground color. Pronotum broader than long, constricted in front and rear, with one median and two lateral callosites. Elytra elongate with tips truncated and surfaces faintly ridged longitudinally and densely and coarsely punctate. ***Larva.*** Mature larva (figure 149B) very elongate, slender, cylindrical, smooth, shiny, and sparsely covered with short, yellowish brown hairs (Craighead 1923). Head brown and remainder of body pale yellow. Larvae legless, body segments gradually decrease in width from front to rear; 16 to 26 mm long. ***Pupa.*** Yellowish with darker eyes, mouthparts and wingpads; 15 to 18 mm long (figure 149C).

Biology. Adults emerge from late June to early August in Michigan (Gosling and Gosling 1977), during May and June in North Carolina (Beal and others 1952), from late April to early June in Mississippi. Females deposit eggs singly in niches chewed in the bark of terminals and near the tips of small branches. The egg niche is made between a double row of punctures chewed by the female, which ring the stem, girdling it and killing the shoot (figure 149D) (Beal and others 1952). Larvae feed downward, enter the main stem, and eventually bore into the base of the stem and the larger roots. Galleries are made in the wood (center of small stems) and may be 1 m or longer, but gallery lengths of 60 to 90 cm are most common. While tunneling in the stem, larvae periodically bore short galleries at right angles to the main gallery and through to the bark surface

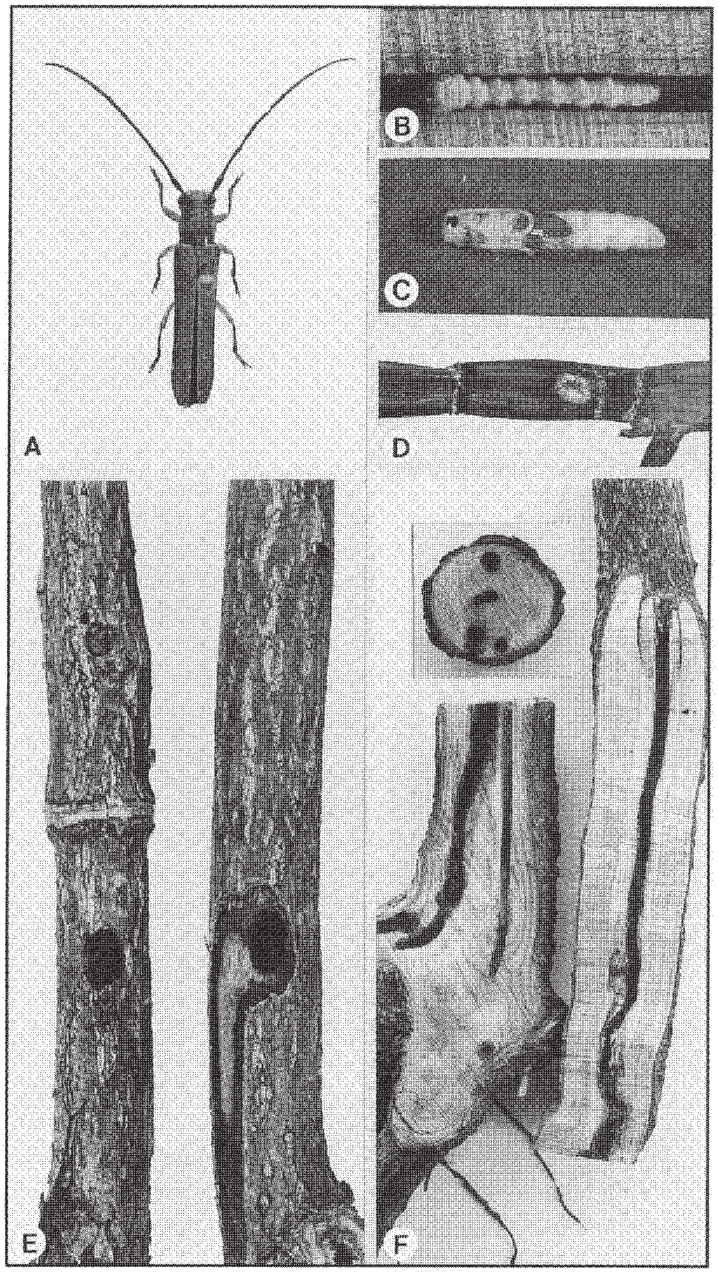

Figure 149—Oberea ruficollis, *[sassafras borer]: A, adult; B, larvae; C, pupa; D, egg site between girdles chewed in tender terminal; E, emergence holes; F, cross section and longitudinal section of galleries extending into root collar.*

to eject frass (Craighead 1923). They pupate in early to mid-April in the South in the gallery near ground level. Emerging adults chew exit holes directly through the bark (figure 149E). In the North, this borer requires 2 to 3 years to complete the life cycle (Craighead 1923). In the Piedmont of North Carolina, one generation per year has been reported (Beal and others 1952), whereas, in Mississippi, larvae of two sizes are commonly found, indicating a 2-year life cycle.

Injury and damage. The first evidence of infestation is wilting foliage on the terminal and branch tips (Craighead 1923, Beal and others 1952). Closer examination of the twig just below the wilt reveals a double ring of punctures around the stem with an egg niche between (figure 149D). As larval boring progresses toward and down the main stem, small holes may be present at regular intervals in the bark, through which frass is extruded. The frass consists mostly of short, cylindrical, excrement pellets, grayish yellow to light brown, and adhering end to end in strands up to 10 mm long. By the end of the second season of an attack, the entire young plant may be dead from extensive mining at the base of the main stem and in the larger roots (figure 149F). Young living sassafras trees from 6.3 to 51.0 mm in diameter are susceptible to attack. Adults leave irregular oval exit holes roughly 3 mm by 4 mm in the bark (figure 149E). Young plants, primarily large seedlings and young saplings, may be tunneled and frequently girdled and killed. Young growth in old fields and field borders has suffered most from infestation. This borer has commonly caused extensive mortality of young sassafras trees on the Piedmont of North Carolina and on similar sites in other states in the South (Beal and others 1952).

Control. Woodpeckers capture small numbers of larvae and pupae as indicated by excavation holes extending into the larval galleries. Direct controls are rarely needed except in ornamentals. Newly infested terminals and branches should be pruned just below the wilted and girdled sites and burned to destroy the young larvae.

Oberea gracilis (Fabricius)

[oak sprout oberea] (figure 150)

Host. Oak. White oak and southern red oak have been mentioned specifically (Turnbow and Hovore 1979), and the author has observed this pest in black oak. Other oak species probably serve as hosts also.

Range. Mainly in the Atlantic Coast region from Massachusetts and New York south to the southern Appalachians and Florida and west to Ohio (Hicks 1962, Knull 1946, Mutchler and Weiss 1923).

Description. ***Adult.*** Slender, elongate longhorn beetle, 10 to 15 mm long (figure 150A) (Hicks 1962, Knull 1946, Mutchler and Weiss 1923). Male antennae extend nearly to apices of elytra; those of female slightly shorter. Adults easily separated from those of closely related *Oberea* species by generally yellowish brown color and elytra with dark brown to black stripe along lateral margins (Turnbow and Hovore 1979). Tibiae, tarsi, and antennae dark brown to black. ***Larva.*** Very elongate, slender, cylindrical, and about 20 mm long at maturity (figure 150B). Larvae yellowish

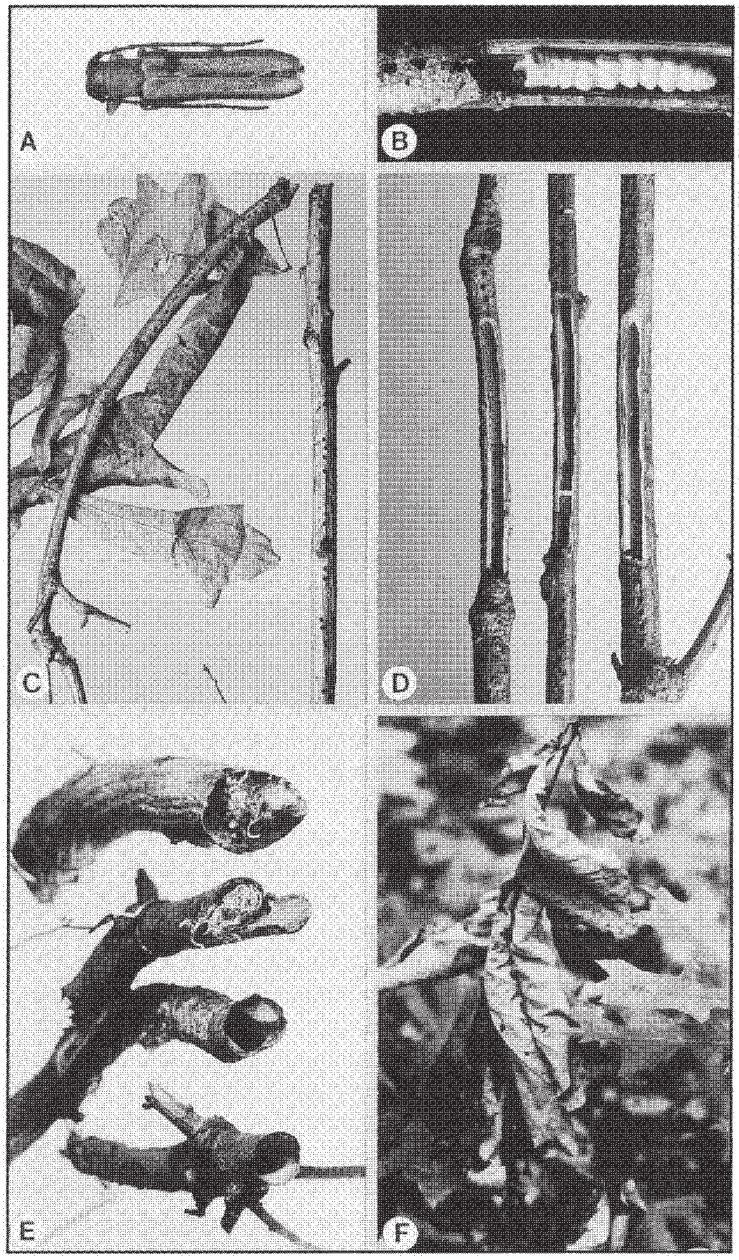

Figure 150—Oberea gracilis, *[oak sprout oberea]: A, adult; B, larva; C, severed oak sprout with linear series of holes; D, galleries in sprouts; E, oblique to V-shaped girdles and fibrous frass plugs; F, infested sprout dying with brown leaves.*

with dark mandibles, brownish yellow pronotum and small amber spiracles. Body shiny and covered with indistinct, fine, short yellowish setae. Larva legless, but abdominal segments with prominent ampullae.

Biology. Adults are present from April to August (Fattig 1947, Mutchler and Weiss 1923). Females lay eggs on terminals of vigorous seedlings and sprouts. Larvae mine down one side of the stem and become inactive in their galleries during winter (Turnbow and Hovore 1979). In spring, they become active and mine farther down the stems. First-year larvae sometimes girdle stems, whereas second-year larvae nearly always girdle plants slightly above the soil surface. They tunnel into the root collar and roots and pupate. The next spring, adults apparently emerge through the frass plugs at the girdles. The life cycle requires 2 years in Georgia (Turnbow and Hovore 1979).

Injury and damage. Both seedlings and sprouts less than 0.5 m tall may be attacked, but sprouts seem preferred, probably because shoots and stems are thicker and more succulent. Larvae burrow into stems a few centimeters below the shoot apex and tunnel downward (Turnbow and Hovore 1979). The larvae expel frass through a linear series of small round holes along the stem (figure 150C). Dissection reveals hollowed-out stems (figure 150D). Infested stems typically are girdled from 10 to 15 cm above the soil surface. Severed ends of infested stems are usually cut off obliquely and less frequently as a V-shaped cut (figure 150E). Ends of stems containing the larvae are tightly plugged with fibrous frass. After girdling, infested plants die holding their dried brown leaves well into dormant season (figure 150F). Many girdled seedlings and sprouts break off during winter. Recently, this pest was troublesome in young plantations in north Georgia.

Control. Evidence of woodpecker predation exists, but no other natural enemies have been observed. Valuable plantings in heavily infested areas may require protection.

Oberea ocellata (Haldeman)

[sumac stem borer] (figure 151)

Hosts. Sumac, apple, peach, plum, pear, currant, blackberry. Prefers common sumac (Craighead 1950), but apple has been a favored host in some apple-growing areas of the East (Chittenden 1899, Slingerland and Crosby 1919). Other fruit trees as well as blackberry and poison sumac are attacked occasionally (Mutchler and Weiss 1923).

Range. Widely distributed in the eastern and central United States from New York south to Florida and west to Kansas and Texas, and in Ontario (Chittenden 1899, Hicks 1962, Slingerland and Crosby 1919).

Description. ***Adult.*** Slender, elongate, cylindrical longhorn beetle, 11 to 15 mm long, easily recognized by contrasting orange and black stripes (figure 151A) (Craighead 1950, Hicks 1962, Knull 1946, Mutchler and Weiss 1923). Antennae and elytra dark brown to black with gray pubescence; legs bicolored, with reddish orange and black; pronotum reddish orange with two round black spots. Female antennae slightly shorter than male antennae. ***Larva.*** Legless, elongate, slender, cylindrical, and

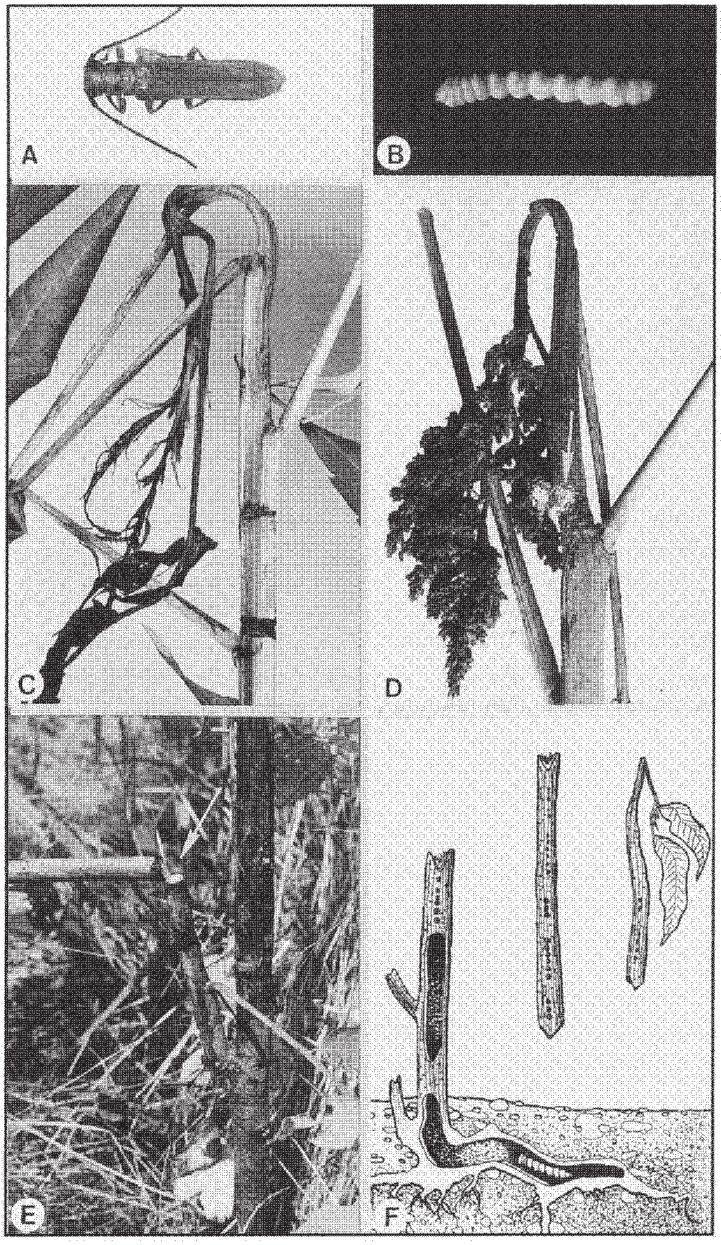

Figure 151—Oberea ocellata, *[sumac stem borer]: A, adult; B, larva; C, drooping sumac terminal with two rings of girdles; D, dead sumac flower stem with fine frass ejected; E, sumac side shoot broken at girdle site; F, linear series of holes, V-shaped girdle, and gallery extending into roots.*

bright yellow with brownish, shield-shaped thoracic plate that is horny, roughened, and arises obliquely from head (figure 151B) (Craighead 1923, 1950; Mutchler and Weiss 1923). Mature larva about 13 mm long (Slingerland and Crosby 1919).

Biology. Adults appear April to July, girdle new shoots, and lay eggs between the two girdles on the shoots (Craighead 1950). Larvae bore down the stems through the pith and wood well into the roots of small plants (Craighead 1950, Mutchler and Weiss 1923). They expel frass through small holes along the stems. Frass sometimes accumulates in small piles on the ground. During fall, larvae cut off the plants near the ground, plug the stub openings with wads of fibrous frass, and pupate a short distance below the plugs. Adults emerge the next spring (Craighead 1950, Slingerland and Crosby 1919).

Injury and damage. Initial evidence of attack is wilting and dying shoots and twigs (Craighead 1950, Mutchler and Weiss 1923, Slingerland and Crosby 1919). Inspection of wilting shoots reveals two rings of mandible girdles about 25 mm apart, 8 to 18 cm from the shoot tips (figure 151C). This pest sometimes girdles and kills shoots bearing flower heads (figure 151D). Succulent side shoots on woody stems also may be girdled and may break (figure 151E). Frass is ejected through pinlike holes cut at irregular intervals in the bark (Slingerland and Crosby 1919). In seedlings and sprouts, the larvae bore in the stems and roots and often cut off the plants by an oblique or V-shaped incision at one or more places, the last just above ground (figure 151F). Dissection reveals that the galleries extend from the stems several centimeters into the roots. In ornamentals and fruit orchards, the pest has been of considerable economic importance in the past. Heaviest infestations have been found in thick stands of small sumac growth on old-field sites bordering wooded areas.

Control. Control consists of pruning and burning all infested twigs and shoots of ornamental and orchard trees in spring before adults emerge (Mutchler and Weiss 1923, Slingerland and Crosby 1919). Direct controls in orchards under recommended spray programs are not apt to be needed but may be needed occasionally for ornamentals.

Parandra brunnea (Fabricius)

[pole borer] (figure 152)

Hosts. Black walnut, hickory, willow, beech, chestnut, oak, elm, yellow-poplar, apple, pear, plum, cherry, locust, soft maple, basswood, black ash, poplar, sweetgum. The insect is a general feeder and probably attacks all hardwoods and some conifers (Brooks 1915, Snyder 1921).

Range. Throughout the eastern United States west to Colorado and southward to the upper Gulf of Mexico region (Linsley 1962a).

Description. ***Adult.*** Somewhat flat longhorn beetle that is shiny, mahogany brown, and 8 to 12 mm long (figure 152A) (USDA FS 1985). Varies in size, color, punctuation, and development of head parts (Linsley 1962a). Mandibles in males very prominent and elongate, with inner margins armed with three distinct teeth. Females more robust with shorter mandibles than males. ***Egg.*** Creamy white, oblong ovate

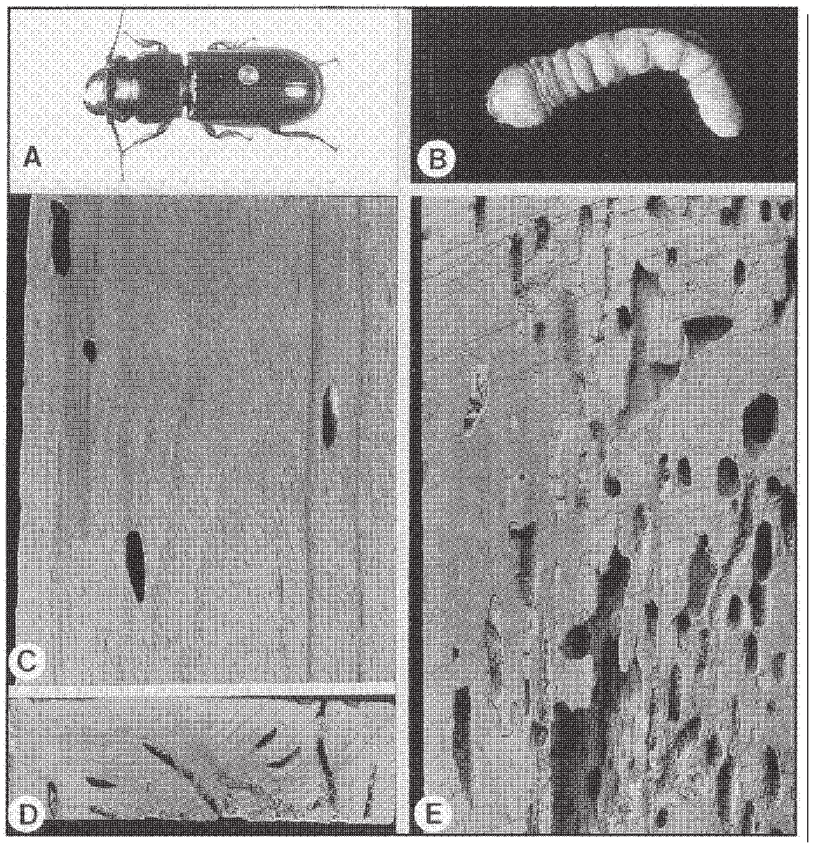

Figure 152—Parandra brunnea, *[pole borer]: A, adult; B, larva; C, galleries in beech sapwood; D, cross section of galleries; E, ash honeycombed with galleries.*

with granular surface and about 1.5 mm by 0.5 mm. ***Larva.*** Yellowish white with black head and about 30 mm long at maturity (figure 152B) (Brooks 1915). Small thoracic legs present, and abdominal ampullae project abruptly (Craighead 1915).

Biology. Adults appear in midsummer, usually in July or August, but remain in the pupal chambers in decaying wood for several days before emerging (Brooks 1915). Many adults do not emerge but mate and lay eggs inside the cavities (Kotinsky 1921). Egg laying begins soon after beetles leave the pupal chambers. Females make small openings in the exposed wood and deposit 1 egg at each site but lay them in clusters of up to 12. In the initial attack on the tree, females insert eggs into the wood of dead areas from the exterior; however, in later generations, eggs are deposited in either the solid or decayed wood that forms the gallery walls or other openings in the tree where the beetles can enter (Brooks 1915). Newly hatched larvae feed away from the egg sites and through the wood in winding or zigzag courses. Galleries, packed throughout most of their length with larval frass, honeycomb the affected parts of trees. Single burrows may meander for 1 m or more. Larvae usually feed in sound wood, so each succeeding generation enlarges and extends the area of decay (Brooks 1915). Pupation occurs in cells at the ends of the larval tunnels. The pupal stage lasts 10 to 14 days (Brooks 1915). A generation may require 3 or 4 years (USDA FS 1985).

Injury and damage. The pole borer attacks living trees almost always near the base, usually where the sapwood is exposed, such as in wounds and scars caused by mechanical bruises, cavities from improper pruning, sunscald, winter injury, fire blight, collar rot, storm injury, and other borers (Brooks 1915, Craighead 1915, Kotinsky 1921). This borer rarely attacks trees that have healthy bark and are free of injuries. Burrows begin in exposed wood and usually proceed upward but may extend throughout the adjacent heartwood and occasionally into the surrounding live sapwood (figure 152C and D). Other boring insects and fungi soon appear and help to accelerate damage. Within a few years, the infested portion of a tree, including the heartwood and a part of the sapwood, may be completely honeycombed (figure 152E), leaving only a covering shell of sapwood intact. A tree so affected may continue to live but will be in danger of falling during even light windstorms. The habits of this borer of always entering the wood at dead spots and cavities and of ejecting little or no frass to the surface (frass is packed within the galleries) distinguish it from most other borers. Sometimes, wounds where larvae enter living trees heal so that injury is not visible (USDA FS 1985). Injury appears most prevalent in older trees in sunny, exposed positions; thus, the insect seems more common in shade and ornamental trees in towns and cities than in forests. It often seriously injures fruit trees in orchards and sometimes seriously damages wood products including logs, crossties, telephone and power line poles, and structural timbers in contact with the ground or in moist locations (USDA FS 1985).

Control. Enemies include two hymenopterous parasites—*Odontacolon mellipes* (Say) (Brooks 1915) and *Pimpla* sp. (Linsley 1962a)—as well as the olive-sided flycatcher (Brooks 1915). The most important feature of control is to prevent injury to trees by maintaining them in vigorous condition. Avoiding damage to the trunk and lower branches is basic to preventing attacks because damage often begins in exposed dead wood. To mechanically remove this borer from trees, it is necessary to cut out all of the wood through which the borer galleries extend, the borers usually being present in large numbers and scattered throughout the decayed and adjacent live wood. The excavation should be cleaned completely of infested decayed wood and filled with cement or other fill material. All cut and injured surfaces should receive regular treatment to protect them against attack from insects and microorganisms. Chemical treatment of injured and susceptible areas on valuable trees may be helpful in preventing infestation.

Prionus imbricornis (Linnaeus)

tilehorned prionus (figure 153)

Hosts. Oak, chestnut, pear, apple, grape, pecan. Oak, chestnut, and pecan preferred; fruit trees heavily infested in small localized areas (Linsley 1962a, Payne and others 1970, Summerland 1932). Hardwoods and some herbaceous plants mentioned.

Range. Throughout the eastern United States from southern New England to Florida and westward to Nebraska and Texas (Linsley 1962a).

Description. ***Adult.*** Very large, robust longhorn beetle, shiny dark reddish brown (figure 153A) (Knull 1946, Linsley 1962a). Males average 31 mm long; females 42 mm. Antennae of males 18 to 20 joints and those of females 16 to 18 joints. Male antennae extend to middle of elytra; female antennae slenderer, barely reach basal third of elytra (Blatchley 1910). Head depressed between eyes and coarsely punctured. Pronotum convex, two or more times as wide as long, depressed along lateral margins; anterior and median lateral teeth prominent and blunt. ***Egg.*** Pale to bright yellow, slightly larger at one end, very finely punctured and from 3.6 to 4.2 mm long (Mullins 1975, Summerland 1932). ***Larva.*** Mature larva (figure 153B) creamy white to yellowish and up to 9 cm long (Payne and others 1976). Larvae have trapezoid heads that are widest behind. Integument tough and shiny (Craighead 1915). ***Pupa.*** Large, robust, and creamy white to yellowish with smooth shiny skin and abdominal segments prominently separated like accordian pleats.

Biology. Adults fly June to September (Linsley 1962a). They are nocturnal and hide during the day beneath debris or loose bark, usually at the bases of trees (Payne and others 1970). Females normally deposit 100 to 200 eggs in groups in the soil at bases of trees. As many as 254 eggs have been found in 1 female (Mullins 1975). Young larvae feed in the bark of roots before penetrating heartwood; later, larger roots may be completely hollowed out and smaller roots consumed. To pupate, larvae leave the roots, tunnel through the soil up to 1 m,

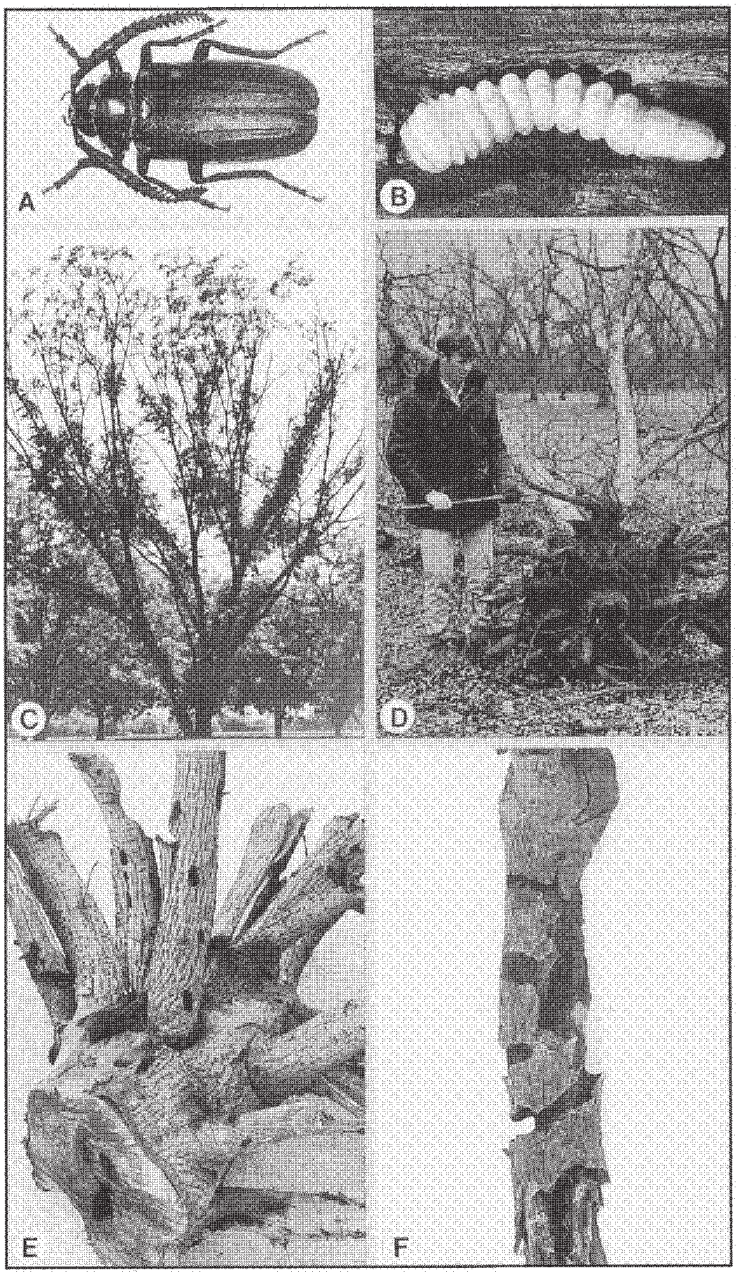

Figure 153—Prionus imbricornis, *tilehorned prionus: A, adult; B, larva; C, weakened infested pecan with thinning crown; D, borer study of excavated roots; E, holes and feeding injury in pecan roots; F, girdled and damaged pecan root (courtesy J. Payne).*

and construct pupal cells within 10 cm of the surface. The pupal cells are a mixture of organic and mineral soil held together by larval secretions. Cells are oval and measure about 7.0 by 4.5 cm (Craighead 1915). Developmental period lasts 3 to 5 years (Payne and others 1976).

Injury and damage. Exclusively a root feeder; the only aboveground symptoms of attack are gradual thinning and yellowing of foliage and limb-by-limb mortality (figure 153C). Young trees are sometimes chewed off just below the surface and the root systems devoured (Summerland 1932). Established trees frequently have one or two small roots left near the surface that keep them alive until the wind blows them over. Larvae may work on the surface of roots, sometimes girdling them; others burrow within roots, honeycombing them. Although small trees may be killed quickly, mortality in large trees is usually gradual. It is difficult to attribute the death of trees to the root borer because symptoms appear gradually (Payne and others 1970). To verify the presence of borers, one must excavate (figure 153D) or expose the larger roots from the root crown outward for a few meters. Excavated roots have burrows and large, oval holes in the root collar and roots (figure 153E). Large galleries, sometimes 5 cm in diameter, often packed with frass and soil can be seen on the surface of roots. Large yellowish white larvae are usually found in some galleries. Many roots will be girdled, completely honeycombed, or severed (figure 153F). Mature trees growing in open stands and in heavily used recreation areas are especially subject to attack. This borer has been a major cause of pecan tree decline and mortality throughout the pecan-growing region of Georgia, where 3 to 10% of the trees in many groves have been attacked (Payne and others 1976). A study in Georgia (Sparks and others 1974) found that declining trees infested by root borers produced significantly fewer nuts, and had shorter shoots and lower leaf weight than uninfested or lightly attacked trees. Apple orchards sometimes suffer high mortality rates. In 1 study plot, all apple trees were infested with up to 67 borers per tree (Summerland 1932).

Control. Little published information exists on natural enemies and other biotic factors that regulate populations. Several insecticides and soil fumigants tested in Georgia pecan groves showed that fumigants are the most effective chemicals for control of the borer when applied to the soil (Payne and others 1976). In tests, larval mortality was 100% when the fumigant was placed at depths of 30 cm. Disease, drought, mechanical injury, and poor soil conditions increase tree susceptibility. Cultural practices that keep trees thrifty and vigorous can help to minimize damage.

Prionus laticollis (Drury)

broadnecked root borer (figure 154)

Hosts. Oak, poplar, basswood, chestnut, apple, pecan, grape, pine, cherry, dogwood, maple, rhododendron. Favors oak, poplar, chestnut, and apple (Beal and others 1952, Farrar and Kerr 1968, Linsley 1962a, Shenefelt and Benjamin 1955).

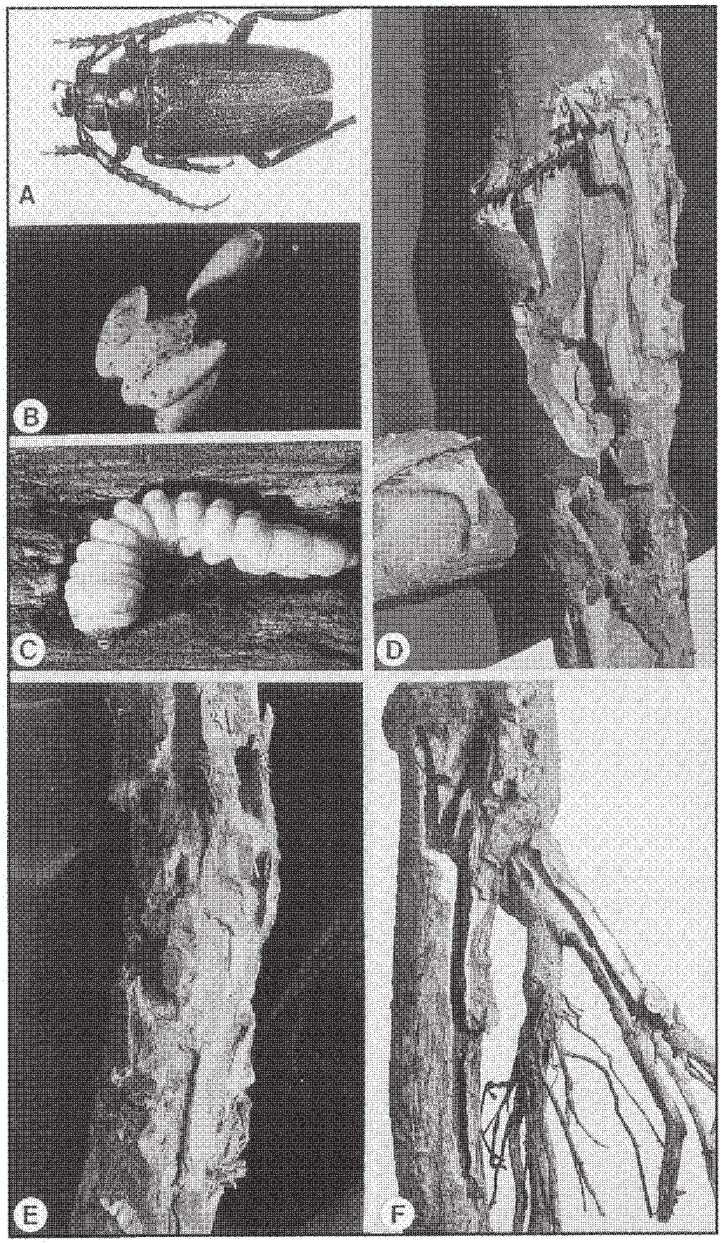

Figure 154—Prionus laticollis, *broadnecked root borer: A, adult; B, eggs; C, larva; D, root-surface feeding and girdling; E, galleries extending into and honeycombing root; F, longitudinal galleries in small roots (B, courtesy R. Farrar; specimens C-F, courtesy W. Johnson).*

Range. Southern Canada and throughout the eastern United States westward to Oklahoma (Linsley 1962a).

Description. ***Adult.*** Large, robust longhorn beetle from 22 to 32 mm long for males and 31 to 44 mm for females (figure 154A) (Knull 1946, Linsley 1962a). Body shiny, dark, brownish black. Head depressed between eyes; antennae have 12 segments. Antennae reach just beyond middle of elytra in males and just beyond base of elytra in females. Pronotum as wide as base of elytra, convex, depressed along margins, and each lateral margin bears three broad teeth. Each elytron has three slightly elevated ridges running lengthwise, and the surface is roughly, coarsely, and very irregularly punctured. ***Egg.*** Irregularly punctate and glossy yellow when deposited; darkens and loses glossiness after several days (figure 154B). Averages 1.4 mm wide and 3.5 mm long; both ends rounded with one end slightly larger (Farrar and Kerr 1968). ***Larva.*** About 9 cm long when mature, creamy white to yellowish with elongate, cylindrical, tapering body (figure 154C) (Craighead 1915, Payne and others 1970). Reddish hue visible beneath tough, shiny skin (Benham and Farrar 1976). Head dark brown to black, wider than long, and partly retracted into large fleshy prothorax. ***Pupa.*** Large and robust, white to cream colored when formed and gradually darkens with maturity; 21 to 57 mm long (Benham 1969).

Biology. Adults emerge and males fly June to August (Farrar and Kerr 1968, Linsley 1962a). Males fly readily and are difficult to collect except around lights; females have never been observed to fly (Benham and Farrar 1976). The digestive tracts of pupae atrophy as they become adults, which may explain why adults do not feed on foliage or roots (Benham and Farrar 1976). Studies in Rhode Island showed that 15 females contained an average of 643 eggs each and deposited an average of 388 eggs (Farrar and Kerr 1968). Eggs are deposited singly or in small clusters of 2 to 10 in the soil around tree bases at depths of 1.2 to 3.8 cm. Larvae molt seven times during their development. Larvae hatch by chewing jagged holes in the larger ends of the egg shells. Newly hatched larvae molt to the second instar after about 1 month. After hatching, the larvae move through the soil and feed on the bark of the roots. They move from root to root through the soil, feeding on smaller root surfaces, causing many wounds. They overwinter as second- or third-instar larvae, depending upon time of hatching (Benham and Farrar 1976). As larvae mature, they feed more intensively in the larger roots close to the root crown, where roots up to 8 cm in diameter may be severed, honeycombed, or completely hollowed. Larvae leave the roots and move to within about 10 cm of the soil surface to pupate. Most pupae are within 30 cm of the tree base. Larvae pupate in earthen cells slightly larger than the enclosed pupa; inner walls are smooth and contain a small amount of debris. Larger cells measure about 33 by 50 mm. The pupal stage lasts about 25 days (Benham 1969). One generation is completed in 3 to 4 years.

Injury and damage. Primary aboveground symptoms of attack are gradual thinning and yellowing of foliage throughout the crown and gradual limb-by-limb mortality, eventually ending in tree death (Payne and others 1970). Since these symptoms are characteristic of prolonged drought or other severe stress, correct diagnosis based on aboveground evidence is difficult. Symptoms often resemble nutrient deficiency in that the leaves may be sparse, small, and pale green to yellowish. Excavation may reveal that many of the smaller roots have been completely consumed. These insects commonly chew away large patches of bark, sometimes girdling the roots (figure 154D). Burrows often extend into and through large roots, frequently honeycombing the interior (figure 154E). In small roots, many of the galleries extend longitudinally just beneath the surface (figure 154F). Larvae cut off small trees at the root collar or just below the soil line. Serious damage and malformation of trees have been reported throughout the South (Beal and others 1952). In recent years, large numbers of bearing apple trees were abandoned in Rhode Island orchards due to damage from this borer (Benham and Farrar 1976). This borer and its close relative—*P. imbricornis*—annually kill significant numbers of trees and reduce crop yields in Georgia pecan groves (Payne and others 1970). Together these borers are capable of destroying from 75 to 90% of the roots of infested trees. They seldom cause substantial damage in natural forests. However, they can destroy open-grown trees in parks, pastures, orchards, and along streets.

Control. Natural controls include a tachnid fly parasite of prepupae, five species of pathogenic bacteria, cannibalism when larval galleries intersect, and subfreezing temperatures for those larvae that fail to move below the frost line in northern areas (Benham and Farrar 1976). Because attacks are most commonly associated with conditions that stress and weaken trees, cultural practices that keep trees healthy should be followed. New plantings should be made some distance away from heavily infested orchards and tracts of woodland. Soil-applied insecticides and fumigants have shown some promise for control (Payne and others 1976).

Prionus californicus Motschulsky

California prionus (figure 155)

Hosts. Oak, walnut, chestnut, poplar, willow, serviceberry, eucalyptus, madrone, apple, pear, almond, peach, cherry, plum, quince, alder, hop. Particularly prevalent in oak, madrone, poplar, and apple (Essig 1929, Linsley 1962a). Reportedly attacks some conifers, brambles, and certain shrubs.

Range. Alaska south through western Canada and the Pacific Coast region into Baja California in Mexico and east into the Rocky Mountains to Colorado and New Mexico (Linsley 1962a).

Description. ***Adult.*** Large, robust longhorn beetle with shiny reddish brown to black body (figure 155A) (Linsley 1962a). Males 24 to 45 mm long, females 38 to 55 mm. Male antennae robust and more than two-thirds as long as body; female antennae slender and only half as long as body.

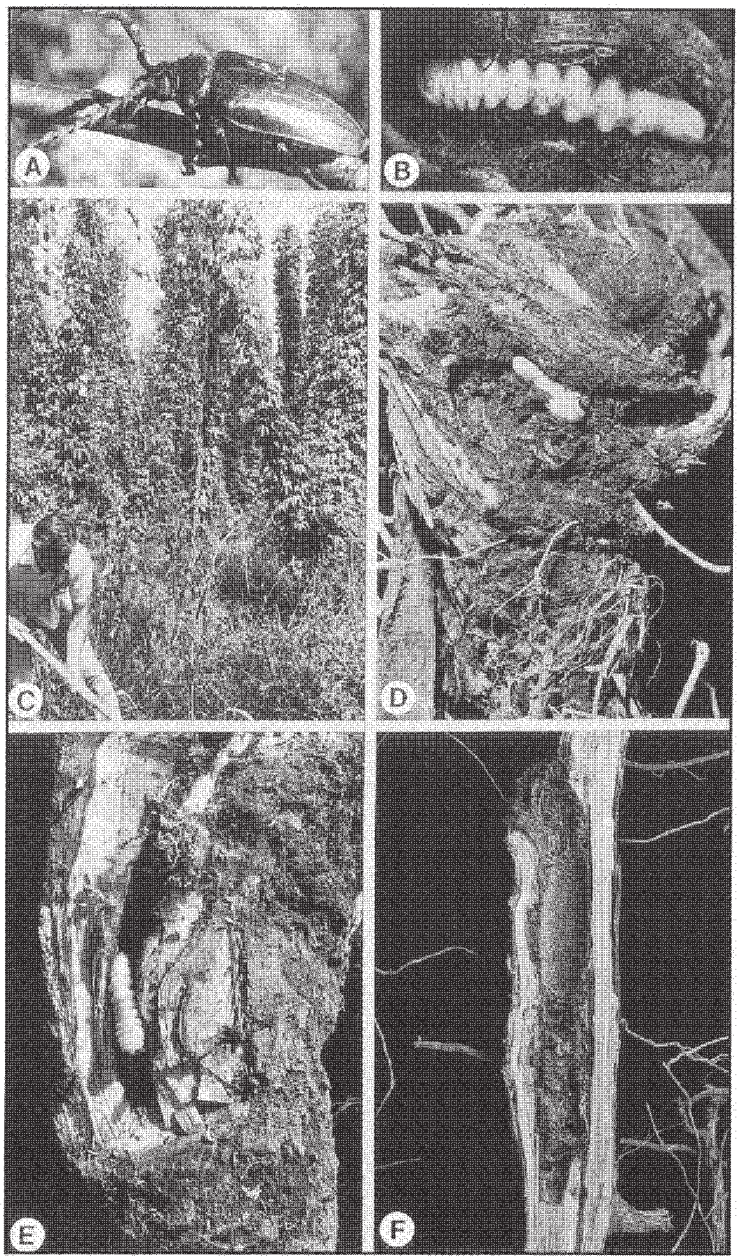

Figure 155—Prionus californicus, *California prionus: A, adult; B, larva; C, infested hop garden weakened by borers; D, crown of hop plant being destroyed by borers; E, large tree root with gallery; F, small root hollowed out (courtesy G. Bishop).*

Thorax narrower than base of elytra. Pronotum polished, sparsely punctate, with prominent, spinelike lateral teeth. Elytra less than twice as long as basal width, hairless, and with three ridges running lengthwise. ***Egg.*** About 4.8 mm long, about twice as long as wide, yellowish brown, with thick chitinous shell (Crawford and Eyer 1928, Eyer 1942). ***Larva.*** Mature larva (figure 155B) about 8 cm long, thick as a man's index finger, deep creamy yellow, and occasionally with reddish brown hue beneath skin. Mandibles large, black, powerful, and capable of inflicting severe wound. Body segments gradually taper toward rear, integument relatively smooth and shiny, and head usually partially retracted. ***Pupa.*** Yellowish white and measures about 38 mm long and 34 mm wide (Craighead 1915).

Biology. Adults fly from June to September (Linsley 1962a). They are nocturnal and often attracted to light (Essig 1929). Females lay eggs in the soil at tree base, singly or in small clusters as with other *Prionus* species (Eyer 1942). Young larvae bore into the bark at the base and when about 25 mm long begin penetrating roots. Larval mines are packed with sawdust and soil (Craighead 1915). Smaller roots may be severed, whereas larger roots and the root crown may be girdled or completely honeycombed with galleries up to 50 mm wide (Crawford and Eyer 1928). After the third or fourth year of development, larvae leave the roots in early spring and construct tunnels in the soil up to 0.9 m long and about 15 cm deep. Larvae line tunnels with frass or debris, then construct pupation chambers at one end. Pupation in southern New Mexico occurs in late May and early June, and adults emerge soon afterward. The life cycle requires 3 to 4 years (Bishop and others 1984, Crawford and Eyer 1928).

Injury and damage. First evidence of injury is dwarfing and yellowing of foliage (figure 155C) followed by defoliation and drying and cracking bark on larger branches; plants often die the following season (Crawford and Eyer 1928). Crowns of severely infested hop plants are sometimes reduced to masses of frass and rot (figure 155D) (Bishop and others 1984). Trees on sandy soils may be killed within a few years of initial attack; nearby plantings on heavy clay soils develop with little injury. Apple orchards on medium- to heavy-clay soils rarely show injury until they are 15 years old (Eyer 1942). Sometimes the boles of trees are severely girdled just below ground, and tunneling damage (figure 155E) to larger roots may be so extensive that trees are easily pushed or blown over (Linsley 1962a). Only the shells of smaller roots may be left after larval feeding (figure 155F). Exposing roots reveals both galleries and feeding larvae. This pest is a serious enemy of apple trees in the Mesilla and other fruit-growing sections of New Mexico (Crawford and Eyer 1928). As many as 22 borers have been found in the roots of trees 10 to 15 years old. Heavy infestations frequently girdle trees. Also, these borers cause death, stag top, stunting, and distorted growth of oaks and other hosts along the Pacific Coast. Hop yards in Idaho have been seriously damaged in recent years (Bishop and others 1984).

Control. Few natural enemies have been found. One parasitic fly—*Sarcophagarapax* Walker—was reared from an adult beetle (Leech 1947). Good cultural practices such as fertilization, irrigation, and weed control help to promote tree vigor and lessen susceptibility to attack. Light, sandy soils should be avoided as planting sites for new orchards in areas of repeated damage, as damage has been most severe on coarse textured soils (Eyer 1942). Soil-applied fumigants put out early in the season and directed at newly hatched larvae have given about 50% control (Crawford and Eyer 1928).

Archodontes melanopus melanopus (Linnaeus)

[live oak root borer] (figure 156)

Hosts. Oak, hackberry, sugarberry, boxelder, persimmon, pecan, apple. Oak, particularly live oak, appears to be major host (Beutenmuller 1896, Herrick 1904, Linsley 1962a, Packard 1890, Riley 1880). Also commonly infests turkey oak and water oak.

Range. Virginia to Florida and westward to Arkansas and east Texas (Linsley 1962a, USDA FS 1985).

Description. ***Adult.*** Broad, elongate, heavy, rather flattened, dark brown to black longhorn beetle with sides subparallel (figure 156A) (Herrick 1904, Linsley 1962a, USDA FS 1985). Pronotum narrower than base of elytra with sides converging anteriorly and usually serrate or dentate. Elytra about 2.5 times as long as wide. Antennae reach basal one-third of elytra in males and slightly shorter in females. One of the largest beetles in the United States, measuring 33 to 57 mm long and up to 16 mm wide. ***Larva.*** Robust, cylindrical, smooth texture, shiny, white, and sparsely hairy with three pairs of tiny thoracic legs (figure 156B) (Craighead 1915). Larvae vary from 76 to 90 mm long and about as thick as a forefinger (Herrick 1904). Resembles larvae of *Orthosoma brunneum* (Forster) but much heavier and thicker (Packard 1890).

Biology. Adults begin emerging in May and June and are present until September (Linsley 1962a). Females prefer small saplings for oviposition and deposit eggs at the base of the tree, typically at the root collar and just below groundline. The newly hatched larvae burrow into the root collar and down into the roots, where they make large, flattened, oval galleries that become surrounded with gall-like growth, well out of proportion to aboveground growth. The gall-like enlargements are appropriated for the domiciles of the larvae. Portions of the galleries are typically packed with frass. Larval growth apparently requires several years (Packard 1890, Herrick 1904).

Injury and damage. Injury is characterized by large galleries in the wood from the root collar downward into the roots (figure 156C and D) (Herrick 1904, Packard 1890, USDA FS 1985). Bark at root collar and at places along infested roots may be cracked or ruptured, exposing tightly packed frass in portions of the larval burrows (figure 156E). Also, irregular to oval holes may occur in bark (figure 156F). This pest attacks trees of all sizes but prefers young trees, especially sap-

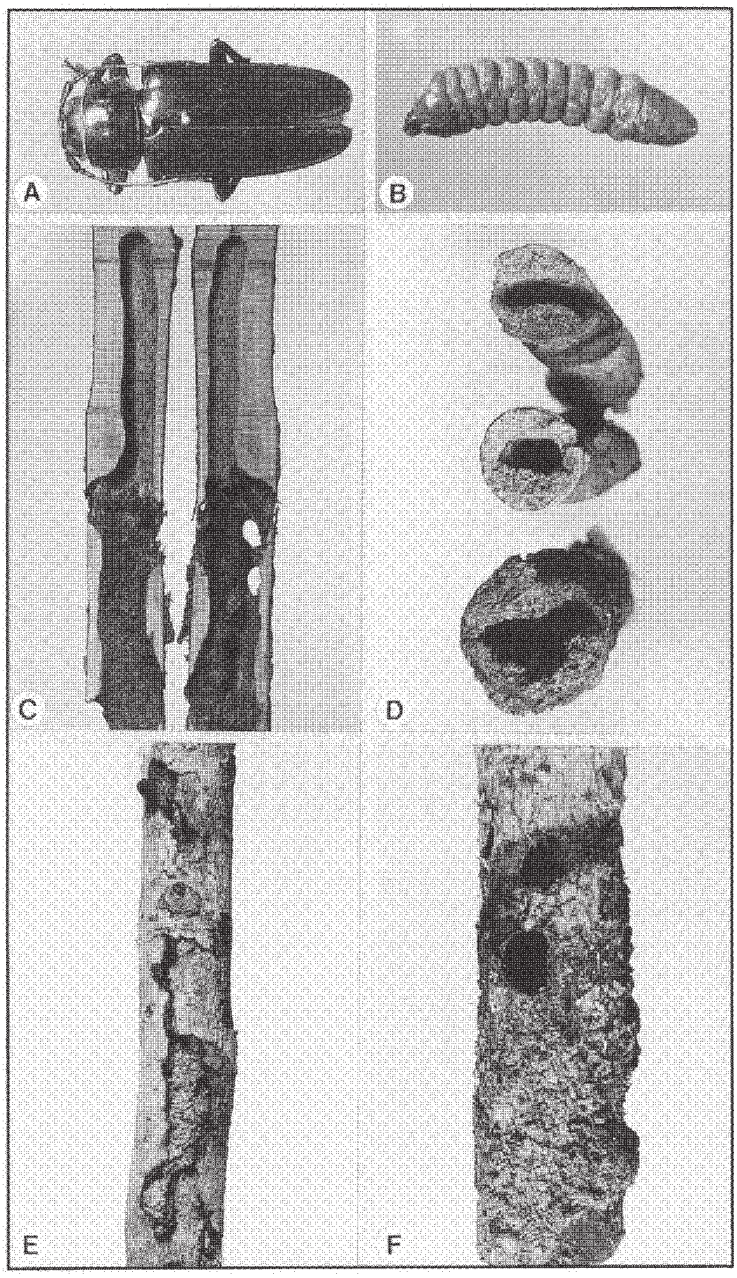

Figure 156—Archodontes melanopus melanopus, *[live oak root borer]: A, adult; B, larva; C, hollowed out root; D, oval to flattened gallery in cross section; E, infested root with openings and frass; F, oval holes in infested root (A & C, specimens courtesy D. Whitehead).*

lings. It sometimes kills roots, resulting in very few new rootlets being formed. Old roots excavated by larvae constantly grow new woody layers that are in turn eaten away, eventually producing gigantic root galls. The galled roots may become gnarled and tangled. Heavily infested trees often die back to the ground and are replaced by a cluster of smaller, straggling suckers, often forming clumps of sprouts or underbrush. Decay is usually associated with root and root-collar injuries. Damage has been particularly severe in south Georgia and Florida, where this borer has been largely responsible for the creation of large, relatively barren areas of scrub oak (Packard 1890). On extremely sandy sites, forest stands have been reduced to scattered oak bushes that barely suffice to cover the sand.

Control. Little is known about control, but the root collars of valuable trees in problem areas should be examined frequently for evidence of this borer's presence. Either the larvae should be dug out or the burrows probed with a wire to kill the larvae (Herrick 1904).

Archodontes melanopus serrulatus (LeConte)

[poplar root borer]

Hosts. Poplar, mesquite. Cottonwood and common mesquite preferred (Leng 1884, Linsley 1962a).

Range. Subspecies found from central Texas west through New Mexico into Arizona and in Mexico (Leng 1884, Linsley 1962a).

Description. ***Adult.*** Large, robust, broad, elongate longhorn beetle, somewhat flattened and dark brown (Leng 1884, Linsley 1962a). One of largest beetles in this country, ranging from 39 to 62 mm long. Similar to *A. m. melanopus*, but lateral margins of pronotum crenulate rather than dentate or serrate, and beetles average slightly larger. ***Larva.*** Robust, cylindrical, white, and shiny; may reach 9 cm long when mature.

Biology. Adults are present June to September (Leng 1884, Linsley 1962a), active at night, and occasionally attracted to light. Females deposit eggs at bases of host trees. New larvae bore into roots and feed. Life cycle requires 3 to 5 years.

Injury and damage. Large, irregular burrows are made in the root collars and roots of hosts (Linsley 1962a). Frass is packed in portions of the galleries. The larvae bore in the roots, weakening and sometimes killing trees.

Control. Keeping trees healthy and vigorous helps to minimize damage. Nothing is known of natural controls.

Archodontes melanopus aridus (Casey)

[willow root borer]

Hosts. Willow. Western species of willow are the only recorded hosts, but adults have been taken in flight around baccharis, indicating possible host status.

Range. Found in hosts growing only along the Colorado River in California and Arizona (Linsley 1962a).

Description. ***Adult.*** Moderately robust, elongate longhorn beetle, rather flattened and dark brown (Linsley 1962a). Similar in appearance to *A. m. melanopus*

and *A. m. serrulatus*, but smaller, sides more parallel, and edges of protonum crenulate rather then serrate or dentate. Adults 21 to 43 mm long.

Biology. Adults have been recorded during July and August (Linsley 1962a). They become active at dusk and can be found on or around host trees. Females deposit eggs around the root collar and groundline. Larvae bore into the roots, and the life cycle probably requires 3 or more years.

Injury and damage. Burrows and galleries can be found in the roots of host trees (Linsley 1962a). Galleries may be partially to completely packed with frass. Weakened trees may succumb to heavy tunneling.

Control. Cultural practices that keep trees healthy will help to minimize injury. Little is known about natural and other controls.

Stenodontes dasytomus dasytomus (Say)

[hardwood stump borer] (figure 157)

Hosts. Oak, hackberry, willow, sycamore, boxelder, hickory, sweetgum, elm. Reported from Australian pine, a deciduous exotic in south Florida. Probably attacks many other deciduous broadleaf trees (Beutenmuller 1896, Hovore and others 1987, Linsley 1962a, Thomas 1977).

Range. Virginia south to Florida and west to Arizona (Craighead 1915, Thomas 1977); also found in eastern and northern Mexico (Hovore and others 1987, Linsley 1962a).

Description. ***Adult.*** Large, elongate, somewhat flattened, reddish brown to dark brown longhorn beetle 23 to 47 mm long (figure 157A) (Craighead 1915, Linsley 1962a). Head large and coarsely punctured. Prothorax wide; sides armed with many small flattened teeth. Antennae reach basal third of elytra in males and slightly shorter in females. Genae bidentate; protonum of male has distinct polished facets, frequently reunited posteriorly, and distinctly punctated. ***Larva.*** Robust, cylindrical with smooth shiny skin, sparsely hairy; and can reach 64 mm long when mature (figure 157B). Head wider than long, retracted into prothorax, and front produced in smooth transverse carina. Two small groups of 5 to 10 chitinous points found on underside of prothorax. Small thoracic legs present, and ampullae bear two transverse impressions. ***Pupa.*** White, head glabrous, and protonum and abdomen with many fine to coarse asperites.

Biology. Most adults emerge from May to July, but a few have been found as early as April in south Florida, and some have been collected in other areas as late as October (Hovore and others 1987, Linsley 1962a, Riley 1880, Thomas 1977). Females deposit eggs around wounds where the wood is exposed, at or near the base of trees, and in sites that have been previously infested. Larvae bore into the sapwood and heartwood where they feed close together for 3 to 4 years. They make large, meandering tunnels and eventually honeycomb the heartwood. Mature larvae prepare pupation cells in galleries deep in the tree by plugging them with fibrous frass. Emerging adults chew holes directly through the wood and bark. Larvae can complete development in dying or recently dead trees.

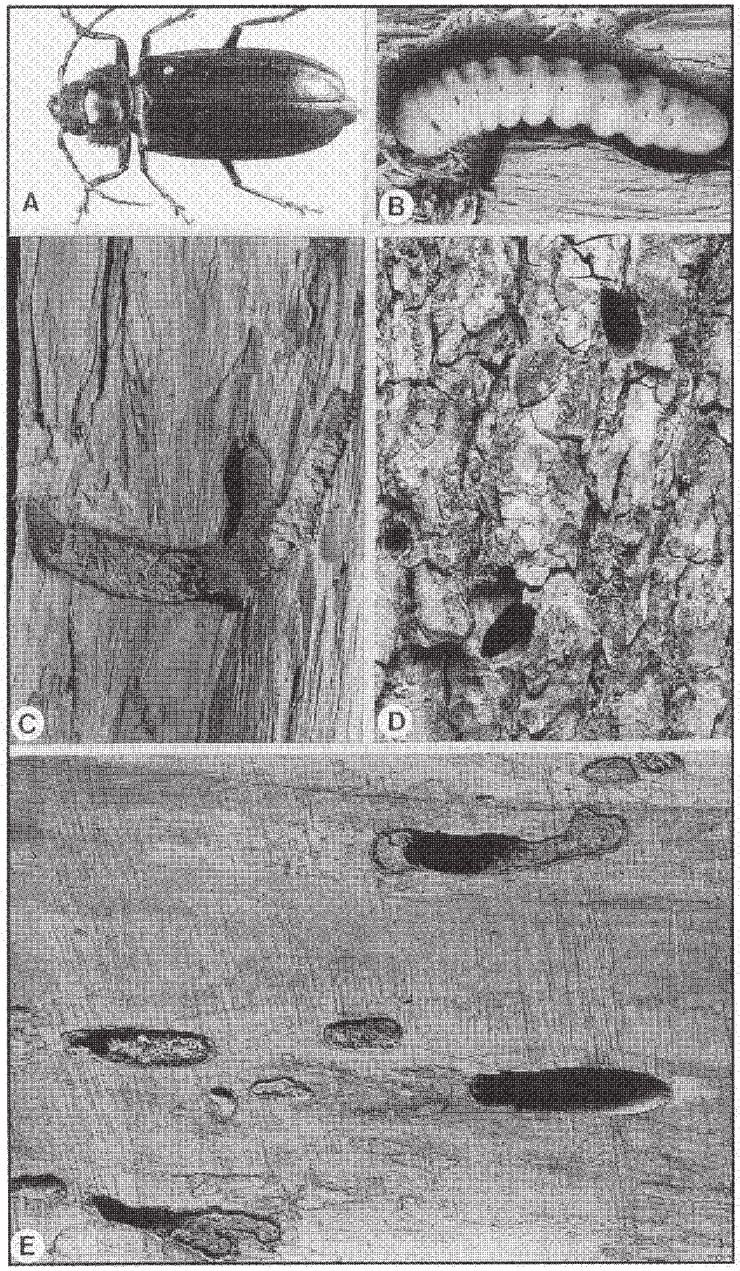

Figure 157—Stenodontes dasytomus dasytomus, *[hardwood stump borer]: A, adult; B, larva; C, fibrous frass-packed gallery in wood; D, large, oval emergence holes in bark; E, large holes in lumber.*

Injury and damage. Infestations often go unnoticed until trees are weakened and break. At the point of break, which usually occurs in the basal portion of the tree, large, flattened oval tunnels that measure up to 8 by 22 mm and are packed with coarse, fibrous frass can be observed (figure 157C) (Craighead 1915). The heartwood at the point of infestation may be completely honeycombed with galleries. Although little frass is ejected to the outside, large, oval emergence holes 8 by 18 mm (figure 157D) are left in standing trees after a few years. Trees with basal wounds within the range of this borer should be suspect, and regular inspections are recommended. Wood products cut from infested portions of trees have numerous large galleries, some packed with frass (figure 157E). Shade trees with little support from the canopy of surrounding trees, as in a forest stand, have been particularly susceptible to breakage. Wood products sawn from infested trees are degraded and reduced in value. Crossties and other wood products in contact with the ground are also subject to attack and damage (USDA FS 1985).

Control. Woodpecker excavation holes have been found in infested trees, but little is known of these or other natural enemies. Shade trees should be kept healthy and vigorous, and basal wounds should be avoided. Fresh wounds should be promptly treated or filled to avoid borer attacks.

Stenodontes dasytomus masticator (Thomson)

[Arizona sycamore borer]

Hosts. Sycamore, alder. Arizona sycamore appears to be major host (Linsley 1962a, Linsley and others 1961).

Range. Arizona, south through Mexico to Colombia (Linsley 1962a).

Description. ***Adult.*** Large, elongate, slightly flattened, and reddish brown to dark brown to black longhorn beetle; 23 to 47 mm long (Linsley 1962a). Adults distinguished from those of *S. d. dasytomus* by genae tridentate; pronotum of male with polished facets small, completely separated; punctation fine. ***Larva.*** Robust, cylindrical, smoothly shiny, sparsely hairy, with small thoracic legs, and up to 64 mm long when mature.

Biology. Adults are present during July and August (Linsley 1962a, Linsley and others 1961) and remain near their burrows for some time after transforming, secreting themselves in the burrows or under loose bark during the day. In early evening, adults can be seen with heads and antennae protruding from the large exit holes or crawling over the surface nearby. Females deposit eggs around wounds and injuries, especially sunscald injuries, and sometimes back into exit holes of previously infested trees to oviposit. Larvae burrow through the wood, packing the galleries with frass. After pupating, adults emerge through large, oval, exit holes cut to the surface by larvae.

Injury and damage. Injuries are characterized by large mines filled with coarse, fibrous frass. Attacks are mostly on the west side of trunks and in association with sunscald injuries and occasionally on branches (Linsley and others 1961). Broken trunks or branches

reveal galleries and sometimes large larvae. The heartwood of repeatedly attacked trees will be honeycombed with burrows. These pests are particularly abundant in host trees in ravines near Portal, Arizona (Linsley and others 1961).

Control. Adults are preyed upon by nocturnal birds, especially the great horned owl and bats. Also, larvae of the large eye-marked elaterid—*Alaus zuniana* Casey—are predacious on the borer larvae (Linsley and others 1961). Valuable trees should be protected from sunscald and other injuries to prevent infestation.

Stenodontes lobigenis (Bates)

[southwestern stump borer]

Hosts. Mesquite, peppertree, fig, baccharis, blue paloverde. Peppertree is favored in ornamental plantings (Linsley and Ross 1940).

Range. Southwestern United States from Texas to southern California, and in western Mexico, including Baja California (Linsley 1962a).

Description. ***Adult.*** Elongate, flattened, and dark reddish brown or brown longhorn beetle (Linsley 1962a). Mandibles long (1.75 times length of head) and extend prominently forward. Antennae reach to about middle of elytra in males and slightly shorter in females. Adults 20 to 42 mm long.

Biology. Adults are present from June to September (Linsley 1962a, Linsley and Ross 1940). They hide during the day and become active at dusk and early evening, when they mate and oviposit. Larvae are primarily root feeders but frequently work upward into the bole of the tree. However, most bole tunneling occurs in the basal 2 m of the trunk.

Injury and damage. Injuries consist of extensive, large galleries mostly filled with coarse frass. Damage occurs primarily in lower trunk and roots (Linsley and Ross 1940). Repeated attacks gradually hollow out the heartwood. Infested trees that break near the base either above or below the ground line usually show extensive evidence of tunneling in the heartwood. Breakage often exposes some tunneling larvae. In the desert resort towns of southern California, especially Palm Springs, this borer has been very destructive to shade and ornamental trees.

Control. Immatures and adults are preyed upon by larvae of the large elaterid—*Chalcolenpidius rubripennis* LeConte (Hovore 1988). Cultural practices that keep the tree vigorous and prevent bark injuries help to minimize infestation and damage.

Desmocerus palliatus (Forester)

[elder borer] (figure 158)

Host. Elder. Wild and ornamental elder, particularly American elder and European elder (Herrick 1923, Linsley and Chemsak 1972).

Range. Throughout the eastern and central United States west to Kansas and north to Ontario (Craighead 1923, Linsley and Chemsak 1972).

Description. ***Adult.*** Elongate, subcylindrical, robust longhorn beetle measuring 18 to 27 mm long (figure 158A) (Linsley and Chemsak 1972, McDaniel 1936, USDA FS 1985). Beetle bright, metallic blue or

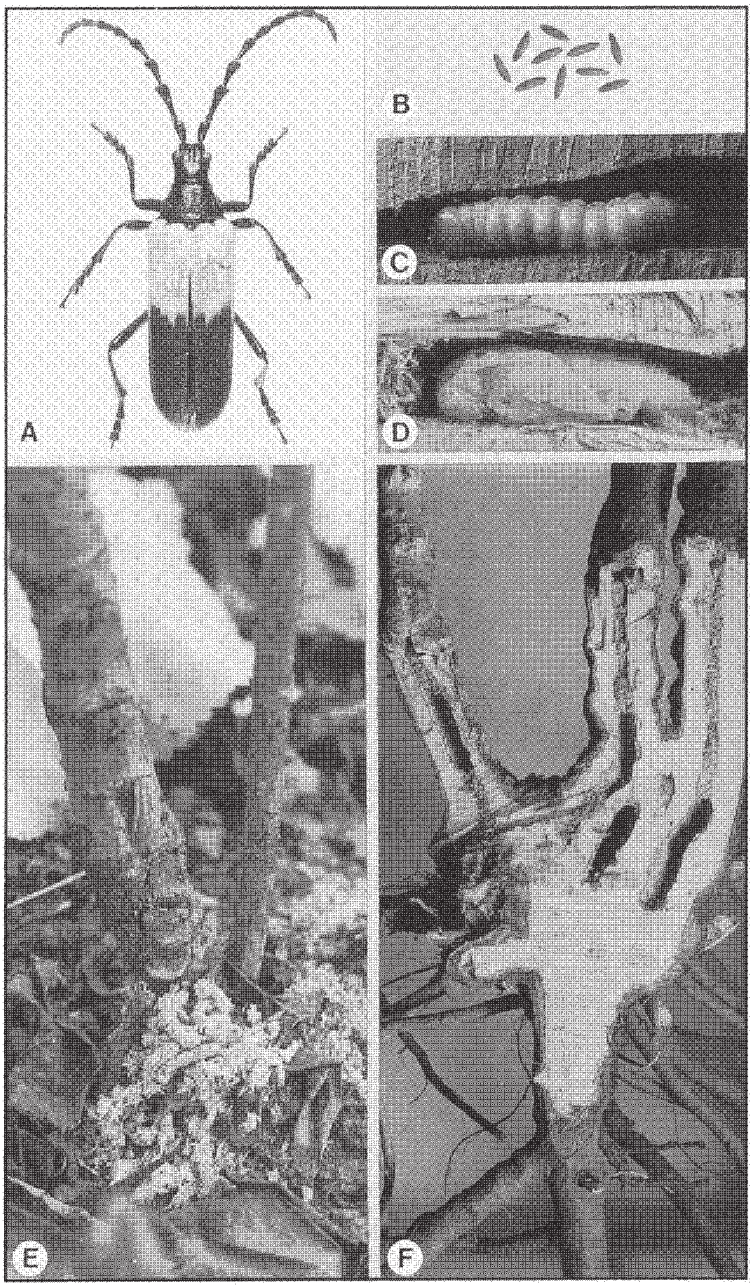

Figure 158—Desmocerus palliatus, *[elder borer]: A, adult; B, eggs; C, larva; D, pupa; E, pile of frass at base of American elder clump; F, galleries in lower stems and roots of elder.*

violet with basal third to half of elytra yellow to yellowish orange except for two small, black spots along basal margin of elytra. Antennae extend to about middle of elytra in females and slightly longer in males. ***Egg.*** Yellowish brown, fusiform in shape, about 3 mm long, and surface longitudinally wrinkled (figure 158B) (Herrick 1923). ***Larva.*** Creamy white and shiny with brown head and black mandibles and about 25 mm long (figure 158C) (Herrick 1923). ***Pupa.*** Yellowish white and 15 to 24 mm long (figure 158D).

Biology. Adults emerge April to June and feed on leaves and flowers through July (Burke 1921, Craighead 1923, Herrick 1923, McDaniel 1936). Females deposit eggs on bark; some reportedly deposit on foliage. Larvae burrow into the pith of stems where they tunnel and feed. Larvae excavate galleries 12 to 20 cm long and 8 to 10 mm in diameter. Galleries are packed with fine frass initially, later with coarse and excelsior-like frass as larvae develop and are enlarged somewhat for the pupal chambers. Mature larvae tunnel in roots below the surface and usually reverse their direction and pupate in the galleries at or just below the soil surface. Pupation occurs in April and May. Life cycle varies from 1 year in the Deep South to 2 or 3 years elsewhere (USDA FS 1985).

Injury and damage. Coarse, fibrous frass is usually extruded in large quantities at the base of infested stems (figure 158E) (Craighead 1923, McDaniel 1936). Exit holes occur at the base of stems up to 15 to 20 cm above the soil line (Herrick 1923). Dieback and mortality may be evident in heavily infested plants. Dissection of infested plants reveals frass-packed tunnels and larvae in lower stems and roots (figure 158F). Injuries may greatly mar the symmetry and beauty of ornamental shrubs (Herrick 1923). Conversely, the insect is considered useful by some who consider its wild hosts to be troublesome plants.

Control. Controls may be needed to protect ornamental shrubs. Fumigants applied in April or insecticides directed at the adult stage on the foliage and stems and applied in May and June can help to minimize losses (Herrick 1923). Nothing is known of natural controls.

Desmocerus californicus Horn

[California elder borer] (figure 159)

Host. Elder. Blue elder is only recorded host (Davis and Comstock 1924, Linsley and Chemsak 1972).

Range. Coastal region and lower Sacramento Valley to the upper San Joaquin Valley in northern and central California (Linsley and Chemsak 1972).

Description. ***Adult.*** Colorful, blue-black and red-orange (fading to yellowish postmortem) longhorn beetle; male 13 to 20 mm long and female 18 to 25 mm long (figure 159A) (Burke 1921, Davis and Comstock 1924, Linsley and Chemsak 1972). Robust; elytra subparallel, tapering apically. Antennae reach middle of elytra in female and slightly longer in male. Two subspecies distinguishable. In *D. californicus californicus* Horn, the elytra of males are mostly blue black with margins reddish orange, whereas in *D. c. dimor-*

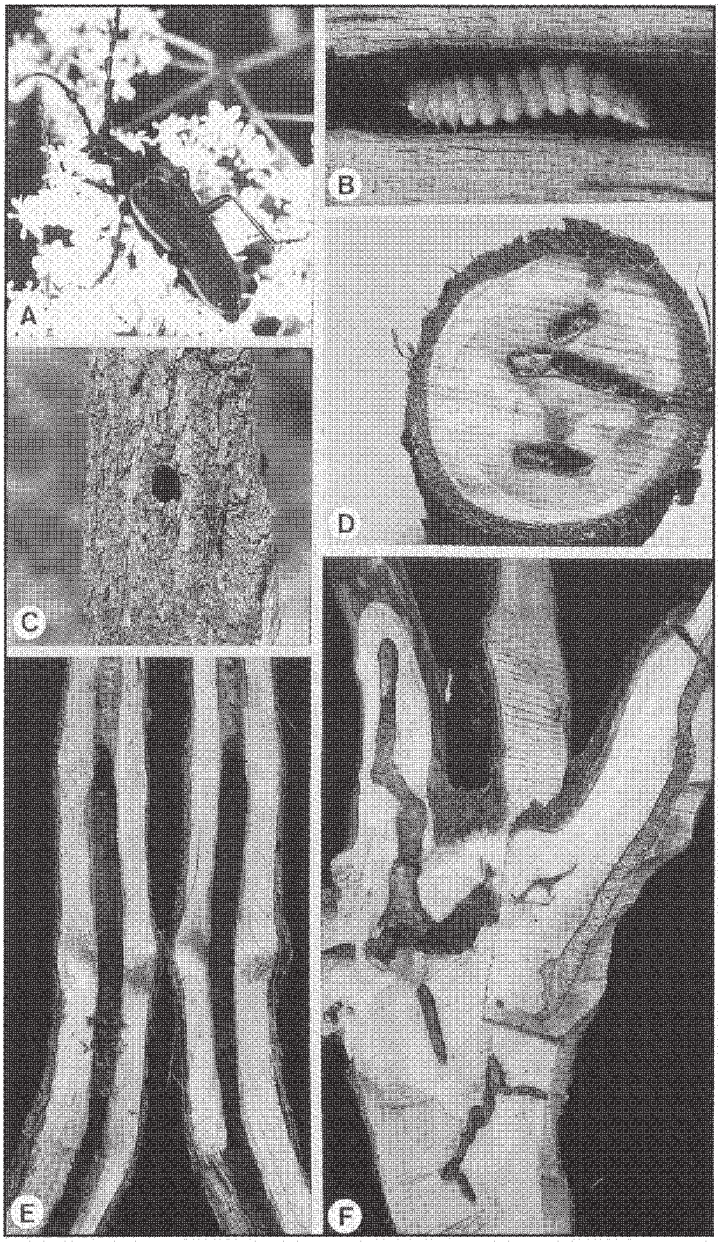

Figure 159—Desmocerus californicus, *[California elder borer]: A, adult; B, larva; C, oval emergence hole; D, cross section of galleries in blue elder; E, longitudinal gallery in pith of small stem; F, frass-packed galleries in lower stems and roots (specimens courtesy F. Hovore and R. Penrose).*

phus Fisher males, the elytral dark pattern is reduced to four, oblong, blue-black spots (Linsley and Chemsak 1972). ***Egg.*** White, becoming brownish white to reddish brown, oblong, pointed at both ends, surface marked with heavy reticulation, and about 3.5 mm long and 1.3 mm in diameter (Burke 1921). ***Larva.*** Elongate, subcylindrical, thoracic segments somewhat flattened, yellowish white with brown head and black mandibles, and about 25 mm long (figure 159B) (Davis and Comstock 1924).

Biology. Adults emerge in March or April and can be found as late as August (Davis and Comstock 1924, Linsley and Chemsak 1972). They feed and rest on foliage and are active during morning hours (Davis 1931). Females deposit eggs in bark crevices, often tucked under the bark at scars or in the wood where small branches have been broken. Newly hatched larvae enter the bark and wander for some distance before entering the wood. Typically, larvae mine into the pith, but in large trunks, they remain in the wood and complete development without reaching the pith. As larvae tunnel, they make lateral mines to the surface at irregular intervals to eject frass. Mature larvae bore to the surface, retreat for several centimeters, and plug galleries with shredded frass to form pupal cells, usually in the pith. Pupation begins as early as January or February and lasts 1 month. A generation requires 2 years.

Injury and damage. Coarse, fibrous, yellowish white frass is extruded from openings in the bark and on the ground near the base of infested plants (Burke 1921). Oval exit holes 6 to 8 mm in diameter (figure 159C) and oval scars on the bark in the lower trunks may be observed. In cross section, the galleries are mostly flattened ovals partly filled with frass (figure 159D). In small stems, the galleries typically occur in the pith and may be 12 to 20 cm long (figure 159E). In large stems and in roots, the burrows are more irregular, shorter, and sometimes largely filled with coarse, fibrous frass (figure 159F). The insect seldom causes mortality, except when it heavily infests plants (Burke 1921). However, blue elder, a commonly used dooryard shade tree in California, is sometimes threatened and may require protection.

Control. Insecticides applied to the foliage and stems, and timed to coincide with early adult emergence, provide protection for ornamental plantings. Natural controls have not been recorded.

Desmocerus auripennis Chevrolat

[golden-winged elder borer] (figure 160)

Host. Elder. Pacific red elder, blackbead elder, and blue elder are attacked (Linsley and Chemsak 1972, Essig 1929).

Range. Through the Sierra Nevada and northern Rocky Mountains east and north from coastal California to Nevada, Montana, and British Columbia (Burke 1921, Essig 1929, Linsley and Chemsak 1972).

Description. Four subspecies have been described on the basis of size, color pattern, pubescence, and distribution, but intermediate populations present a transition from one subspecies to another (Linsley and Chemsak

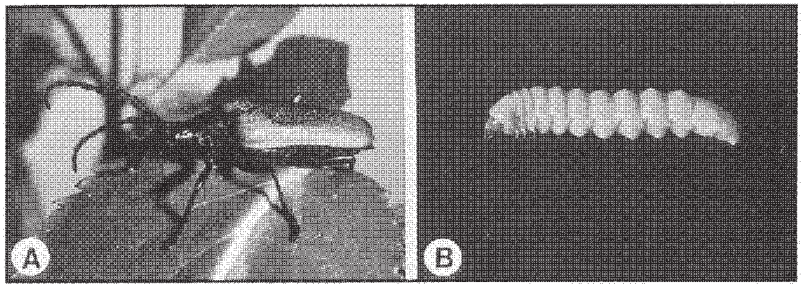

Figure 160—Desmocerus auripennis, *[golden-winged elder borer]: A, adult; B, larva (courtesy F. Hovore).*

1972). They will be treated together here. ***Adult.*** Medium to large, robust longhorn beetle from 11.5 to 30.0 mm long (figure 160A) (Burke 1921, Linsley and Chemsak 1972, Webb 1905). Head, antennae, thorax, and legs dark metallic blue or violaceous. Elytra golden orange or red orange (fading to yellow postmortem), usually concolorous in males, with blue-black median pattern varying widely in size in females. ***Larva.*** Creamy white with brown head and black mandibles and about 25 mm long when mature (figure 160B). Larvae distinguishable from other members of genus only by taxonomists (Craighead 1923).

Biology. Adults emerge in April and May, are most common in June and July, and can be found through August (Burke 1921, Craighead 1923, Linsley and Chemsak 1972). Adults feed on foliage and flowers. Females deposit eggs in crevices on bark of trunks and branches. Young larvae mine through to the pith, where they feed until grown. Several larvae may occupy one stem, but galleries are usually kept separate. Galls up to 25 mm in diameter sometimes form from tunneling at the base of plants. Larvae feed on the abnormal tissue inside the galls. Mature larvae mine to the surface and then retreat into the pith, plugging the burrows with shredded frass to form pupation chambers. Pupation begins in March. A life cycle requires 2 years.

Injury and damage. Large swellings or galls, particularly at the bases of stems, provide evidence of infestation (Burke 1921, Craighead 1923, Linsley and Chemsak 1972). Dissection of galls and stems reveals larval burrows and larvae. Coarse, fibrous frass ejected from bark openings provides additional evidence of infestation. Mortality occurs only when populations are high.

Control. Chemical sprays during the adult stage on leaves and stems can protect ornamentals.

Leptura pacifica (Linsley)

[California scrub oak borer] (figure 161)

Host. Oak. Reared from California scrub oak (Skiles and others 1978). Probably infests other oak species on the same sites.

Range. The arid mountains and yucca flats of southern California, where its hosts are found; however, full geographic distribution has not been determined.

Description. ***Adult.*** Elongate and cylindrical longhorn beetle with body tapering posteriorly; 10 to 14 mm long (figure 161A) (Linsley and Chemsak 1976). Antennae about as long as body with bases partially surrounded by eyes. Adults vary from all black, except for abdomen, to yellow-marked elytra and yellow legs. Typical specimens have yellowish elytra with black transverse band at basal and apical third and two black lateral spots at middle. Apices of elytra diverge slightly along midline, and tips are obliquely truncate. ***Larva.*** Mature larva (figure 161B) yellow orange, about 10 mm long with well-developed thoracic legs (Skiles and others 1978). ***Pupa.*** Yellowish, slender, and about 11 mm long (figure 161C).

Biology. Adults emerge during May and early June and are active daytime flyers (Skiles and others 1978). Little is known

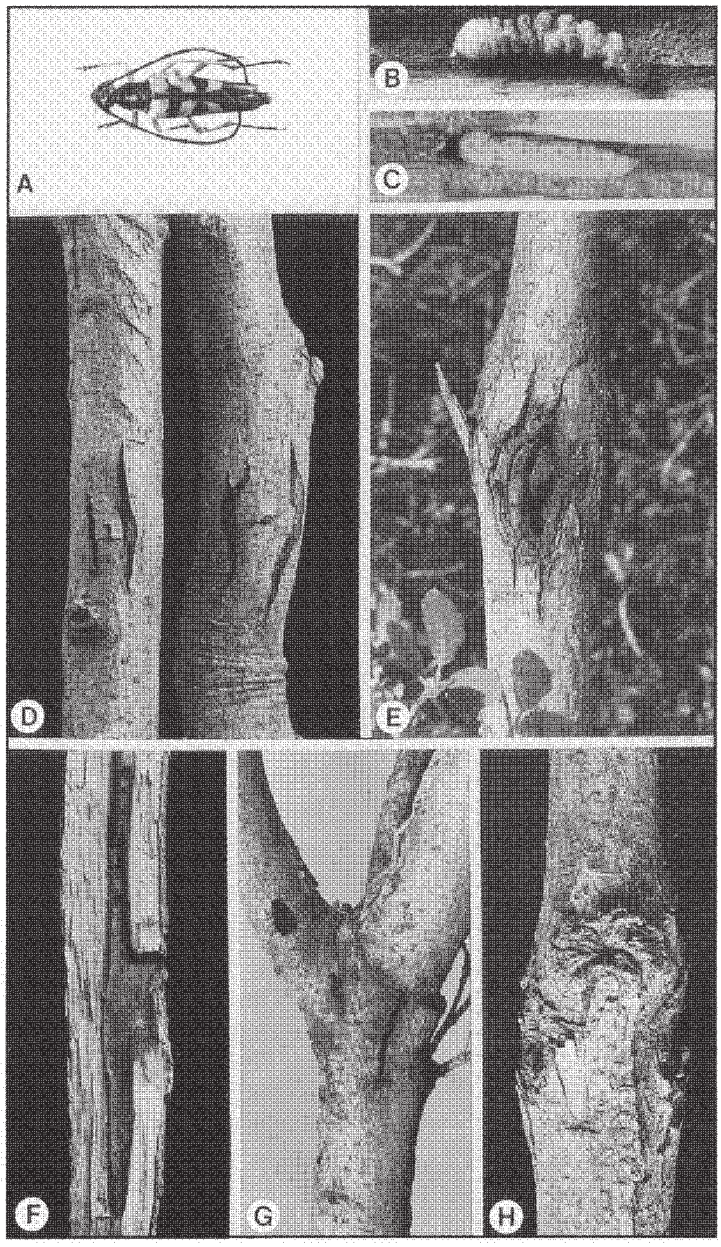

Figure 161—Leptura pacifica, *[California scrub oak borer]: A, adult; B, larva; C, pupa; D, early larval attack sites; E, old larval attack site partially plugged with frass; F, gallery; G, oval emergence holes; H, puckered scar over old attack (specimens courtesy F. Hovore and R. Penrose).*

about adult activity and oviposition. Early in their development, larvae slightly rupture the bark, but the openings seldom show much sign of having been used to expel frass. The oval larval galleries run in the heartwood parallel to the grain and are usually 15 to 20 cm long at pupation. Larvae burrow repeatedly up and down the branch, enlarging the galleries and partially filling them with a compact mixture of excrement and excelsior-like frass. As the larvae enlarge their galleries, they generally construct one or more additional openings through the bark. One or more of these openings are about 4 by 6 mm and plugged with a tight wad of excelsior-like frass. Larvae pupate just below the larger openings, and the new adults ultimately chew oval holes, often through the frass plug, to emerge. The life cycle is about 3 years, as larvae of two distinct sizes are found during and immediately after the adults fly. *Leptura pacifica* is frequently found in close association with another cerambycid borer—*Purpuricenus dimidiatus* LeConte—whose habits are remarkably similar. Larvae of *L. pacifica*, however, do not girdle branches, but their tunneling may kill small branches. Galleries of the two species may merge and completely overlap, particularly in dying branches. Often *L. pacifica* appears to rework the galleries and frass of *P. dimidiatus* (Skiles and others 1978).

Injury and damage. Chlorotic foliage and dead or dying branches indicate infestation (Skiles and others 1978). Small elongate openings in the bark evidence early larval attack (figure 161D). These openings are gradually enlarged, and infested stems may become slightly swollen (figure 161E). Such openings may or may not be plugged with excelsior-like frass. Splitting infested stems reveals galleries extending usually to the pith and then longitudinally in both directions from the entrance (figure 161F). The walls of the galleries and adjacent wood are usually stained by fungi. Adults leave oval exit holes in the branches (figure 161G). Entrance and exit holes heal to form oval irregular puckered scars on the bark (figure 161H). California scrub oak is most often a shrub 1 to 3 m high with several stems rising directly from the root crown. Infestations occur in the healthy living branches 1 to 3 cm in diameter and in dying and recently dead branches up to 5 cm in diameter. Occasionally, larvae burrow downward in the wood below the ground surface and into the root crown. In dead or dying branches, infestation occurs most often at bases, adjacent to the living wood. Because its hosts are not commercially valuable species, this borer is of little economic importance. However, the hosts serve as important cover in arid areas and as browse for sheep, goats, deer, and other wildlife, so that the borer could cause environmental harm.

Control. Natural control agents have not been reported, and artificial control measures have not been needed.

Strophiona nitens (Forster)

[chestnut bark borer]

Hosts. Chestnut, oak, hickory, walnut, beech, maple. Favors chestnut followed by

oak; attacks other species less frequently (Linsley and Chemsak 1976).

Range. Massachusetts south to Florida and west to Colorado and in parts of southern Canada (Linsley and Chemsak 1976).

Description. ***Adult.*** Robust, moderately elongate longhorn beetle 10 to 15 mm long (Linsley and Chemsak 1976). Light brown antennae extend to about middle of elytra (Knull 1946). Velvety black body with golden yellow bands on margins of thorax; four transverse yellow bands on each elytron; the elytral bands widen toward midline (Craighead 1950). Underside of thorax densely clothed with recumbent golden hairs (Linsley and Chemsak 1976). Elytra about twice as long as wide, tapered posteriorly, tips obliquely truncate, each bearing short spine at outer angle (Linsley and Chemsak 1976). ***Larva.*** Head and general body form flattened (Craighead 1923). Head sparsely clothed with short, stiff hairs; body hairs coarse and chestnut colored. Legs very slender with long end-segment. ***Pupa.*** Similar in form to adult, forked spine on last abdominal segment, and covered with very stiff, short, reddish brown hairs that taper sharply at tips.

Biology. Adults emerge from May to July and feed on flowers. Females deposit eggs in bark crevices at moist areas. Larvae bore into the bark, forming large, irregular galleries that they pack with coarse, fibrous frass. Larvae feed mostly on the bast fibers in living bark and destroy patches of cambium. Some frass is ejected from the bark opening. Pupation occurs during May and June in the bark mine in an oval cell lined with fibrous frass. Life cycle is 2 to 3 years (Craighead 1950).

Injury and damage. Only external evidence of infestation is one or more holes in the thick, moist bark in limb crotches or near the tree base. Coarse, fibrous frass may be expelled through holes in the bark (Craighead 1950). Larval galleries occur largely in the outer bark and occasionally extend to the cambium and surface of the sapwood. Burrows are usually large, irregular, almost cavelike. Galleries are packed with coarse, fibrous frass and sometimes meander or radiate in several directions, particularly when more than one larva is feeding. Infested trees rarely die from insect feeding. This pest reportedly helped bring about the rapid destruction of American chestnut because of its habit of feeding in living bark, thus creating infection courts for spores of the chestnut blight fungus, *Cryphonectria parasitica* (Murrill) Barr. In the southern Appalachians, *S. nitens* populations increase enormously by exploiting bark cankers of blighted chestnut sprouts.

Control. The ichneumon wasp—*Xorides rileyi* (Ashmead)—is the only reported parasite (Linsley and Chemsak 1976). Keeping the bark healthy and free of disease, cankers, and other wounds helps prevent infestation.

Styloxus fulleri (Horn)

[roundhead oak twig girdler] (figure 162)

Host. Oak. Coast live oak is primary host but also found in interior live oak (Brown and Eads 1965a, Linsley 1962b). Probably

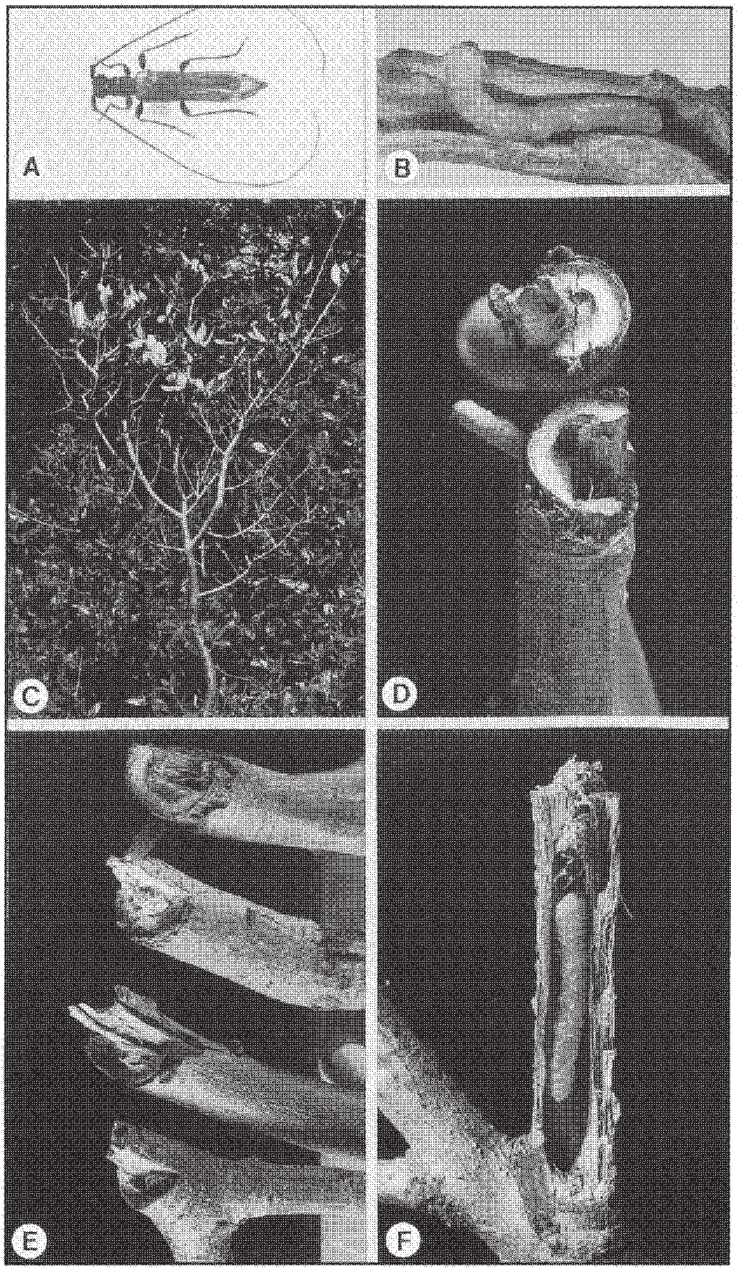

Figure 162—Styloxus fulleri, *[roundheaded oak twig girdler]: A, adult; B, larva; C, girdled branch dying; D, branch broken at girdled site; E, oblique girdles half way around stems; F, larva in gallery with severed end plugged with frass (specimens courtesy F. Hovore).*

occurs in other oaks to a lesser extent.

Range. Two subspecies have been described: *S. fulleri fulleri* (Horn) in south central Texas and *S. fulleri californicus* (Fall) from southern California to southern Oregon (Linsley 1962b).

Description. ***Adult.*** Very slender, brown to olive brown longhorn beetle with front of head reddish brown, measuring 10 to 18 mm long (figure 162A) (Brown and Eads 1965a, Linsley 1962b). Body surface coarsely punctured and sparsely pubescent. Unlike those of most other cerambycids, this beetle's elytra do not cover entire abdomen. In males of *S. f. fulleri*, elytra cover only first three abdominal segments, whereas in *S. f. californicus* elytra cover first four abdominal segments. Female antennae about one and a fourth the body length; male antennae about twice as long as body. ***Larva.*** Taper to posterior end with prothorax somewhat enlarged and head sunken deeply within prothorax (figure 162B). Larvae legless and glistening, deep yellow (Brown and Eads 1965a).

Biology. Females deposit eggs on small twigs in the crown. Eggs hatch in about 2 weeks (Linsley 1962b). Larvae tunnel down the twig, ejecting little or no frass, but packing it tightly behind in the galleries (Brown and Eads 1965a). Larvae overwinter and pupate within the galleries during late spring or early summer. Pupal period requires 10 to 14 days. Adults fly from April to September in California with most activity in June and July. In Texas, adult activity has been recorded from July to October (Hovore and others 1987). This species requires 2 years to complete development (Furniss and Carolin 1977, Linsley 1962b).

Injury and damage. First signs of infestation are patches of dead leaves in the crown (figure 162C). Damage is often confused with that of *Agrilus angelicus*, which makes spiral girdles around twigs. Stems severed by *S. fulleri* have oblique girdles or tracks halfway or slightly further around the stem (figure 162D and E). Tunnels are large, broadly oval, and partly filled with frass. Tunnel openings at severed ends are always tightly plugged with excelsior-like fibers (figure 162F). The insect hollows out and girdles twigs and branches 6 mm to 12.7 mm long mostly in the crowns of large trees (Brown and Eads 1965a, Linsley 1962b). Serious pruning may occur, causing patches of dead leaves scattered over the crown, ruining the beauty of ornamental trees. In southern California, this girdler is responsible for up to 30% of the patches of dead leaves previously attributed to *A. angelicus* (Brown and Eads 1965a).

Control. This girdler attacks trees already infested by *A. angelicus*. Chemical controls directed at *A. angelicus* also appear to control *S. fulleri*. Little is known of natural and cultural controls.

Tylonotus bimaculatus Haldeman

[ash and privet borer] (figure 163)

Hosts. Ash, privet, elm, hickory, black walnut, butternut, yellow-poplar, birch. Green, black, and velvet ash, and privet preferred (Craighead 1950; Linsley 1961, 1962b; Lugger 1899; Riley 1880).

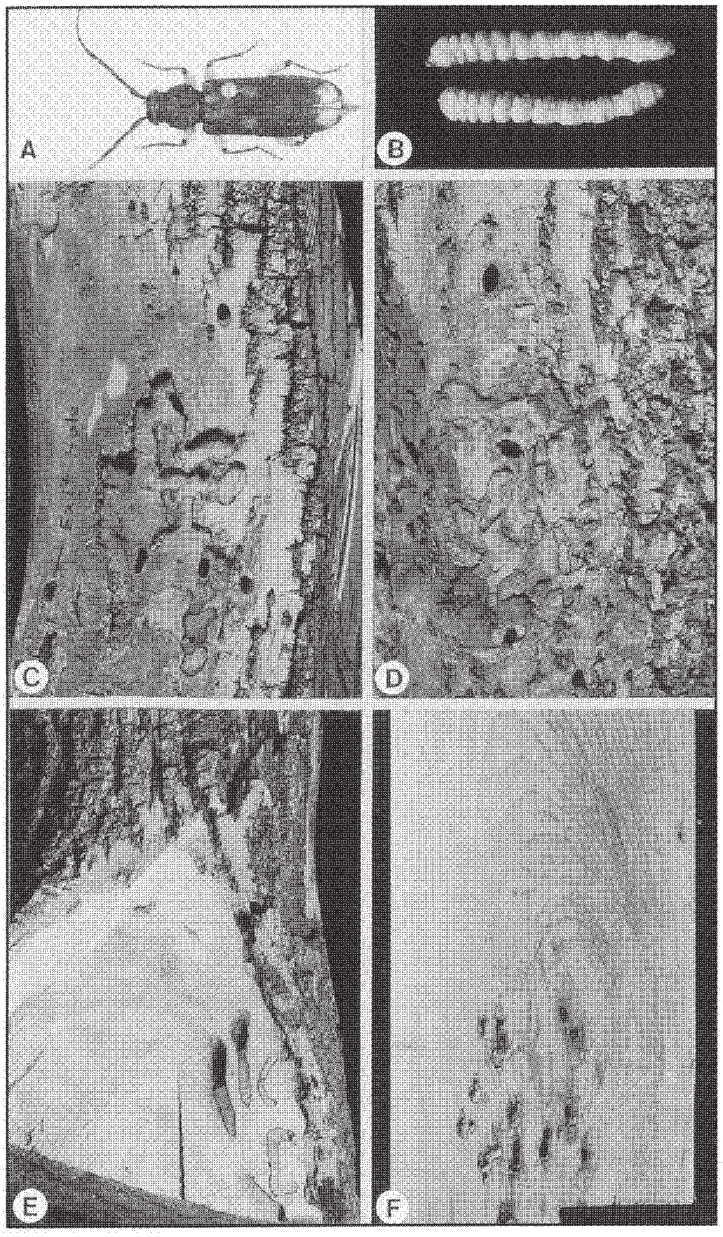

Figure 163—Tylonotus bimaculatus, *[ash and privet borer]: A, adult; B, larvae; C, meandering surface mines packed with frass; D, oval exit holes; E, basal attack with galleries extending into wood; F, ash lumber with cluster of holes (C-F, specimens courtesy J. Simeone).*

Range. New York south to Florida and west to North Dakota and Arizona and in eastern Canada (Linsley 1962b, Stein and Tagestad 1976).

Description. ***Adult.*** Elongate, robust, and somewhat flattened longhorn beetle (figure 163A) (Craighead 1950, Knull 1946, Linsley 1962b). Dark brown, typically with median and apical light spots on each elytron. Legs pale with yellowish femora. Antennae in males stout, extending slightly beyond tips of elytra; those in females slender and reaching only apical third of elytra. Beetles 9.5 to 18.0 mm long. ***Larva.*** Elongate, slender, subcylindrical, with integument firm and shiny, and sparsely covered with short, fine, light yellow hairs (figure 163B) (Craighead 1923). Head wider than long; mouthparts greenish brown with black mandibles. Thoracic legs very short. Dorsal ampullae projecting, oval, and shiny. ***Pupa.*** Few short, stiff hairs on pronotum and two groups of small conical points on upper surface of each abdominal segment.

Biology. Adults emerge in May and are present into early August (Hovore and others 1987, Kirk and Knull 1926, Linsley 1962b). Females deposit eggs beneath scales of bark on living or dying ash trees or at the bases of privet plants. Larvae enter the bark and initially feed principally in the phloem tissue. Larvae bore deeper into the cambium and finally into the sapwood. In privet, they mine beneath the bark and in the wood. Larvae make extensive mines that meander in different directions. Little or no frass is ejected, but the larvae pack it behind within the galleries as they extend the mines. Pupal cells are constructed in or beneath the bark and sometimes near the surface in the sapwood. Two years are required to complete a generation.

Injury and damage. Sap oozing from the bark marks the point of attack (Craighead 1950). Removing bark reveals broad, meandering mines packed with granular frass (figure 163C). Oval, exit holes 4 to 6 mm in diameter are left in the bark (figure 163D). In ash, it usually attacks and kills large branches first; later, the infestation proceeds downward, often on one side of the trunk (figure 163E). Ash sawn for lumber may have clusters of larval holes (figure 163F). In privet, attacks are nearly always around the base of the plant. Old and drought-injured trees are attacked and gradually die branch by branch, especially in parks and windbreaks. A single larva can kill a small tree. Infestations are often associated with other borers, especially cossids and sesiids. Although the pest sometimes attacks healthy trees, it favors trees that have been stressed, weakened, or injured. This pest is economically important in dry areas such as the Great Plains, where it has been particularly troublesome in windbreaks (Tunnock and Tagestad 1973, Wygant 1938). Privet hedges frequently suffer severely when these insects are abundant.

Control. This borer is most apt to attack trees that are stressed or weakened, so cultural practices should be followed that promote tree vigor. Nothing is known of its natural enemies.

Aneflus prolixus insoletus Chemsak and Linsley

[guajillo borer]

Host. Guajillo. Guajillo is only known host (Rice and others 1985).

Range. Southwestern subspecies reported from San Patricio and Starr Counties in southern Texas and from the northern and east central states of Mexico—Tamaulipas, Coahuila, Durango, and Chihuahua (Rice and others 1985, Turnbow and Wappes 1978).

Description. ***Adult.*** Moderately robust, reddish brown to brown longhorn beetle, covered with whitish pubescence except for rows of small denuded areas on elytra (Linsley 1963, Turnbow and Wappes 1978). Antennae about as long as body, segments 3 through 7 spinose at apex. Beetles 20 to 27 mm long. Distinguished from the related subspecies, *A. p. fisheri* (Knull), by denser, finer pubescence, longer antennae, and smaller antennal spines (Turnbow and Wappes 1978).

Biology. Adults fly from May to September (Hovore and others 1987, Rice and others 1985, Turnbow and Wappes 1978). Larvae extend their galleries down the stem into roots. Before pupation, larvae excavate preemergence holes through the sapwood to the bark. Pupation occurs between two wads of coarse, fibrous frass. New adults chew exit holes through the bark. The life cycle is unknown.

Injury and damage. This borer attacks basal stems and roots of host plants (Rice and others 1985). Infestation is evidenced by piles of frass expelled around the bases of the plants. Dissection reveals linear tunnels through the heartwood.

Control. Nothing is known of natural or other controls.

Aneflus protensus (LeConte)

[mesquite borer]

Hosts. Mesquite. Attacks only mesquite (USDA FS 1985).

Range. A southwestern species reported from Texas, New Mexico, Arizona, and in Baja California and northern Sonora, Mexico (Linsley 1963).

Description. ***Adult.*** Elongate, subcylindrical, light to dark brown longhorn beetle clothed with whitish gray pubescence; 20 to 31 mm long (Linsley 1936, 1963). Antennae about as long as body in females and slightly longer than body in males. Antennal segments 3 through 5 have prominent apical spines. ***Larva.*** Elongate, cylindrical, tough, with shiny integument and clothed with stiff reddish hairs (Craighead 1923).

Biology. Adults emerge and are present from June to September (Linsley 1963). Beetles are often attracted to light (Linsley 1936). Females deposit eggs in bark crevices, usually at branch crotches, particularly those of small branches (USDA FS 1985). Larvae bore into the stems, making large mines and completely hollowing small branches. As the larvae feed and grow, they extrude frass through tiny openings in the bark, and dark sap oozes and drips from the many entrances. The interior walls of the larval mines are always stained black. The life cycle is completed in 2 years.

Injury and damage. Weak, deteriorating, dying, and dead branches and trees provide evidence of infestation (USDA FS 1985). Small openings in the bark with frass can usually be found. Dark, watery liquid often drips from the attack sites and stains the foliage and ground beneath. Dissection of infested branches reveals tunnels and larvae. Branches and small trees are sometimes killed by larval tunneling (USDA FS 1985). This borer might be considered (along with the mesquite girdler) a biocontrol of mesquite where landowners wish to slow the spread of the trees.

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

Psyrassa unicolor (Randall)

[branch pruner] (figure 164)

Hosts. Pecan, hickory, oak. Prefers pecan in the lower Mississippi River Valley but readily attacks hickories and, to a lesser extent, oaks (Solomon 1985b). Collected occasionally from walnut, chinkapin, beech, redbud, mulberry, plum, and grape (Blatchley 1910, Champlain and others 1925, Knull 1946, Linsley 1963, Loding 1945).

Range. Primarily an eastern species, distributed from New York south to Alabama and west to Texas, Kansas, and Minnesota (Linsley 1963).

Description. ***Adult.*** Very narrow and elongate, light brown to reddish brown coarsely punctured longhorn beetle, with short and inconspicuous pubescence (figure 164A) (Knull 1946, Linsley 1963). Antennae about as long as body in females and slightly longer in males. Females 9 to 15 mm long and average 2.2 mm wide; males slightly smaller. ***Larva.*** Slender, elongate, cylindrical, whitish, with dark brown mandibles, yellowish thoracic shield, very short rudimentary thoracic prolegs, measuring about 12 to 18 mm long at maturity (figure 164B) (Craighead 1923).

Biology. In Mississippi, adults emerge from late April to early June (Solomon 1985b), markedly earlier than the June to July flight in Indiana (Blatchley 1910) and June 10 to August 15 in Michigan (Gosling 1973). Although oviposition has not been observed, it is apparent from the points of gallery origin that eggs are deposited singly near the apex of small twigs 2 to 4 mm in diameter. Newly hatched larvae tunnel under the bark toward the twig base, often intersecting one or more larger twigs or branches. Larvae often penetrate to the center of the twig before reaching a larger branch that they eventually sever. Twig galleries are 12 to 36 cm long, meandering from one side of the twig to the other, and filled with granular frass. Larvae next bore into larger branches and begin girdling, which is completed during late winter and spring. The larvae make very smooth, concentric, circular cuts, often completely severing the wood but leaving the bark intact (figure 164C). Larvae in severed branches bore distally 4 to 18 cm, usually just below the wood surface (figure 164D). They plug the open ends of the galleries with fibrous frass. Severed branches fall in Mississippi from late January to mid-May (figure 164E). Pupation occurs within the

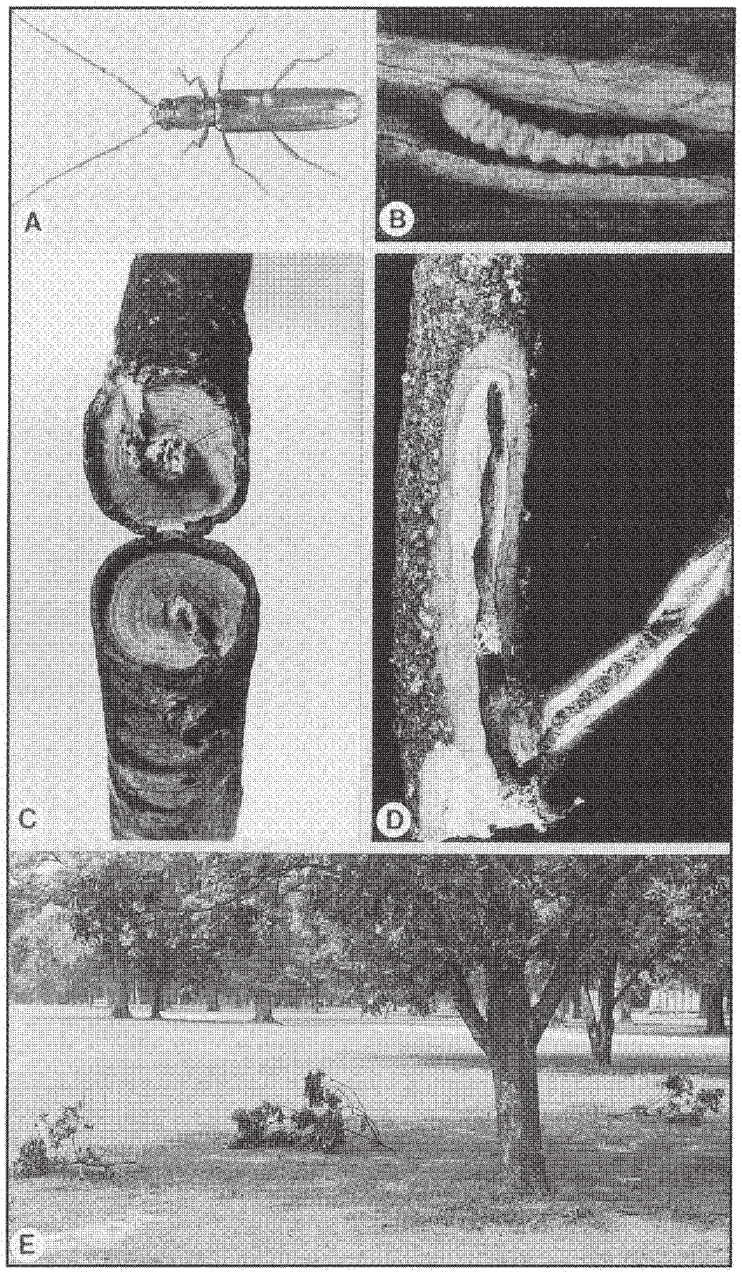

Figure 164—Psyrassa unicolor, *[branch pruner]: A, adult; B, larva; C, pruning cut is smooth, flat, and circular; D, frass-packed gallery in side twig and open gallery and pupation chamber in large branch; E, pruned branches under pecan tree.*

galleries. New adults cut irregularly shaped holes through the bark to emerge. The life cycle requires 1 year, possibly longer.

Injury and damage. Branches pruned by this species are distinguished by the kind of girdle, time of year, and size of pruned branches. The smooth, circular pruning cut made by the larvae of *P. unicolor* (figure 164C) is similar to those of several twig pruners—*Anelaphus villosus* Fabricius and *A. parallelus* (Newman)—except that the larval gallery of the *P. unicolor* rarely ends at the center of the pruned branch. The end usually occurs just below the bark near a small side twig. The internal pruning cut of *P. unicolor* is considerably different from the external V-shaped girdling cut made by the adult twig girdler—*Oncideres cingulata*. Branches pruned by *P. unicolor* fall to the ground during late winter and spring, as opposed to the summer, fall, and early winter for those pruned by *A. villosus, A. parallelus*, and *O. cingulata*. Branches pruned by *P. unicolor* are much larger (10 to 50 mm in diameter and 0.6 to 3.6 m long) than those girdled by *O. cingulata* (6 to 12 mm in diameter and 0.3 to 0.6 m long) and are generally larger than those pruned by *A. villosus* and *A. parallelus* (8 to 20 mm in diameter and 0.2 to 0.9 m long). Because of their size and weight, branches pruned by *P. unicolor* almost always fall free to the ground (figure 164E), seldom lodging in the canopy or hanging from the tree at the severed end, as happens to branches severed by other pruners and girdlers. Individual pruned branches are generally much larger than those girdled by other twig girdlers or twig pruners, but the number of pruned branches is usually fewer. Individual trees, particularly shade and ornamentals, and occasionally orchard trees, may be seriously pruned, but entire stands or groves seldom sustain economic damage.

Control. Severed branches on the ground (figure 164E) should be picked up in spring and destroyed before the adults emerge. To be most effective, the pick-up-and-destroy practice should encompass an entire orchard or neighborhood. Direct control in natural forest stands or woodlots is rarely needed. Two hymenopterous parasites—*Agonocryptus discoidaloides* (Viereck) and *Labena grallator* (Say)—help to reduce infestations (Linsley 1963). Predation, presumably by squirrels and woodpeckers (based on characteristics of their excavations), is less than 2% (Solomon 1985b).

Aneflomorpha subpubescens (LeConte)

[oak stem borer] (figure 165)

Hosts. Oak, chestnut. White oak preferred but black, southern red, blackjack, post, willow, and water oaks have also been listed as hosts (Beal and others 1952).

Range. Eastern United States from Pennsylvania south to Florida and west to Oklahoma (Linsley 1963). Collected most often in the Appalachian Mountains from Georgia northward.

Description. ***Adult.*** Very narrow, extremely elongate longhorn beetle, 15 to 18 mm long and only about 3 mm wide (figure 165A) (Knull 1946, Linsley 1963).

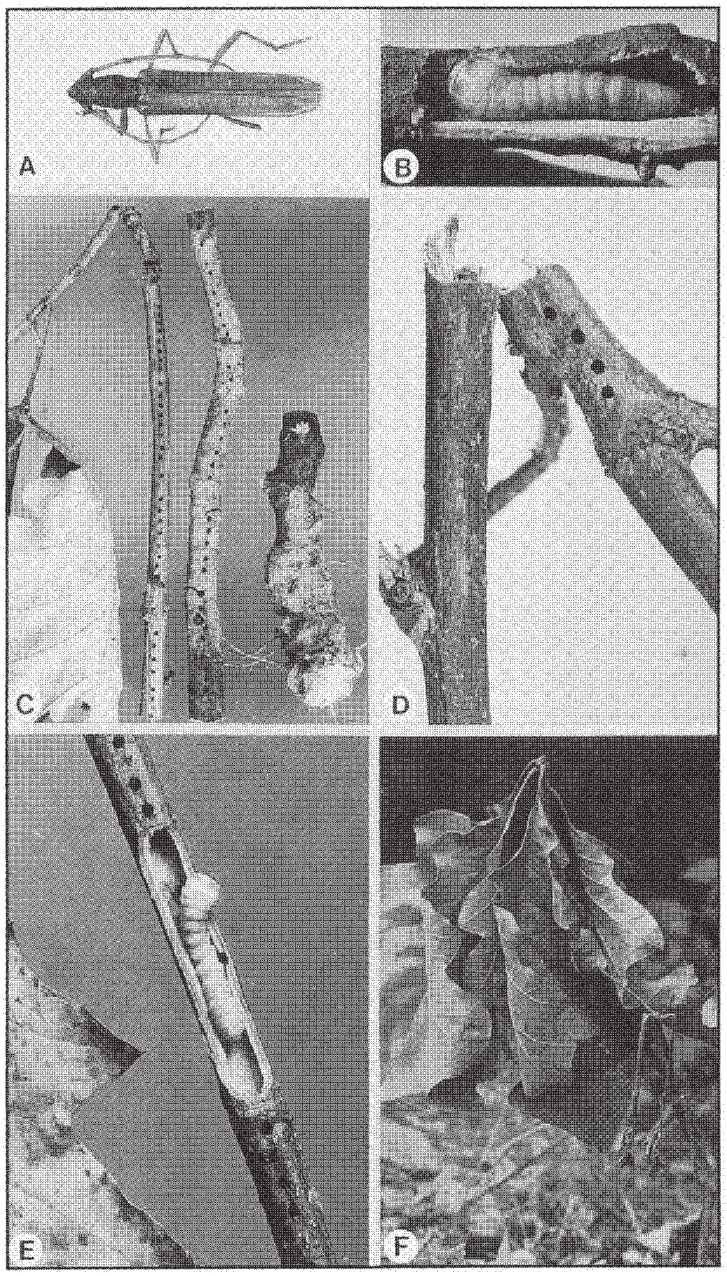

Figure 165—Aneflomorpha subpubescens, *[oak stem borer]: A, adult; B, larva; C, closely spaced, linear series of holes in oak sprout; D, oak seedling girdled and broken; E, hollowed-out stem; F, dying infested sprout with brown leaves.*

Beetles generally light brown to reddish brown with semierect brown pubescence. Tips of elytra notched and bispinose. Antennae slightly shorter than body in females, slightly longer than body in males, and equipped with single short spines on third and fourth segments. ***Larva.*** Very slender and cylindrical, with body thickly covered with fine, white setae that become golden on thorax (figure 165B). Grown larvae yellowish except for light brown mandibles and tergal plates; up to 18 mm long. ***Pupa.*** Head and thorax glabrous; posterior half of abdomen has prominent spines.

Biology. Adults emerge late May through July and deposit eggs at leaf bases, mostly on small twigs near the tops of seedlings and sprouts (Knull 1946, Linsley 1963, USDA FS 1985). Newly hatched larvae burrow into the twig and tunnel within the branch toward the main stem. Larvae make tiny round holes in a straight line to eject frass. As the larvae grow, they consume and hollow out the woody part of the stem, often cutting the stem off or causing it to break off in sections. During late summer and fall, larvae typically make their way to the base of the plant and enter the root collar and upper roots to overwinter. They usually cut off the main stem just above groundline and plug the open gallery tightly with fibrous frass. During spring, they prepare pupal chambers between two wads of frass within the gallery and pupate (Champlain and others 1925). New adults chew through the upper wad of frass to emerge. There is one generation per year (Beal and others 1952, Craighead 1923).

Injury and damage. Attacks usually begin in a small branch near the top of the plant but sometimes in a small twig on a side branch. Seedlings and sprouts 20 to 70 cm tall and 6 to 25 mm in diameter at the root collar seem most susceptible. Larvae tunnel in the twig down to the main stem or trunk and then to the root collar or below. Examination reveals a single straight row of small round holes 3 to 6 mm apart along the branch or twig and down the main stem to the groundline (figure 165C). Frass is extruded through these holes and can be found in small piles at or near the base of the plant. Larvae hollow the stem, sometimes cutting or girdling portions so that sections break (figure 165D). A stem may be completely hollowed, leaving only a shell (figure 165E). Browning foliage and dying terminals, branches, or entirely dead seedlings are quite noticeable during the growing season (figure 165F). Dying leaves remain attached to the plant as flags of continuing infestation. Occasionally, this borer becomes abundant and kills a high proportion of the oak regeneration in parts of the Southeast (USDA FS 1985).

Control. Little is known of natural enemies. Some evidence of woodpecker predation has been observed. No direct controls have been investigated.

Aneflomorpha lineare (LeConte)

[antelope brush girdler]

Hosts. Antelope brush, oak. Antelope brush favored, but coast live oak, Arizona white oak, and Emory oak, are readily attacked (Linsley 1963, Tyson 1970).

Range. Western species occurring in foothills in Arizona, California, and Oregon (Furniss and Carolin 1977, Linsley 1963).

Description. ***Adult.*** Elongate, subcylindrical, and slender longhorn beetle measuring 10 to 17 mm long (Linsley 1963). Body brownish yellow and sparsely clothed with whitish hairs that lie close against body and appendages (Furniss and Carolin 1977). Antennae extend one antennal segment beyond end of elytra in males, considerably shorter in females. Antennal segments 3 through 5 have distinct but diminishingly smaller spines at apices. Elytra about four times as long as wide with parallel sides and end in shallow-notched tips that do not bear spines.

Biology. Adults are active from July to September (Linsley 1963). Larvae burrow down the centers of small twigs and branches, making spiral galleries to the bark surface at frequent intervals and ejecting frass through holes. When they reach stems 19 to 38 mm in diameter, they make one incision, a spiral cut from the pith outwards. Larvae construct pupal chambers just beneath the thin bark (Linsley 1963, Tyson 1970). The life cycle is completed in 1 year.

Injury and damage. Flagged twigs and small branches scattered over the crowns of hosts are evidence of infestation. Examination of flagged twigs reveals that they are hollow and girdled from within at several places along their length. Numerous small holes occur along the tunneled portions of the stems for frass ejection (Linsley 1963, Tyson 1970). Larvae burrow in stems 8 to 38 mm in diameter. Most of the antelope brush at Ebony Flats in the Death Valley National Monument, California, is in very poor condition because of severe branch girdling by this borer (Tyson 1970).

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

Enaphalodes rufulus (Haldeman)

red oak borer (figures 166 and 167)

Hosts. Oak. Red and white oak groups are attacked (Donley and Acciavatti 1980). Upland hosts include northern red, black, and scarlet oaks, with particular preference for black oak (Hay 1974a); in bottomland forests Nuttall, water, and overcup oaks are preferred.

Range. Throughout the eastern half of the United States and westward to Oklahoma, Texas, and in southeastern Canada (Donley and Acciavatti 1980).

Description. ***Adult.*** Robust longhorn beetle from 23 to 33 mm long (figure 166A). Newly emerged beetles covered with short tan to very light brown pubescence that is partially lost with activity, giving a light brown appearance. Antennae about as long as body in females and about twice body length in males, reaching maximum length of about 62 mm. ***Egg.*** White, parchment-like, elongate, and about 2 to 3 mm long. ***Larva.*** Robust and shiny white except for stout, dark mandibles and amber spiracles (figure 166C). Thorax has tiny four-jointed legs.

Biology. Adults emerge during June and July, varying about 2 weeks from South to

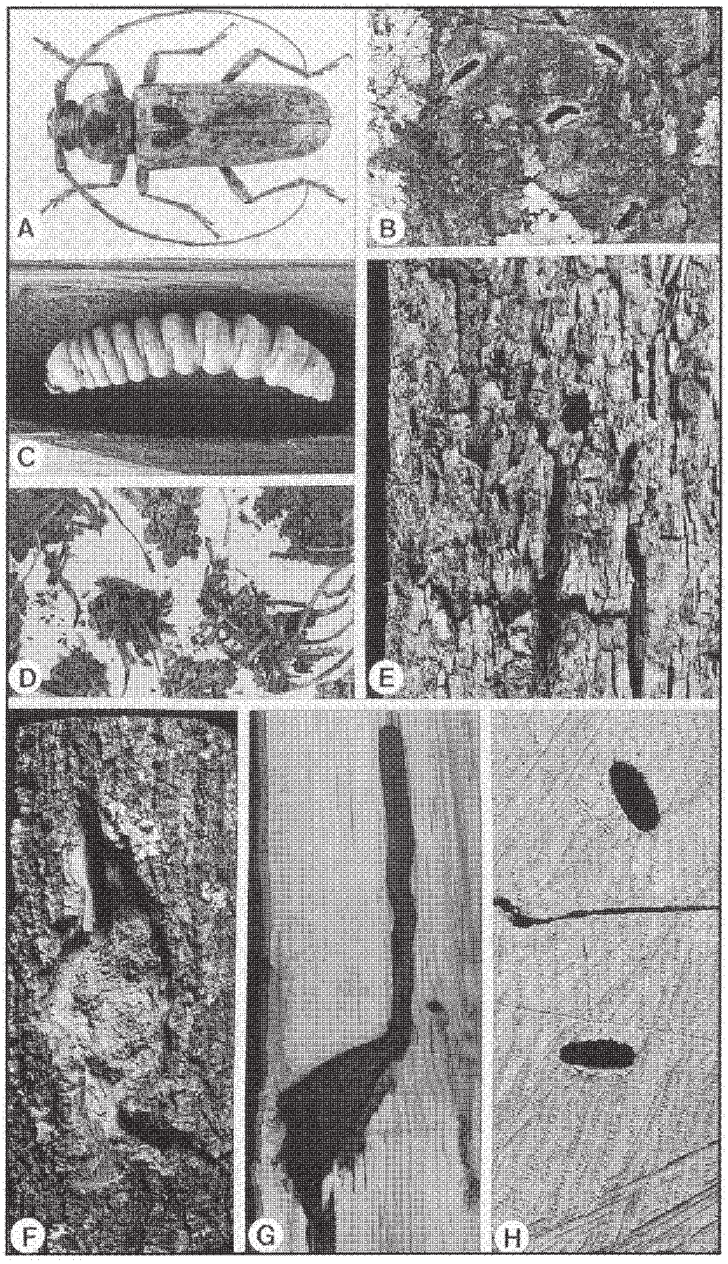

Figure 166—Enaphalodes rufulus, *red oak borer: A, adult; B, tiny, flat holes of early attack; C, larva; D, granular frass mixed with wood fibers; E, oval exit hole; F, frass-packed cavity beneath bark; G, gallery in red oak; H, cross section of oval galleries.*

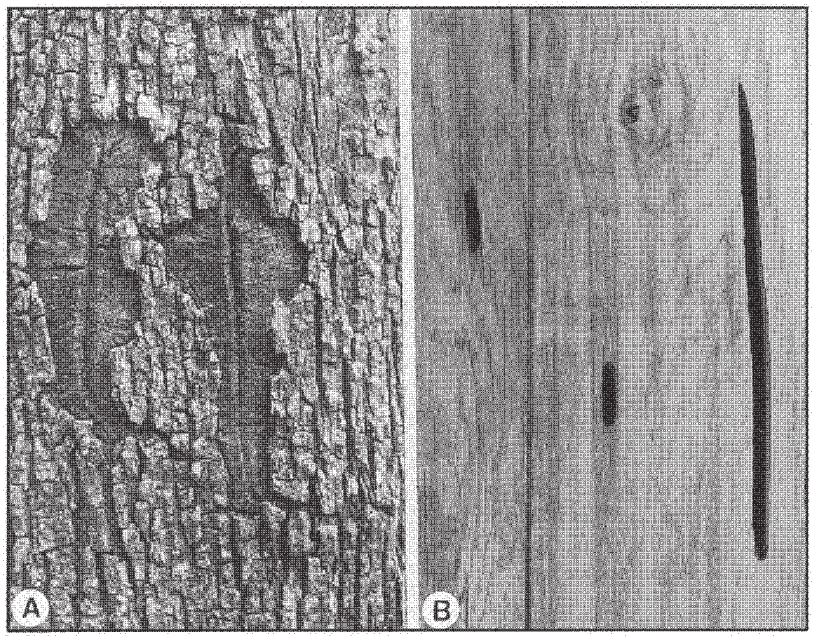

Figure 167—Enaphalodes rufulus, *red oak borer: A, two L-shaped bark scars; B, large hole defects in oak lumber.*

North, and may be present until mid-August (Donley and Acciavatti 1980). They emerge almost entirely at night, and most activity is nocturnal (Hay 1972). Adults generally do not feed on twigs and foliage as do some cerambycids; however, they drink water and sap ooze. Females mate once or more and deposit an average of 200 eggs singly or in groups of 2 to 4 in bark crevices, under bark scales, under lichen patches, and under tightly attached vines (Donley 1978b). Eggs hatch after incubating 10 to 13 days. Hatching larvae chew through the egg chorions and bore directly into the phloem. By the end of the first growing season, larvae make small oblong holes in the bark for frass ejection (figure 166B) and are well established in 12-mm cavelike burrows in the inner bark or phloem. During spring and summer, larvae burrow upward or laterally in the phloem, then upward. During early summer, larvae begin etching the wood, and by midsummer begin to enter the sapwood, pushing out large amounts of frass. The following spring, larvae extend their tunnels slightly and eject small amounts of frass of almost entirely excelsior-like wood fibers. Then, mature larvae (figure 166C) prepare pupal chambers at the uppermost parts of their galleries by packing them tightly with plugs of fibrous frass. Pupation occurs in May and June and lasts about 3 weeks. New adults emerge by chewing through the frass plug and bark near the upper portions of the phloem burrows. A generation is completed in 2 years. In the central United States, the cycle is synchronized so that adult beetles emerge almost entirely during odd-numbered years. In the southern United States, beetles emerge every year, but more emerge during odd-numbered years.

Injury and damage. During the first fall and winter, attacks are difficult to detect because only tiny pin holes with fine light frass are present (Donley and Acciavatti 1980). During the following spring and summer, dark stain spots make the sign of attack more prominent. Also, one or more oblong 3- by 1-mm holes (figure 166B), fine frass, or frass tubes and sap-ooze may be found. Frass becomes brown and coarsely granular during summer and often piles up at the base of the tree below the entrance hole. A few excelsior-like fibers appear in the frass during fall and become more numerous during the second spring just before pupation (figure 166D). Beetles leave oval exit holes 10 to 14 mm in diameter in the bark (figure 166E). Larvae excavate sizeable cavelike chambers in the phloem-cambium area that eventually extend about 37 mm wide and 62 mm long (figure 166F). These chambers are commonly partially packed with brown granular frass. In the upper parts of each chamber, a gallery is extended obliquely upward for 62 to 75 mm into the wood, then straight upward for another 10 to 15 cm. Completed galleries are typically 15 to 25 cm long (figure 166G). In cross section, the oval galleries are more flattened than carpenterworm galleries and typically are about 9 by 17 mm (figure 166H). Wounds heal in 1 to 2 years, leaving vertically elongate bark scars with median seams. Bark scars some-

times have a short horizontal extension at the bottom, giving an L-shaped appearance (figure 167A). Tunnels are usually free of granular frass but may contain some excelsior frass. Tunnels are stained only slightly compared to those of carpenterworms (figure 167B). Ingrown bark pockets are more extensive than with most other borers. A high percentage of the large oaks in the eastern, southern, and central United States has been attacked by this species. A pest of shade or ornamental trees, this longhorn beetle has gained attention as a pest of timber stands as well. Large holes seriously degrade lumber sawn from infested trees. The red oak borer is one of the major species responsible for damage averaging $24 per thousand board feet in red oaks in three leading upland hardwood-producing states in the East (Donley 1974). Annual losses are estimated at over $100 millon result from the actions of this borer (plus several other species) in the eastern United States.

Control. Natural controls are important in reducing red oak borer populations but do not prevent economic damage. Larval mortality in the early instars averages 40% primarily from woodpecker predation (Hay 1974a). The hairy woodpecker and downy woodpecker are major predators (Hay 1972). In the middle instars, an average of 30% are killed mostly by fermenting sap, nitidulid sap beetles, and ants (Galford 1985). Lepidopterous woodborers, primarily *Prionoxystus* spp., invade wound sites when red oak borer larvae are in the mid- or late-larval stages and kill 4 to 5% of the larvae (Hay 1974a). Overall survival averaged 16% in one study (Hay 1974a) and only 6% in another (Hay 1972). Silvicultural control through recognizing and removing "brood trees" is recommended for young timber stands (Hay 1962). In Ohio studies, these cultural controls reduced red oak borer populations 63 to 68% (Donley 1983). Also, borer attacks can be prevented by spraying with insecticides at the proper time.

Enaphalodes cortiphagus (Craighead)

[oak bark scarrer] (figure 168)

Host. Oak. White oak group preferred. Chestnut oak, white oak, and chinkapin oak especially subject to attack (Champlain and others 1925). Other oaks are undoubtedly attacked.

Range. Throughout the eastern United States west to the Ozark Mountains and north to North Dakota (Stein and Tagestad 1976, USDA FS 1985).

Description. All stages of this borer resemble those of *E. rufulus* (Craighead 1950). ***Adult.*** Reddish brown longhorn beetle but covered with gray pubescence, giving grayish brown appearance (Linsley 1963). Females 20 to 30 mm long; males slightly smaller, varying from 16 to 24 mm (figure 168A). Antennae about length of body in females and twice body length in males. Adults are slightly smaller and slightly darker when compared to those of *E. rufulus*. ***Larva.*** Somewhat robust, body shiny white, mandibles dark brown, and spiracles amber (figure 168B) (Craighead

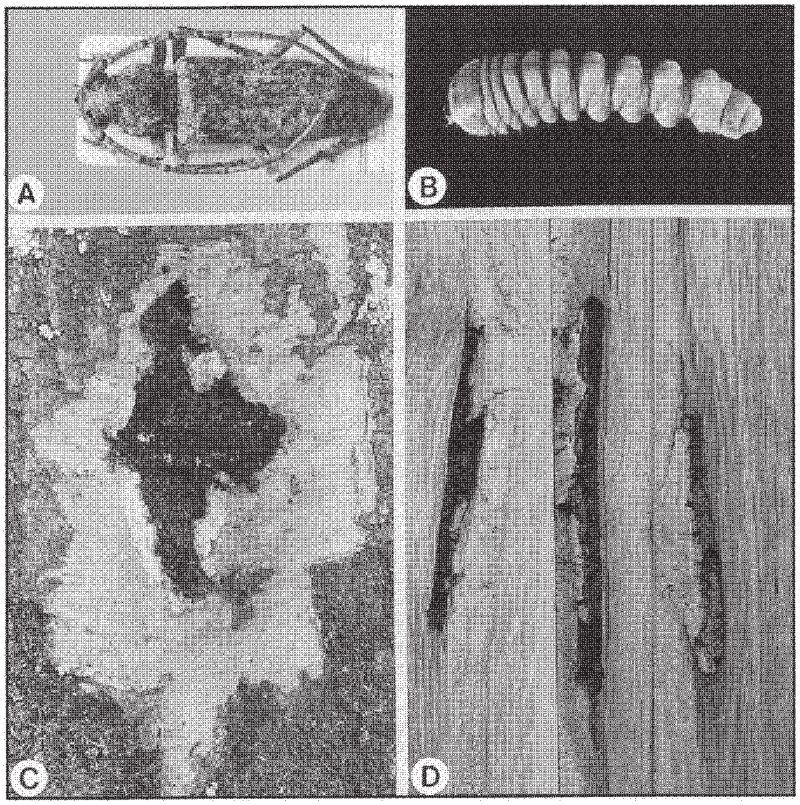

Figure 168—Enaphalodes cortiphagus, *[oak bark scarrer]: A, adult; B, larva; C, large cavity under bark with granular frass; D, large bark pocket defects in oak lumber (A & B, specimens courtesy D. Whitehead).*

1923). Although larva of *E. cortiphagus* closely resembles that of *E. rufulus*, it is distinguishable by several deep transverse wrinkles or folds across the underside of the head (in *E. rufulus*, this region is wrinkled longitudinally). Body texture thinner and scattered body hairs finer than those of *E. rufulus*. ***Pupa.*** Resembles that of *E. rufulus* except for larger, well-dispersed, erect, acute spines on upper surface of abdominal segments.

Biology. Adults emerge when chestnut and chinkapin are in full bloom and continue emerging for a short time afterward (Craighead 1950). Flight period is July to September (Linsley 1963). Adults have been taken in North Dakota as late as August 22 (Stein and Tagestad 1976). Females deposit eggs in bark crevices, selecting large mature trees with thick bark. Newly hatched larvae bore into the bark and feed within the thick ridges (Craighead 1923). Larvae gradually mine deeper into the bark as they grow. They eject little frass at first but pack the frass tightly behind them as they mine through the bark. After about 3 years, they burrow deep into the inner bark and cambium where they make large excavations for the pupal chambers. New adults emerge by chewing through the bark. Although little is known about the biology of this longhorn beetle, a life cycle of 3 years has been suggested (Craighead 1950).

Injury and damage. New attack sites are difficult to detect, but careful observation will reveal tiny pin holes in the bark with fine, light brown frass in the bark crevices. As attacks progress, injury becomes more apparent. As larvae tunnel the bark, much of the frass is packed within the gallery, but some is ejected through large openings (Craighead 1950). Breaks gradually appear, causing irregularities in the bark and imparting a rough appearance. Frass becomes coarsely granular and dark brown during later development. When bark is removed, the large, irregular mine through the bark ridges is exposed (figure 168C). The mine is packed tightly with brown, granular frass except near the larva. The cambium and sapwood are scarred, especially as the larva matures and approaches pupation. After larval development, attacks can be recognized by long elliptical scars on the bark parallel to the trunk, often resembling a long blaze or axe cut. Galleries do not extend deep into the wood as in the related *E. rufulus*. Injuries to wood products are large, black pockets of bark or defect (figure 168D). This defect is most commonly found in the wood of large thick-barked oaks, especially at higher elevations in the Appalachian and Ozark Mountains. An ingrown pocket of bark develops as the wound heals. These defects degrade lumber and other wood products sawn from infested trees and cause considerable quality loss.

Control. Because this insect prefers mature oaks with thick heavy bark ridges, foresters should promptly harvest mature or overmature trees to minimize losses through defect. Heavily scarred trees should be removed. Practices that maintain or improve tree and stand vigor help to minimize populations. Although little is known of natural controls, woodpeckers are partic-

ularly effective in capturing the larvae mining in the bark. No direct controls have been investigated. Utilization of the bark for tannin extracts destroys many of the larvae (Craighead 1950).

Anelaphus parallelus (Newman)

[oak twig pruner] (figure 169)

Hosts. Oak, hickory, walnut, apple, plum, cherry, peach, elm. Prefers oak, particularly northern red and black oaks (Dean 1920; Gosling 1978, 1981; Linsley 1963). Nuttall oak suffers heavy pruning in southern bottomland forests. White and bur oaks are occasionally attacked.

Range. Throughout the eastern United States west to Texas and northward into southern Canada (Linsley 1963). Geographic distribution coincides closely with that of *A. villosus* (Fabricius).

Description. ***Adult.*** Narrow, elongate, parallel-sided, longhorn beetle; male 10 to 13 mm and female 12 to 15 mm long (figure 169A) (Linsley 1963). Generally, brown to dark brown with small patches of pale pubescence scattered irregularly over body, giving a blotchy appearance. Male antennae barely surpass apices of elytra, whereas female antennae barely reach elytral tips. Antennal segments 3 through 5 have spined apices. In closely related *A. villosus*, antennal segments 3 through 6 are spined (Linsley 1963). Adults smaller and less robust than those of *A. villosus* (Gosling 1978). Apex of each elytron bispinose. Apex of fifth sternite truncate (apex of fifth sternite rounded in *A. villosus*) (Gosling 1978).
Larva. Elongate, slender, cylindrical, and creamy white with short rudimentary thoracic prolegs (figure 169B). Mature larvae 14 to 22 mm long.

Biology. Information is based largely on research reported from southern Michigan (Gosling 1978, 1981). Adults emerge in late May and early June. They are nocturnal and frequently attracted to lights around oak and hickory forests. Eggs are deposited at the base of bud clusters near the tip of a short (10 to 12 cm) twig, about 20 cm from the end of a branch that is about 10 mm in diameter. Larvae consume all the woody portions of the short twigs by the end of the first summer and extend their galleries into the nodes of main branches where they remain dormant through winter. In early summer, they bore into the center of branches near the twig nodes and burrow for 20 to 30 mm toward the branch base, making their characteristic pruning cuts in progressively larger arcs until only the bark of the branch remains. Galleries are then firmly plugged with shredded wood. Cuts are made in late June and early July in southern Michigan. In the South, pruning cuts are made during late summer and fall. Affected branches nearly always break off shortly afterwards. During the second summer, the larvae construct pupal chambers by firmly plugging galleries with a wad of shredded wood 20 to 30 mm from the distal end. Pupation occurs in September or later. Adults emerge during spring in the South and continue until June in the North. This pruner requires 2 years to complete its life cycle in Michigan and is single brooded, so most twig pruning occurs in even years, and

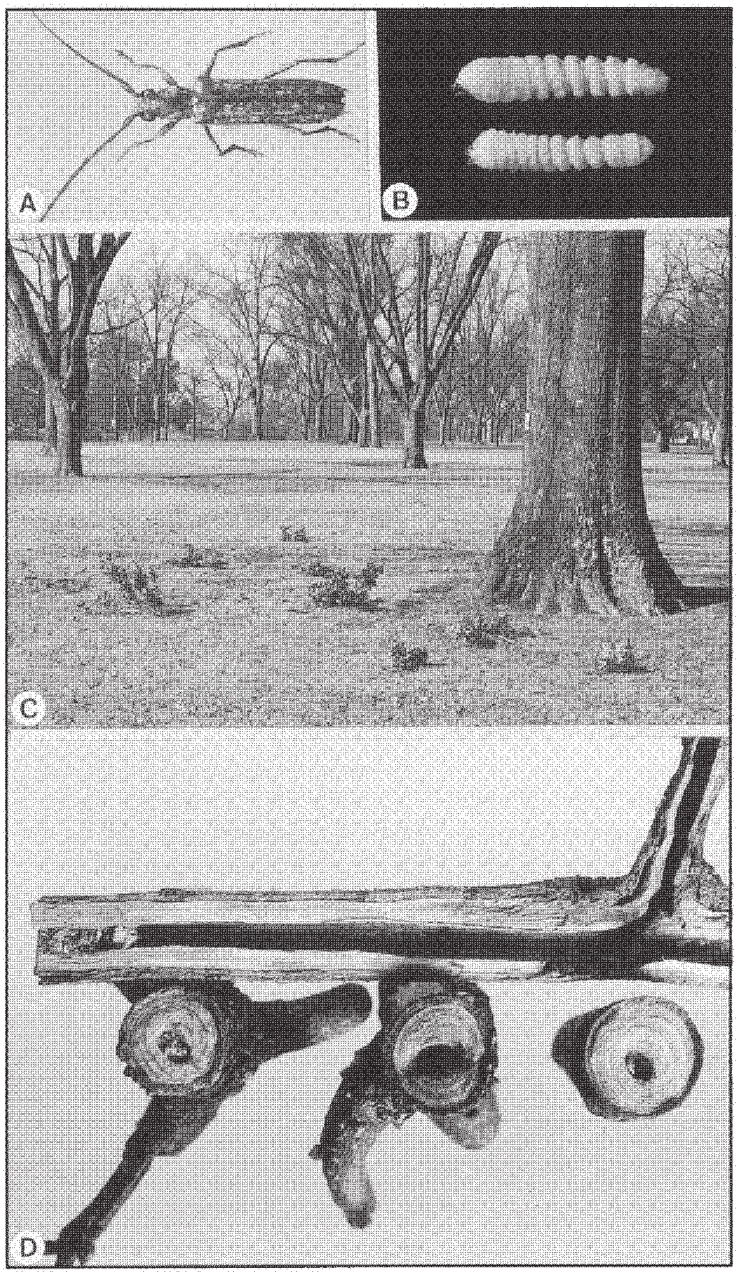

Figure 169—Anelaphus parallelus, *[oak twig pruner]: A, adult; B, larvae; C, pruned branches under Nuttall oak; D, smooth pruning cuts with oval frass-packed holes in severed ends of branches.*

adults emerge in odd years (Gosling 1978).

Injury and damage. Attacks occur most commonly on the edges of forest stands, along fence rows, in fields, and on ornamentals (Gosling 1978). In late summer and fall, numerous small branches and twigs from 8 to 20 mm in diameter and 20 to 90 cm long are on the ground in such areas (figure 169C). Concentric cuts from the stem center outward leave the bark intact, so the end of the severed branch is smoothly cut. Near the center is an oval gallery opening plugged lightly with fine, fibrous frass (figure 169D). Sometimes partially severed branches with green, wilted foliage are scattered throughout the tree crown. On the broken branches, a hole plugged with wood fibers marks where the branch was attached to the tree. Plugged holes may be found where smaller twigs have been broken from larger branches. This pruner can severely disfigure crowns of trees and retard growth. It is a serious nuisance where esthetics is a primary objective. Branches dropping onto lawns in late summer and fall may also annoy homeowners. Young trees, especially seedlings and sprouts, may be girdled and killed. An unusually severe infestation occurred in Minnesota in the late 1800's, when these borers destroyed all the black oak reproduction on several hundred hectares in less than 5 years (Lugger 1899).

Control. Natural controls are effective in reducing pruner infestations. Rodents, particularly squirrels, have destroyed up to 31% of the larvae (Gosling 1978). Insectivorous birds also destroy large numbers of the larvae. In one study, 4 hymenopterous parasites—*Agronocryptus discoidaloides* Viereck, *Iphiaulax eurygastor* Brulle, *Meteorus tibialis* Muesebeck, and *Minthozelia ruficanda* Reinhard—parasitized 6% of the larvae in 557 infested twigs. Destroying fallen, infested branches is recommended (Dean 1920). However, because many pruner larvae are parasitized after the twigs have fallen in late June or early July, fallen twigs should be gathered and burned just after they fall, killing the pruners but not the parasites (Gosling 1978). Insecticidal control of this borer has not been investigated and is probably not justified under most circumstances.

Anelaphus villosus (Fabricius)

twig pruner (figure 170)

Hosts. Hickory, pecan, basswood, redbud, chestnut, locust, sassafras, sumac, Osage-orange, apple, pear, plum, peach, orange, quince, walnut, elm, hackberry, sweetgum, birch, maple, oak, poison ivy. Seems to prefer hickories and basswood (Felt 1905, Gosling 1981).

Range. Throughout the eastern United States northward to Canada and westward to Arizona (Chittenden 1910, Gosling 1981, Linsley 1963).

Description. ***Adult.*** Elongate longhorn beetle with parallel sides; male 12 to 17 mm long and female 11 to 18 mm long (figure 170A) (Linsley 1963). Body brown to dark brown or reddish brown and sparsely covered with yellowish, somewhat mottled, pubescence. Male antennae surpass ends of elytra by length of two antennal segments; female antennae barely surpass ends of

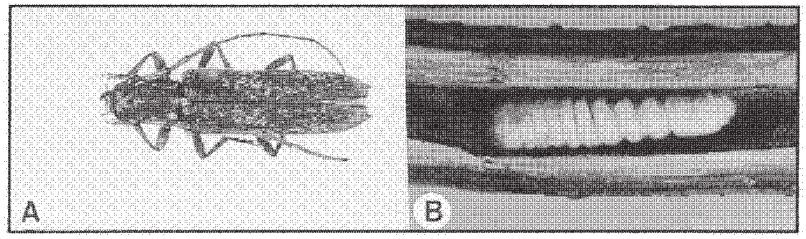

Figure 170—Anelaphus villosus, *twig pruner: A, adult; B, larva.*

elytra (Linsley 1963). Antennal joints 3 to 6 armed with small spines. Elytra end in two small spines. ***Larva.*** Mature larva (figure 170B) shiny, white to yellowish, and about 19 mm long (Craighead 1923). Body cylindrical and slender with segment prominently defined. Prothorax covered with very long lemon yellow hairs.

Biology. This borer is frequently confused with its sibling species *A. parallelus* (Gosling 1981). Adults emerge from mid- through late June in Michigan and deposit eggs in weakened, dying, and recently dead hosts, whereas adults of *A. parallelus* prefer living hosts for oviposition. (Craighead 1923, Felt 1905, Gosling 1981, USDA FS 1985). After hatching, larvae feed beneath the bark, excavating large, irregularly shaped galleries. Boring removes the inner bark and cuts into the sapwood, leaving paper-thin layers of outer bark covering the chambers. In small branches, larvae usually pupate between plugs of shredded wood in narrow extensions of the chamber. In larger branches, larvae extend narrow, oval galleries to the center of the branch and continue down the center for varying distances. Pupation occurs between shredded wood plugs near the ends of galleries. Adults emerge through holes in the bark cut for expelling frass. The life cycle requires 2 years in Michigan; adults are usually present only in odd-numbered years.

Injury and damage. Older literature describes infested branches as being pruned from living trees by circular cuts made from within by larvae (Craighead 1923, Felt 1905, Gill 1924). However, recent studies in Michigan suggest that this species largely attacks recently dead trees and does not typically sever infested branches (Gosling 1981). This new information indicates that larvae make broad, various-shaped cavities beneath the bark. Dissection reveals that these chambers are typically 100 to 150 mm long and 5 to 20 mm wide. In larger branches, narrow galleries can penetrate the stem centers and continue for as much as 120 mm. No pruning cuts are made, but hollowed branches containing the larvae may break and fall to the ground.

Control. Two hymenopterous parasites—*Bracon eurygaster* Brulle and *Odontobracon elaphivorus* Rohwer—have been recorded (Linsley 1963). Predaceous birds include the downy woodpecker, blue jay, and black-capped chickadee (Chittenden 1910). A spider—*Theridium tepidariorum* C. Koch—has been observed preying on the adults.

Anelaphus inflaticollis Chemsak

[box-thorn borer] (figure 171)

Hosts. Box-thorn, greasewood. Widespread in *Lycium* spp. and common in box-thorn (Hovore and Giesbert 1976, Hovore and others 1978). A small series has been reared from black greasewood (Cope 1984).

Range. Western species confined to three counties in the Mojave Desert of California (Cope 1984, Hovore and Giesbert 1976, Linsley 1963).

Description. ***Adult.*** Elongate, black to reddish black longhorn beetle with yellowish or grayish pubescence; about 13 mm long (figure 171A) (Linsley 1963). Head coarsely punctate with raised area between

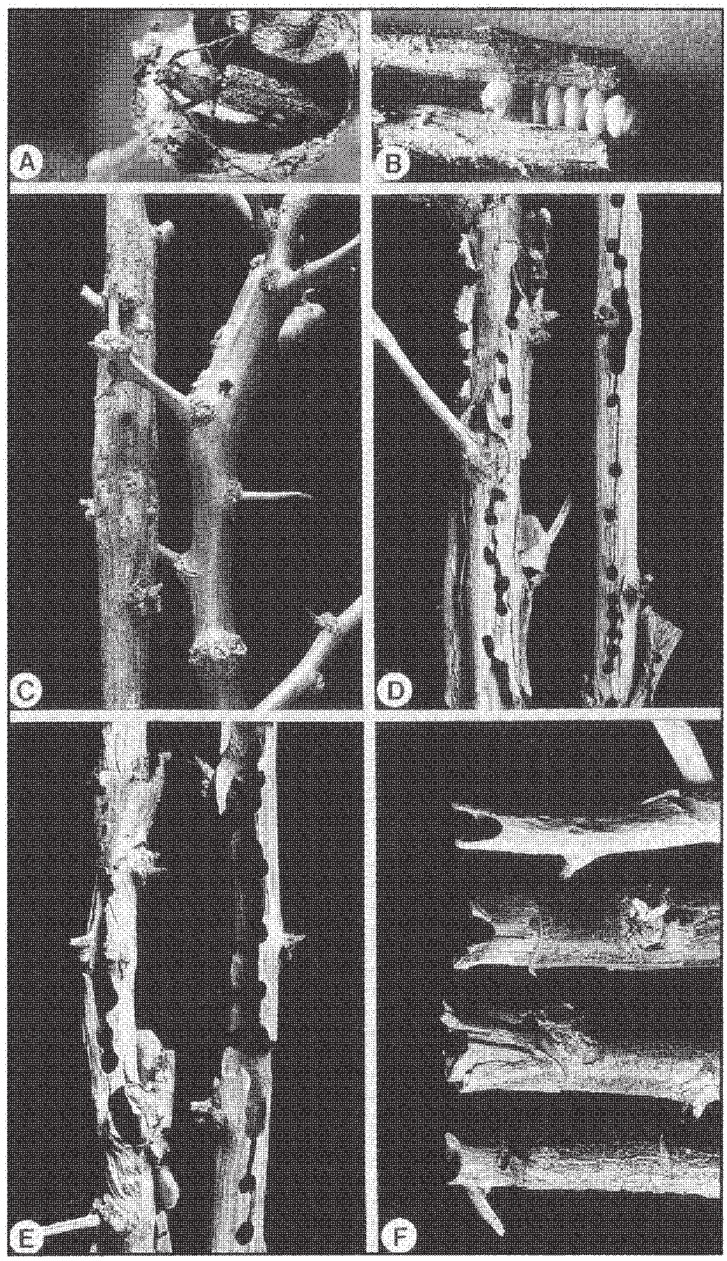

Figure 171—Anelaphus inflaticollis, *[box-thorn borer]: A, adult; B, larva; C, infested stems; D, linear series of holes in branches; E, old injuries with galleries; F, saddle- to V-shaped stem girdles (specimens courtesy F. Hovore and R. Penrose).*

eyes. Antennae slightly shorter than body. Pronotum inflated, broadly rounded, and equal to elytra in width. Elytra about 2.7 times longer than broad, surface sparsely and coarsely punctured, dense yellowish pubescence mixed with depressed whitish hairs. Legs short and moderately pubescent. ***Larva.*** Elongate and white with well-developed ampullae (figure 171B).

Biology. Adults are in flight during May (Linsley 1963). However, teneral adults have been collected from pupal cells as early as January in Los Angeles County (Hovore and Giesbert 1976), which indicates that adults emerge early in the year. Some appear to begin in twigs, then proceed downward to larger branches or main stems. Larvae expel frass from numerous holes along the stems. Mature larvae girdle the stem, then retreat into long, pupal chambers below the girdle. Life cycle is unknown but this borer probably requires 1 to 2 years for development.

Injury and damage. Branches, twigs, and main stems 5 to 24 mm in diameter may be attacked. In the early stages of infestation, stems may become swollen and have 1-mm-diameter round holes (figure 171C). The holes increase in number and size (2.0 to 2.5 mm diameter) and are scattered along the stems in nearly straight lines (figure 171D), giving many stems a flutelike appearance. Stems are sometimes nearly hollowed out with tunnels from 14 to 42 mm long (figure 171E). Infested stems are partially to completely girdled with the severed ends varying from a saddle- to V-shaped girdle (figure 171F). Exposed girdles are tightly plugged with a wad of shredded wood (Hovore and Giesbert 1976). Larvae hollow the stems, causing dieback and mortality of plant parts.

Control. Nothing is known of natural controls, and direct controls are not needed.

Parelaphidion incertum (Newman)

[mulberry bark borer]

Hosts. Mulberry, oak, hickory. Favors red mulberry but is sometimes found in chestnut oak and pignut hickory (Linsley 1963, Stein and Tagestad 1976).

Range. Eastern United States from New York south to Florida and west to North Dakota and Texas (Leonard 1928, Linsley 1963, Stein and Tagestad 1976, USDA FS 1985).

Description. ***Adult.*** Small, rather robust longhorn beetle (Blatchley 1910, Linsley 1963). Dark reddish brown with antennae and legs paler; 8.5 to 17.0 mm long. Pubescence short and sparse with scattered, irregular white or grayish brown patches. Antennae of males about body length and slightly shorter in females. ***Larva.*** White with dark mouthparts, robust, elongate, and thickly covered with long golden hairs.

Biology. Adults present from April to September (Blatchley 1910, Fattig 1947). Larvae feed and develop mostly in outer bark of hosts, sometimes feeding into the cambium (Craighead 1923, Linsley 1963). They excavate irregular, contorted galleries mostly in outer bark. Life cycle requires 2 years in living and dying trees and 3 years in dead trees (Stein and Tagestad 1976).

Injury and damage. Galleries and burrows are limited largely to the outer bark, only occasionally reaching the cambium (Craighead 1923, Linsley 1963). Living, dying, and recently dead trees may become infested. Damage in most cases is negligible.

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

Phoracantha semipunctata (Fabricius)

[eucalyptus longhorn borer] (figure 172)

Host. Eucalyptus. Eucalyptus species are attacked but vary considerably in susceptibility. Of four species studied, bluegum eucalyptus and manna gum are preferred, whereas Blakely's red gum and sugar gum are less susceptible (Scriven and others 1986).

Range. Native to Australia, recently introduced into California. Discovered first in October 1984, near El Toro in Orange County, California (Ali and Garcia 1988, Scriven and others 1986). Now covers most counties in southern California (Ali and others 1988). Expected to spread to northern California, the Central Valley, and possibly Arizona (Anonymous 1986).

Description. ***Adult.*** Elongate, dark brown to shiny black longhorn beetle, with moderately long legs; body 20 to 35 mm long (figure 172A) (Ali and Garcia 1988, Scriven and others 1986). Antennae of females about length of body and somewhat longer and heavier with prominent spines on each segment in males. Elytra have two, distinctive, yellow, zigzag markings or bands proximally and two yellow oval dots distally; elytral apices spined. ***Egg.*** Elongate to spindle shaped and creamy white, resembling miniature grains of rice (figure 172B). ***Larva.*** Moderately robust, thorax slightly widened, yellowish white except for dark head and mandibles, and 26 to 38 mm long (figure 172C). ***Pupa.*** Less robust, white, and 22 to 36 mm long (figure 172D).

Biology. Adults active February to November (Scriven and others 1986). Females begin mating when 2 days old and oviposit at 4 to 6 days. Adults are nocturnal, usually hiding under loose bark in the daytime. They feed on eucalyptus flowers and other plants. Eggs are usually laid beneath the bark, typically in clusters of 3 to 30, but up to 100 eggs have been found in some clusters (Ali and Garcia 1988, Scriven and others 1986). Females may live 40 days during summer and up to 180 days in winter and lay up to 300 eggs, which hatch in 10 to 14 days. Newly hatched larvae feed superficially in the bark, leaving dark trails 1 to 2 cm long. They penetrate the phloem to the cambium and feed until nearly mature. Galleries are gradually widened to three times the head width and sometimes extended up to a meter or more in length. Mature larvae make short tunnels to the bark surface, then burrow 6 to 10 cm into the wood and excavate pupation chambers. Larvae develop in about 70 days in fresh hosts and about 180 days in dry logs. Pupal stage lasts about 20 days. New adults exit through large oval holes. The life cycle is 3 to 4 months during spring and summer but up to 9 months in fall and

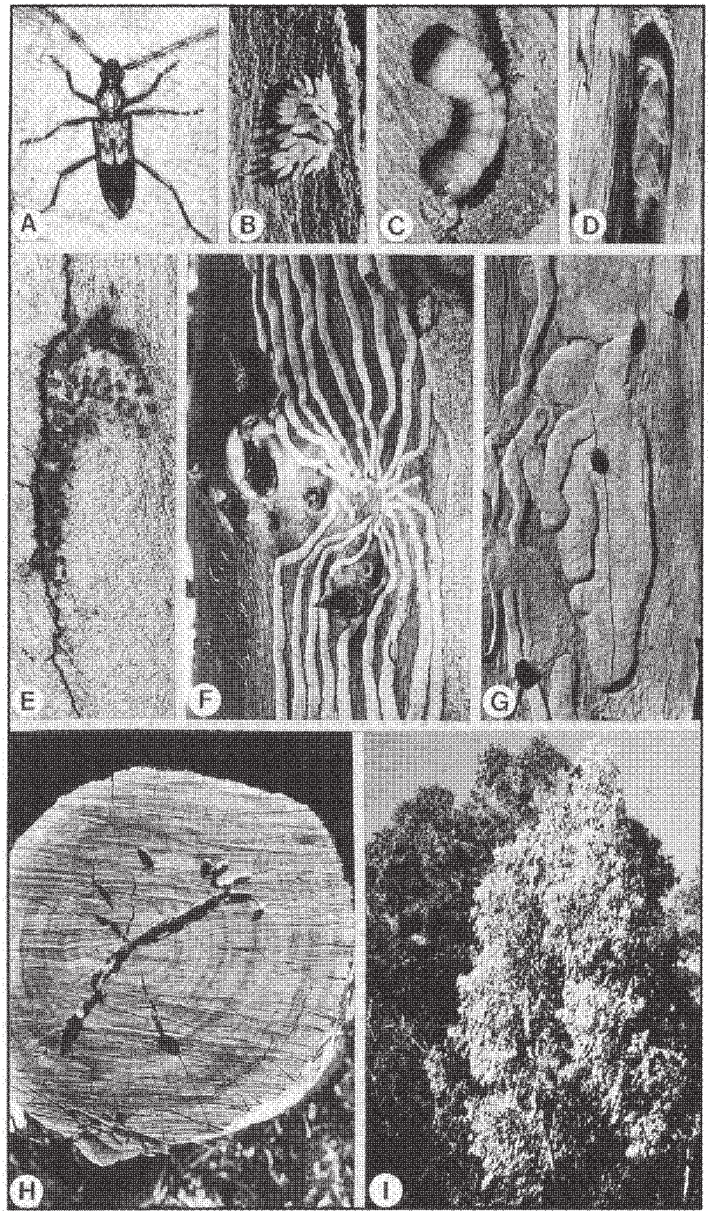

Figure 172—Phoracantha semipunctata, *[eucalyptus longhorn borer]: A, adult; B, egg mass; C, larva; D, pupa; E, cluster of egg niches in bark; F, frass-packed galleries radiating from egg mass; G, oval exit holes; H, cross section of galleries; I, eucalyptus dying from borer attacks (A & D, courtesy R. Penrose; B, C, & F, courtesy G. Scriven; E, G, & H, specimens courtesy F. Hovore).*

winter. Two to three overlapping generations occur per year in southern California.

Injury and damage. Earliest sign of infestation may be a cluster of egg niches in the bark (figure 172E). Egg niche clusters usually appear near bark cracks, branch stubs, or injuries where the bark begins to loosen. Lifting the bark reveals a cluster of white eggs. Healthy, vigorously growing trees respond to larval feeding by producing and exuding copious quantities of kino (dark brown, resinous, gummy fluid), which stains the bark and sometimes runs down the trunk. Larvae leave many long, wide galleries, tightly packed with frass under the bark and etched in the surface (figure 172F). Later, many large, oval exit holes are made in the bark and sapwood (figure 172G). In bole or log cross section, the oval galleries are deep within the wood (figure 172H). Trees that show sprouting from inactive buds along the bole and changes in leaf color should be examined for borer infestation. When limbs are attacked, branches flag and die back. Heavily infested trees may die suddenly, and their leaves will turn yellow and then brown and remain on the tree for 4 weeks or longer (figure 172I). Although this borer will attack healthy trees, it prefers stressed, weakened, dying, and recently dead trees and fresh-cut logs (Scriven and others 1986). Trees suffering from moisture stress are particularly susceptible. This pest kills many trees and inflicts heavy damage, particularly in urban settings. Eucalyptus, one of the more common broadleaf trees in urban southern California, is threatened for use in landscape and woodlot plantings (Scriven and others 1986).

Control. Natural controls cause significant mortality of borers in Australian eucalyptus forests and are being studied for introduction into California (Ali and Garcia 1988, Anonymous 1986, Scriven and others 1986). In California, only light woodpecker activity and a predacious mite—*Pyemotes* sp.—of eggs have been observed. In Israel, the Syrian woodpecker causes about 28% mortality. Because trees under stress are most susceptible, good cultural practices such as timely irrigation and fertilization can help many withstand attacks. Prompt removal and destruction of beetle-infested trees, logs, and slash are recommended. Freshly cut trap logs treated with insecticides have been used in Spain to limit the borer's impact. Firewood cut from infested trees should be fumigated and then covered tightly with sturdy tarpaulins or placed in screened enclosures to prevent spread. Two species of eucalyptus—Blakely's red gum and sugar gum—have substantial gum defenses and are much less susceptible than bluegum eucalyptus and manna gum. Soil- and trunk-injected systemic insecticides have given only partial control; application costs are also high, making these impractical control options (Ali and others 1988).

Dryobius sexnotatus (Linsley)

[maple dryobius] (figure 173)

Hosts. Maple, elm, beech, basswood. Sugar maple preferred (Perry and others 1974). Basswood and beech occasionally attacked; beech is a secondary host. One

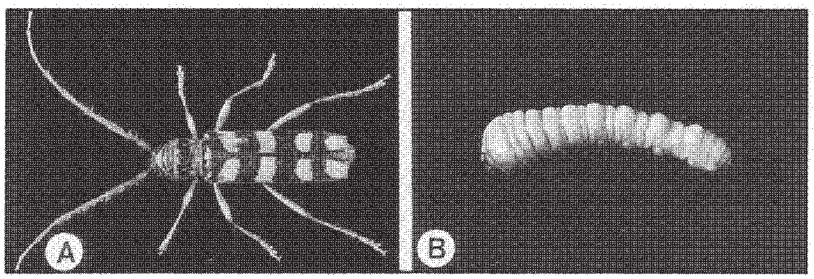

Figure 173—Dryobius sexnotatus, *[maple dryobius]: A, adult; B, larva (B, specimen courtesy D. Whitehead).*

record of the insect from elm.

Range. Eastern North America. Reported in 14 states from New York west to Michigan and Kansas and south to Louisiana (Perry and others 1974). Best known from the Ohio River Valley, especially in Pennsylvania and Ohio, where it has been studied and collected (Dury 1902, Linsley 1964, Perry and others 1974).

Description. ***Adult.*** Moderately robust, slightly elongate longhorn beetle, and 20 to 26 mm long and 5 to 6 mm wide (figure 173A) (Knull 1946, Linsley 1964, Perry and others 1974). Body generally dark brown to black and banded with golden yellow pubescence. Two bright yellow bands on head, two on pronotum, and four across elytra. Antennae and legs reddish to light brown. Males have antennae about twice length of body; antennae of females only slightly longer than body. ***Larva.*** White to yellow, subcylindrical, slightly depressed across thorax, and widest across prothorax (figure 173B) (Perry and others 1974). Mandibles and other mouthparts black to reddish brown. Head pale yellowish brown. Tiny thoracic prolegs present and distinctly four segmented. Mature larvae reach 32 mm long and 7.7 mm wide.

Biology. Adults fly from March to September; most appear in June and July (Perry and others 1974). Beetles emerge from galleries during the afternoon. Diurnal activity occurs from midmorning until late afternoon on host tree trunks exposed to sunlight; in shady, heavily wooded areas, beetle activity has been observed only from noon to midafternoon. Beetles spend the night in cavities and under loose bark; none are found fully exposed after dark. Mating was observed during high temperatures but not oviposition. Larvae tunnel into the wood and extend their galleries. They eject little or no frass, instead packing the fine-textured frass behind in the galleries. Larvae feed 2 to 3 years and work their way close to the bark surface before pupating.

Injury and damage. This borer attacks living, dying, and recently dead standing trees, but most commonly attacks large mature and overmature trees that have been wounded or scarred and are deteriorating (Perry and others 1974). Injury is caused by larvae boring in and through the trunk. Larvae may continue to tunnel in susceptible trees even after the trees succumb. Larvae work throughout the wood but prefer the heartwood of sugar maple. In beech, the larvae tunnel less into the heartwood. Large, meandering galleries in infested trunks are packed solid with fine-textured frass. The wood is eventually so riddled that it becomes a mass of old, frass-packed galleries. Extensive tunneling in the sapwood and heartwood can weaken infested trees, making them susceptible to breakage and causing degrade in any wood products. The large old trees tapped and used by the sugar maple industry have come under attack. Losses have been negligible because the pest is widely scattered and populations are sparse.

Control. Excessive humidity appears to affect survival (Perry and others 1974). Because attacks are limited mostly to large, overmature trees, harvesting as soon as trees are mature and begin declining in

vigor will help minimize losses. No parasites or predators have been reported. Infestations are so infrequent that direct controls have not been needed.

Physocnemum brevilineum (Say)

[elm bark borer] (figure 174)

Hosts. Elm. American elm mentioned, but other elm species are undoubtedly infested (Haliburton 1951).

Range. Most of the eastern United States south to Mississippi and west to Oklahoma and in southern Canada (Linsley 1964).

Description. ***Adult.*** Subdepressed, elongate-oblong longhorn beetle with parallel sides, and 9 to 20 mm long (figure 174A) (Haliburton 1951, Linsley 1964). Body black to dark brown; elytra having purple, bluish, or brassy lustre and sometimes ornamented with three raised, longitudinal white marks of variable length (Haliburton 1951, USDA FS 1985). Antennae of females slightly shorter than body and those of males slightly longer. ***Larva.*** Slender, smooth, and dull white with shiny, longitudinally striate pronotum and gouge-shaped mandibles (figure 174B) (Craighead 1923, Haliburton 1951). Largest larvae are about 40 mm long.

Biology. Adults emerge May to July, with specimens taken in Michigan as late as August 25 (Gosling 1973, Linsley 1964). Beetles can be found crawling up and down trunks, particularly on sunlit portions of the bark (Haliburton 1951). Females deposit eggs in bark crevices and beneath bark scales at selected places on the trunk and branches. Newly hatched larvae mine in the dry outer bark, occasionally reaching the inner phloem and cambium. Mining in the cambium is more common in weakened, stressed, and dying trees. In recently dead trees and felled logs, larvae may extend galleries into the sapwood. Galleries are sometimes extensive, meander, and are usually tightly packed with granular frass. Late in the season, larvae boring in the outer bark of a healthy tree typically mine deeper into the living phloem, where they prepare loci for hibernation. During spring or early summer, the larvae construct pupal cells, usually in the outer bark but sometimes in the inner bark or outer sapwood. New adults cut elliptical holes (3 to 7 mm across at the major axis) in the bark to emerge (figure 174D). Life cycle is usually 1 year, but sometimes requires 2 years (Linsley 1964).

Injury and damage. In healthy trees, mines are limited mostly to the dry, dead phloem tissue of the outer bark. Galleries occasionally reach the living phloem and cambium. In weakened, stressed, and recently dead trees, frass-filled mines commonly extend into the inner bark, cambium, and outer sapwood, particularly during late season (figure 174C). Necrotic areas may form where the inner phloem and cambium have been injured. Small areas of injured bark usually heal rapidly, but large areas of dead bark sometimes slough off when larval mines coalesce. This, together with the corking out of phloem injuries, may completely alter the appearance of the bark, replacing the regular pattern of vertical ridges and fissures with irregular patches of scales.

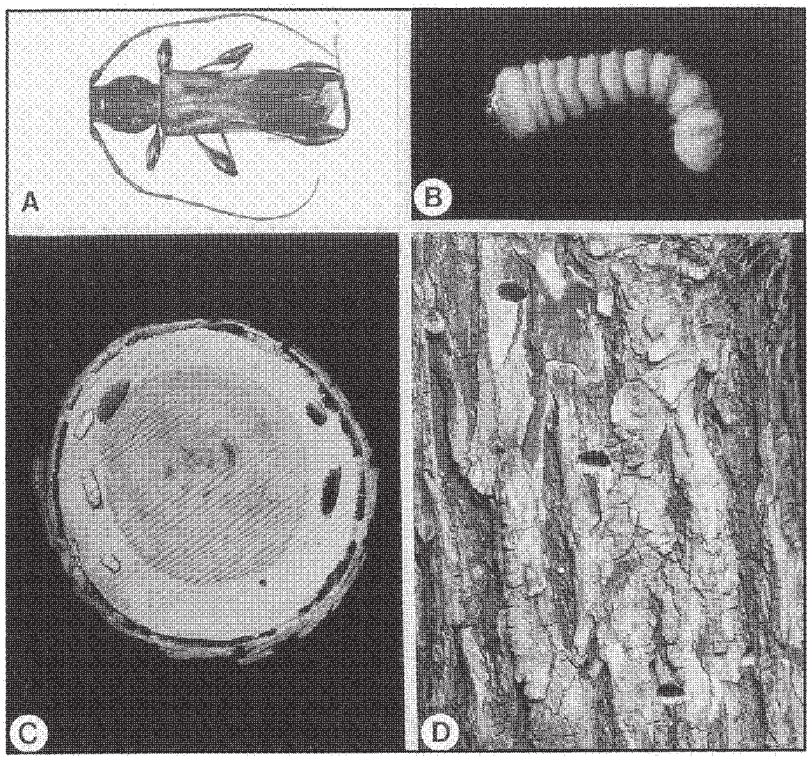

Figure 174—Physocnemum brevilineum, *[elm bark borer]: A, adult; B, larva; C, cross section of mines in and under bark, and outer sapwood; D, oval emergence holes in elm bark (A & B, specimens courtesy D. Whitehead; C & D, specimens courtesy J. Simeone).*

Attacks occur in all types of bark, from the lower trunk to branches as small as 5 cm in diameter. In felled logs, mines are more common in the cambium area and on the wood surface and much more extensive than in standing living trees. Emerging beetles leave elliptical holes (figure 174D). Large patches of killed bark reduce the esthetic beauty of shade and ornamental trees. Phloem injuries that heal often have ingrown pockets of bark along with stain and decay. Such injuries on trees sawn for wood products result in defect, degrade, and lost value. Fortunately, infestations are widely scattered, with only one tree or a small clump of trees being infested. The borer is capable of transmitting Dutch elm disease, but its role is considered of negligible importance.

Control. Parasite emergence holes in the bark of infested trees have been observed, but the identity of the parasite(s) has not been determined (Haliburton 1951). Populations are so widely scattered that this pest is of little economic importance. Direct controls have not been investigated.

Xylocrius agassizi (LeConte)

[gooseberry rootborer] (figure 175)

Hosts. Gooseberry. Wild and cultivated gooseberry varieties have been attacked (Essig 1929). Willow mentioned but not confirmed.

Range. Along the Pacific Coast and through the Rocky Mountains from British Columbia, Canada, south to California and New Mexico (Linsley 1964).

Description. ***Adult.*** Moderately robust longhorn beetle, usually black, 10 to 17 mm long (figure 175A) (Linsley 1964). Most of body and appendages clothed with short, semierect, black hairs. Antennae about one-third body length. The third and fourth antennal segments of both sexes rounded at apices; remaining antennal segments truncate at apices. Pronotum about as wide as elytra and sides broadly rounded. Elytra less than twice as long as wide, sides curved slightly inward near middle, and tips broadly rounded. ***Egg.*** Transparent and milky white when first deposited, turning pale, sea green in about 48 hours (Chamberlin 1925). Egg gradually becomes opaque, and in about 4 days, dark mandibles become visible through chorion. ***Larva.*** White, moderately robust, with body shape typical of longhorn group (figure 175B).

Biology. In Oregon, adults emerge from mid-March through early April, but beetles have been taken in flight as late as July (Chamberlin 1925, Linsley 1964). Eggs are deposited under bark scales or in roughened areas of bark close to or slightly below ground (Chamberlin 1925). Eggs are deposited singly, but sometimes several females will oviposit at the same location making clusters of 3 to 4 eggs. An average of 5 eggs (range 2 to 11) is deposited per female (Chamberlin 1925). New larvae generally bore into plants at or near stem forks, then burrow downward in the center of stems and enter the larger roots, where they overwinter (Chittenden 1900c, Essig 1915). In light infestations, usually only one larva is found per plant. In heavy infestations, plants show decline symptoms, and as

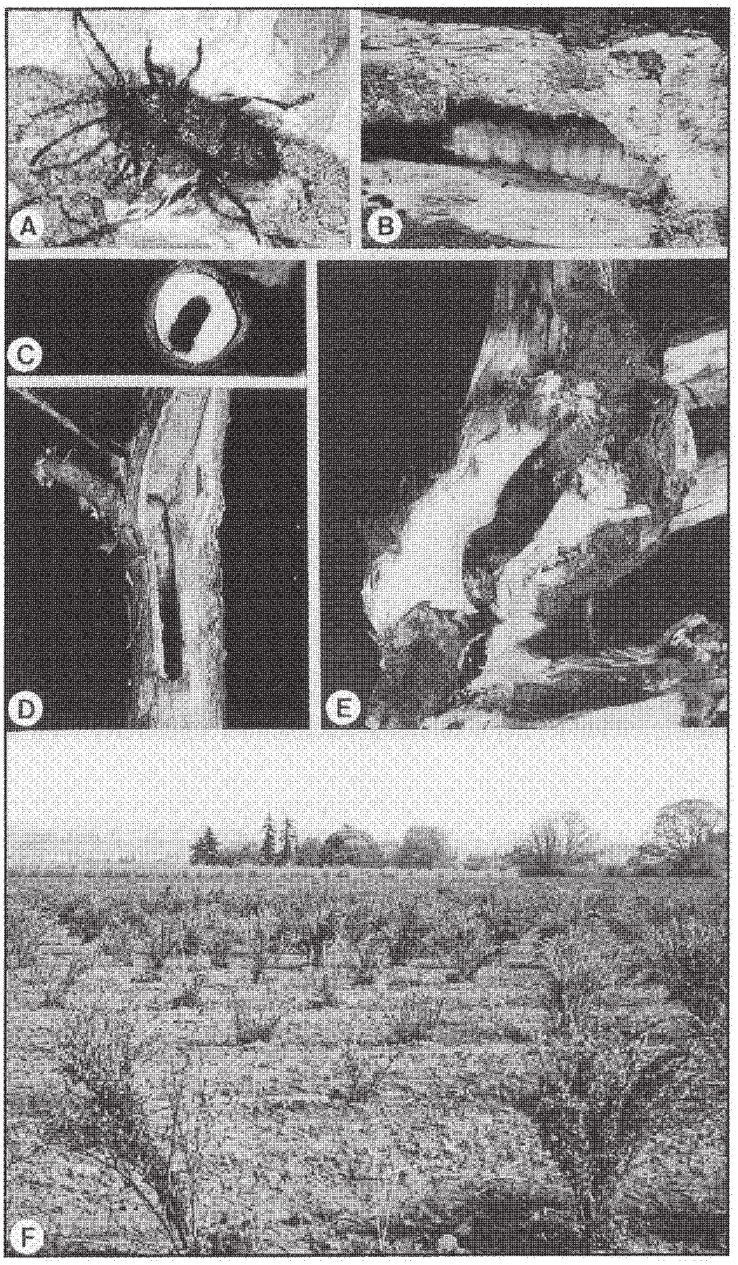

Figure 175—Xylocrius agassizi, *[gooseberry rootborer]: A, adult; B, larva; C, cross section of oval gallery; D, stem with gallery, larva, and packed frass; E, rootstock with galleries and frass; F, weakened, dying plants in gooseberry planting (courtesy R. Penrose).*

many as 21 larvae can infest a plant (Chamberlin 1925, Penrose 1977). In Oregon, by September a wide range of larval instars, including prepupae and pupae, can be found in plants, indicating that the borer probably overwinters in all immature developmental stages, except the egg (Penrose 1977). Pupation occurs in a chamber at the end of the larval gallery just beneath the bark surface, usually several centimeters above ground (Chittenden 1900c). The life cycle presumably requires 2 years to complete, because adults appear in much larger numbers during odd-numbered years than in even-numbered years (Chamberlin 1925).

Injury and damage. Infested plants suffer reduced growth and leaf size, flagging branches, reduced fruit production, dieback, and sometimes death (figure 175F) (Penrose 1977). Borers may work in a plant for several years without signs of infestation, except for reduced berry production. Occasionally, injury becomes visible at the root collar. Excavating and dissecting the root collar and roots reveal larval burrows and larvae within the tunnels (figure 175C, D, and E). Heavily injured plants often succumb. During the early 1900's, infestations were so severe in many commercial gooseberry plantings in Oregon that growers were forced either to destroy all plants or replace all older ones (Chamberlin 1925). In the 1970's, heavy damage occurred near Salem, Oregon; in one 12-ha commercial gooseberry planting, the number of larvae ranged from 8 to 21 per plant (Penrose 1977).

Control. Cutting and burning infested plant parts has been effective. Cutting out the aboveground canes has been only partially effective (Essig 1915). Removing and burning the plants including roots have been most effective (Chittenden 1900c). No natural controls have been reported, and chemical controls have been only partially effective.

Megacyllene robiniae (Forster)

locust borer (figure 176)

Host. Black locust. Only black locust and its cultivars or horticulturally derived varieties in the genus *Robinia* are attacked (Galford 1984, Wollerman 1962).

Range. A native insect, first discovered in 1702 (Wollerman 1962). Original distribution probably coincided with its host, ranging from Pennsylvania to Georgia and into the Ozark Mountains. Widespread use of black locust as a shade tree and in reforestation and land reclamation plantings has enabled the borer to disperse widely. Now occurs from eastern Canada south to the Gulf Coast; and west to Washington, Colorado, and Arizona (Galford 1984, Harman and others 1985).

Description. ***Adult.*** Colorful, slender, longhorn beetle 12 to 19 mm long (figure 176A) (Galford 1984, Wollerman 1962). Bright yellow bands mark jet black background of adult. A W-shaped band extends across elytra. Males and females similar in appearance, with moderately long, yellow legs and antennae; males slightly smaller and more slender than females. ***Egg.*** White, oval, and about 2.4 mm long and 0.8 mm in diameter; typically tucked into bark crevices

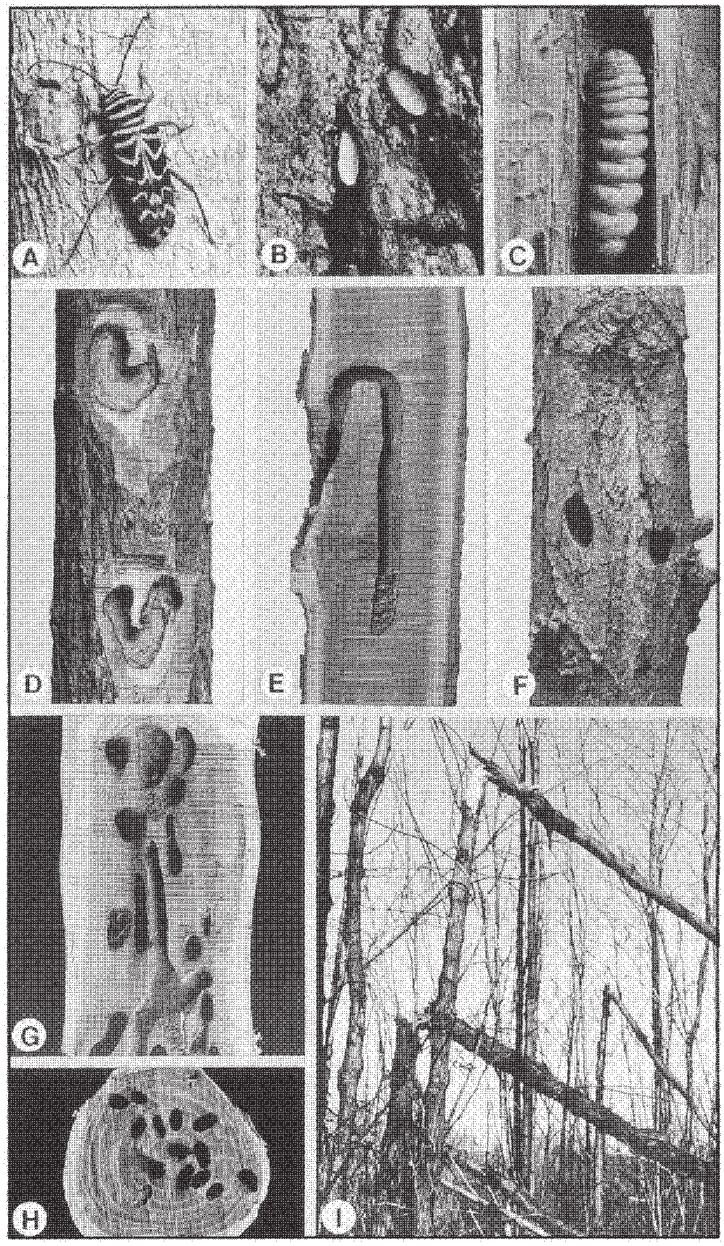

Figure 176—Magacyllene robiniae, *locust borer: A, adult; B, eggs in bark crevices; C, larva; D, heart-shaped, larval cavities under bark; E, single, uninterrupted gallery; F, oval emergence holes; G, black locust riddled by galleries; H, cross section of galleries; I, breakage from borer attacks (specimen I, courtesy J. Galford).*

(figure 176B). ***Larva.*** White, 18 to 26 mm long with black head and mouthparts, measuring about 6 mm in diameter (figure 176C). ***Pupa.*** Newly formed pupa creamy white and about 12 mm long.

Biology. Adults appear during late summer and early fall and are abundant during September. They feed on the pollen of goldenrod blossoms and in the morning fly back to locust trees (Galford 1984, Garman 1916, Wollerman 1962). Later in the day until well after sunset, the beetles run up and down tree trunks in search of oviposition sites. Females deposit eggs singly, mostly during the afternoon, usually in rough bark crevices and around wounds. Eggs hatch in about a week, and the larvae burrow into the inner bark and make small hibernation cells to overwinter. In spring, activity begins about when locust tree buds swell. The larvae work their way into the woody parts of the tree trunk and branches and approach maturity around mid-July. They usually transform to the pupal stage in late July and early August. Adult beetles in excavated tunnels emerge through exit holes in August. Life stages may be modified as much as 2 weeks by local climate.

Injury and damage. Borer attack becomes apparent in spring about when locust leaf buds swell (Galford 1984). Activity of young larvae in the inner bark is evidenced by wet spots and sap around the tiny larval entry holes in the trunk or branches. Granular frass is pushed through the tunnels to the outside, where it may accumulate at the base of the tree. In late spring or early summer, developing larvae work into the sapwood and push white frass from their galleries. When the larvae burrow deeper and reach the heartwood in late summer, the frass becomes yellow. Removing bark from attack sites reveals heart-shaped cambium cavities 2 to 3 cm wide (figure 176D). Uninterrupted galleries extend obliquely upward, inward, and then straight down, and measure 9 to 14 cm long and 6 to 8 mm in diameter (figure 176E). Adults make oval exit holes about 5 by 10 mm across (figure 176F). Trunks that suffer repeated attacks are badly riddled with galleries (figure 176G and H). Severely attacked trees have dead, broken trunks and branches and knotty swellings (figure 176I) (Garman 1916, Wollerman 1962). Repeated attacks and breakage often result in nothing more than shrubby sprout growth. Black locust will grow on nutrient-poor soils and is often planted on badly eroded sites for land reclamation. Trees on such sites are more prone to borer damage, especially during droughts, after wildfire, when livestock graze the land, and when other influences damage the site and reduce tree vigor (Berry 1945). Locust borers annually destroy thousands of hectares of natural regeneration and young plantations of black locust, and enormous numbers of older trees, especially slow-growing overtopped trees. On the other hand, trees on good sites and thrifty dominants older than age 10 are seldom killed.

Control. Woodpeckers are the most important natural enemies. Downy and hairy woodpeckers destroyed an average of 30% of the larvae during 4 years in Ohio (Hall

1942). Two hymenopterous parasites—*Dolichomomitus irritator* (Fabricius) and *Habrolepoidea depressa* Girault—destroy less than 1% of the larvae (Hall 1942, Krombien and others 1979). Silvicultural controls are partially effective in minimizing damage (Galford 1984). Slow-growing young stands and severely injured stands should be cut back during dormant periods to initiate regeneration by sprouting. Sprouts should be thinned to leave only the most vigorous. Mixing tree species in plantings is beneficial. Mixed stands usually produce denser shade (reducing oviposition) and more leaf litter (improving the site) than pure stands. Pruning, however, allows more light penetration to the trunk, which favors egg-laying females, and provides crevices favorable for oviposition around wounds and callus tissue. Ornamental and other small plantings benefit from mulching. Fencing out livestock and preventing wildfire can promote site quality and tree vigor, reducing borer damage. Old trees with stag-headed tops serve as brood trees. Removing them from the vicinity of planting sites can help to minimize damage. Planting superior varieties of black locust can help reduce borer injury. Shipmast locust and a strain called "Higbee" have exhibited resistance to the locust borer (Hall 1942). Insecticides may be needed to prevent or control borers in valuable ornamental trees (Galford 1984). Trunk sprays during egg laying have been effective in preventing new attacks.

Megacyllene snowi snowi (Casey)

[locust root borer] (figure 177)

Hosts. Locust. New Mexico locust is the specific host (Linsley 1964). Adult beetles have been collected on goldenrod flowers but do not reproduce in this plant (Linsley and others 1961).

Range. Southwestern subspecies in Arizona, New Mexico, and northern Mexico (Linsley 1964) west of the Continental Divide in New Mexico into Arizona. Another subspecies—*M. s. zuniana* (Casey)—occurs east of the Continental Divide only in central New Mexico (Tyson 1982). Associated with host plants growing mostly at high elevations (Lewis 1979).

Description. ***Adult.*** Moderately large, robust, dark brown to black longhorn beetle ranging from 11 to 18 mm long and 3.5 to 7.0 mm wide (figure 177A) (Hopping 1937, Linsley 1964). Antennae reddish brown and reach to middle of elytra in males and extend to basal third of elytra in females (Linsley 1964). Legs pale red or reddish brown. Head with band of dense yellow pubescence at base that extends along margin of eyes and above base of antennae. Pronotum has four transverse bands of gray to yellow pubescence. Elytra have seven narrow, transverse, gray and yellow, pubescent bands. Abdomen densely clothed along sides with bright yellow pubescence. Female abdomen covered with dense, yellow pubescence. ***Larva.*** Moderately robust, yellowish white except for dark brown head and mouthparts and about 22 mm long (figure 177B).

Biology. Adults present from July through September and often found on bark and foliage of hosts and feeding on nearby goldenrod flowers (Linsley 1964, Linsley

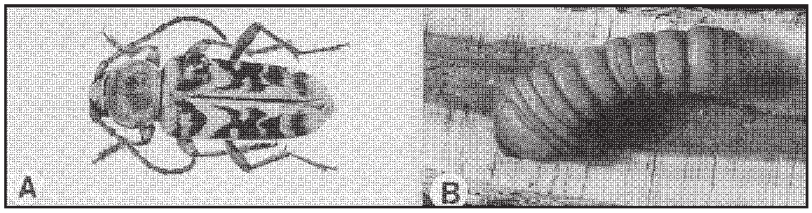

Figure 177—Megacyllene snowi snowi, *[locust root borer]: A, adult; B, larva (specimens courtesy D. Whitehead).*

and others 1961). Females deposit eggs around the root collar, and larvae mine the roots (Linsley 1964).

Injury and damage. Presence of these colorful beetles on the foliage of host plants or on nearby goldenrod flowers is evidence of a local infestation. Infested locust, particularly saplings and small trees, are often broken over at the groundline (Linsley 1964). Inspection of breaks and excavating the stump reveals tunneling larvae. Galleries are found in stems slightly above ground down into the root crown; those made by the subspecies *M. s. zuniana* (Casey) occur as high as 30 cm above ground (Tyson 1982). Damage is usually negligible.

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

Megacyllene robusta (Linsley and Chemsak)

[honey mesquite borer]

Host. Mesquite. Honey mesquite is only known host. Adult beetles have been collected from goldenweed blossoms, but none have been reported boring into these stems (Hovore and others 1978).

Range. Limited distribution in southwestern New Mexico and southeastern Arizona (Linsley 1964).

Description. ***Adult.*** Large, robust, black longhorn beetle with brownish red legs, reddish black antennae; about 21 mm long (Linsley 1964). Pronotum has three transverse yellow bands, with the first just behind anterior margin, the second behind middle, and the third, basal. Elytral pattern of seven yellow or yellow and white transverse partial-to-complete bands. Antennae reach to about apical quarter of elytra in male and extend only to basal third of elytra in females. Abdomens densely yellow pubescent along sides.

Biology. Adults are present during October and November (Linsley 1964). Females lay eggs in bark crevices. Larvae mine beneath the bark and tunnel into the wood, making broad and meandering galleries that are packed with fine, grainy frass. Pupal cells are made in the sapwood or heartwood and plugged with coarse, shredded frass. Frass plugs are sometimes visible. New beetles chew holes through the bark to exit (Hovore and others 1978). The life cycle is unknown but presumably requires at least 1 year.

Injury and damage. Presence of the colorful adult beetles on blossoms and foliage can alert landowners of local infestation. Typically, attacks the base of small trees 10 to 15 cm in diameter and the large lateral branches of older trees (Hovore and others 1978). Dissection of infested stems reveals frass-packed galleries and larvae. Frass can sometimes be seen protruding from the bark. Fresh emergence holes in the bark are conspicuous in late fall. Old holes from previous years are evident as oval rings of scar tissue (Hovore and others 1978). Populations are generally small and infestations are scattered; thus, its impact on mesquite is very light.

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

Glycobius speciosus (Say)

sugar maple borer (figure 178)

Hosts. Maple. Sugar maple is only known host (Hoffard and Marshall 1978).

Range. Throughout most of the range of sugar maple, extending from southern Canada through the southern Appalachian Mountains to Tennessee and North Carolina and westward to Missouri and Minnesota (USDA FS 1971). Less common in its southern range and found mostly at higher elevations.

Description. ***Adult.*** Brilliant black and yellow longhorn beetle; stout and 22 to 27 mm long (figure 178A) (Packard 1890, Shenefelt and Benjamin 1955, USDA FS 1971). Head bright yellow. Thorax has two parallel yellow bands not joined at middle. Elytra with five, dark yellow bands, the middle one near base W-shaped. Can be distinguished from the locust borer by yellow legs and two black dots near end of elytra. ***Egg.*** Elongate, whitish, and 2 to 2.5 mm long. ***Larva.*** Robust, rosy white, and cylindrically shaped, with minute thoracic legs and brownish head and mouthparts (figure 178B). When fully grown, 40 to 58 mm long.

Biology. Adults emerge during June and July. Eggs are laid in cracks or crevices in the bark from June into August (USDA FS 1971). After hatching, the larvae bore beneath the bark and form meandering mines in the cambium. Larvae feed until early fall, when they excavate shallow cells in the sapwood to overwinter (Hoffard and Marshall 1978). During the second season, larvae tunnel just under the bark, longitudinally or transversely, and partially around the bole or branch, but generally upward. In winter, larvae bore into the wood, upward at first and then parallel to the grain for several centimeters, often forming a J-shaped gallery (USDA FS 1971). At the far end of tunnels, the larvae form pupal chambers. Before pupating in spring, larvae cut exit holes (Hoffard and Marshall 1978).

Injury and damage. The first sign of activity is wet, discolored spots on the bark. Subsequently, dust and frass can be found exuding from the holes in the bark or in bark crevices below the holes (Hoffard and Marshall 1978). Borer attacks on branches may cause foliage discoloration, branch breakage, or death of the branches. Stems may break in small trees when galleries partially or completely encircle them (USDA FS 1971). Old borer scars are horizontal or vertical (figure 178C and D). Callus tissue bulges to form swellings and cankerlike scars (figure 178E). Horizontal scars are left (figure 178F) when larvae do not complete their life cycle and generally indicate less internal damage than vertical scars. Vertical scars (figure 178D) indicate that larvae survived into the second year. Ridges of bark that form over the galleries rise, crack, and sometimes slough off, leaving open-faced scars (figure 178C) (Hoffard and Marshall 1978). Lumber sawn from infested trees has oval holes measuring 7 by 13 mm to 10 by 18 mm in cross section (figure 178G). Although this pest prefers intermediate or co-dominant trees of low vigor, vigorous trees from sapling to mature may be attacked. The percentage of trees injured is likely to be greater in uneven-

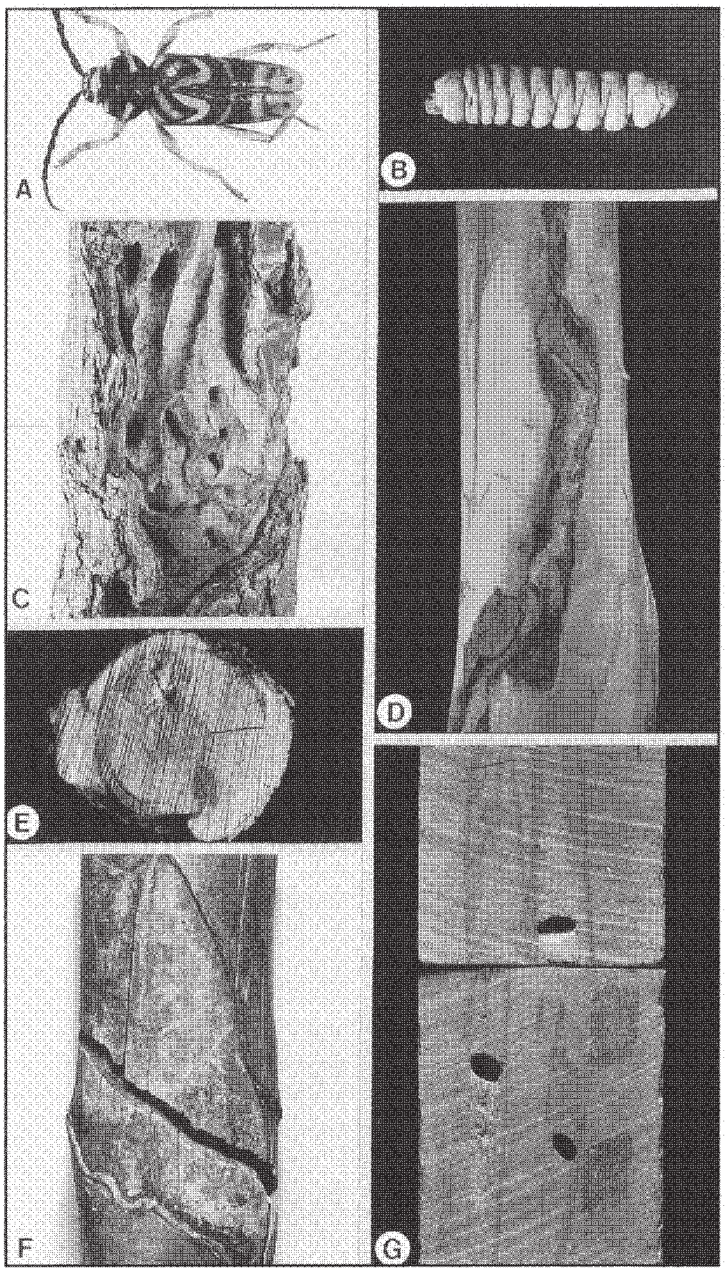

Figure 178—Glycobius speciosus, *sugar maple borer: A, adult; B, larva; C, maple trunk heavily scarred by borers; D, vertical gallery; E, cross section with cankerlike scars; F, spiral or horizontal gallery; G, oval galleries in lumber (specimens courtesy J. Simeone).*

aged stands than in even-aged stands (Shigo and others 1973). Attacks occur from ground level up to 9 m, but injuries are more likely on the lower part of the bole, with as many as 95% of the attacks on the lower 6 m of the bole (Talerico 1962). This borer is generally considered the most important insect pest of sugar maple. Infestations have been most damaging in the Northeast, particularly in New York and Pennsylvania (Newton and Allen 1982). Girdling impairs maple sap production. The Armstrong Forest Company of Johnsonburg, Pennsylvania, found that borer damage interrupted the upward movement of herbicides used during chemical girdling (Talerico 1962). Borers feeding close together can often completely girdle and kill trees (Shenefelt and Benjamin 1955). The greatest economic loss results from defects caused by larval galleries, discoloration, decay, and twisted grain (Hoffard and Marshall 1978). Mineral streak in sugar maple is actually discolored wood from sugar maple borer wounds (Shigo and others 1973). Damage is generally most severe in shade trees and in trees in open stands and near streams. Forest infestations appear to be heaviest in open, second-growth stands or in heavily grazed understocked stands (USDA FS 1985). As much as 26 to 43% of the sugar maple trees in stands may be damaged (Newton and Allen 1982, Shigo and others 1973).

Control. Several cultural methods have been suggested (Hoffard and Marshall 1978). Large, low-vigor, exposed trees are most suseptible to attack, and cultural controls should be used. In uneven-aged stands, trees should be selectively cut at maturity; in even-aged stands, all large trees should be harvested at the same time. All old, low-vigor, and heavily infested trees should be harvested before June, when adults normally emerge. Excluding grazing livestock (which may reduce stand vigor) and maintaining well-stocked stands also offer control. Timber stands should be surveyed to assess borer impact and determine control needs (Hoffard and McCreery 1977). For valuable specimens, such as shade trees, water and fertilizer should be used as needed, especially during droughts and other periods of stress. Infested branches of shade trees should be pruned and burned. Larvae in the early stage of attack may be destroyed by probing through the entrance hole with a wire. Chemicals may be necessary for control in valuable trees.

Megacheuma brevipennis (LeConte)

[greasewood borer]

Hosts. Greasewood, saltbush. Black greasewood favored but shadscale saltbush, Gardner saltbush, and Parry saltbush also attacked (Barr and Penrose 1969, Hovore 1979).

Range. Occurs in California north to Oregon and east to Wyoming, Nevada, and Utah (Hovore 1979, Linsley 1964). Most abundant in the northern Great Basin and adjoining areas (Barr and Penrose 1969).

Description. ***Adult.*** Robust, elongate longhorn beetle with slightly abbreviated elytra and greatly distended abdomen, 11 to 20 mm long (Hovore 1979, Linsley

1964). Reddish antennae reaching about middle of elytra. Legs hairy. Upper surface of thorax and abdomen somewhat flattened. Elytra have three well-defined transverse bands and poorly defined dark areas near their apices; elytral length slightly more than twice basal width. Body reddish brown to black and clothed entirely with short, dense, grayish white to yellowish hairs that lie flat against integument. Two subspecies—*M. b. brevipennis* Hovore (with grayish white body pubescence and dark appendages) and *M. b. tiemanni* Hovore (with yellow body pubescence and pale appendages)—have been described (Hovore 1979). Both are treated together here because there is little difference in their habits, biology, and damage.

Biology. Adults fly from July to October (Hovore 1979, Linsley 1964) and have been seen on foliage of host plants at midday mostly from 11 a.m. to 2:30 p.m. When disturbed, they drop to the ground; females immediately attempt to burrow into the soil and debris near the base of the plant. Females do not fly, but males run swiftly into open sandy areas and take flight when disturbed. Mating occurs in late afternoon on the ground at the base of host plants. After mating, females thrust their abdomens into the soil near the root crown, presumably depositing eggs. Multiple larval infestations are common; as many as eight beetles have been reared from one 3- by 19-cm root-crown section. Pupation occurs within galleries at the root collar. Life cycle is 1 year in southern California but 2 years in Idaho and Oregon.

Injury and damage. Larvae burrow in the main stem, root collar, and roots just above and below ground, and plants sometimes succumb or break at weakened sites. Cutting into the root crown reveals larval galleries, oval to round in cross section, running parallel to the wood grain. Galleries are tightly packed with fine, grainy, dried frass (Hovore 1979). It is common to find dead, dried females on the ground beneath heavily infested hosts. Damage is negligible.

Control. A clerid beetle—*Enoclerus acerbus* Wolcott—preys on larvae and pupae in the roots of host plants (Barr and Penrose 1969). Little else is known about control.

Xylotrechus aceris Fisher

gallmaking maple borer (figure 179)

Hosts. Maple. Red maple is favored. Silver maple, sugar maple, and Norway maple are also attacked (Linsley 1964, MacAloney and Ewan 1964).

Range. Eastern United States south to North Carolina and Georgia and west to Michigan and in southern Canada (Gosling 1973, Linsley 1964).

Description. ***Adult.*** Elongate, slender longhorn beetle with subparallel sides, 10 to 14 mm long, 2.5 to 3.8 mm wide (figure 179A) (Hopping 1932, Linsley 1964, MacAloney and Ewan 1964). Thorax dark brown with four indistinct spots of yellowish white pubescence. Elytra clothed with obscure brownish pubescence sparsely suffused with white and marked with faint lines. Antennae short, extending barely past base of elytra. ***Larva.*** Moderately robust, legless, and

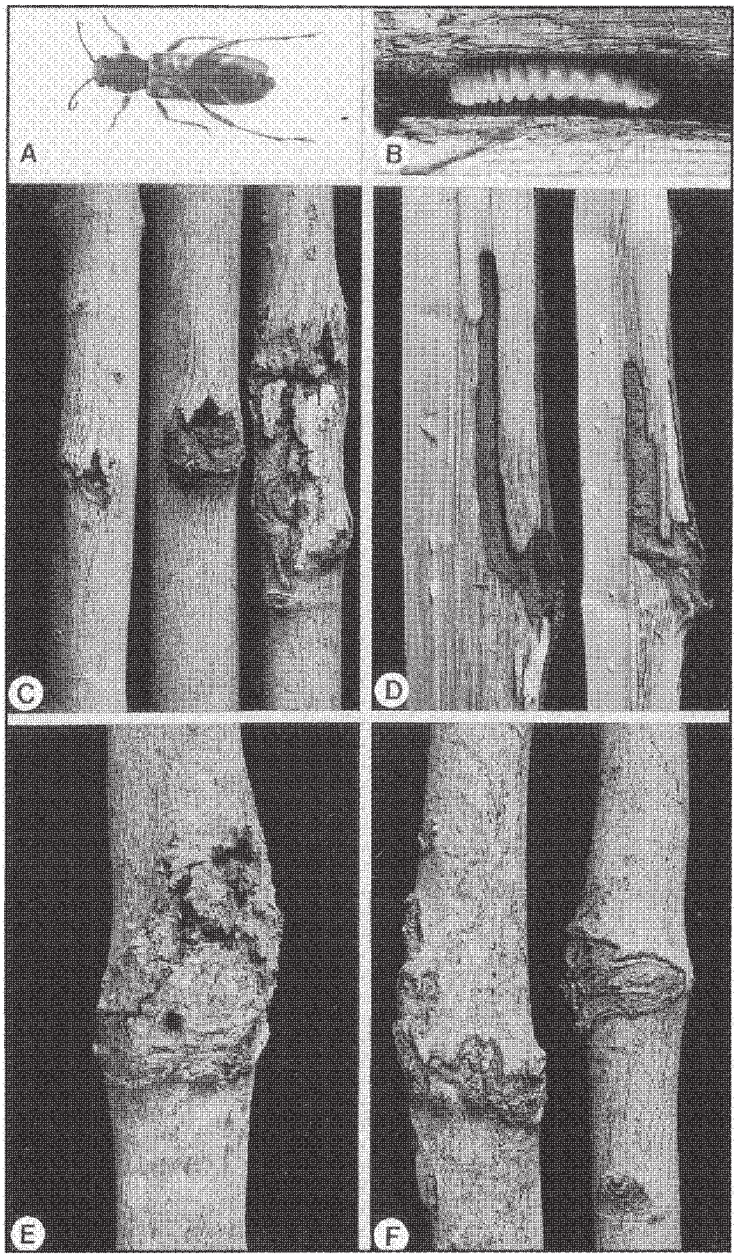

Figure 179—Xylotrechus aceris, *gallmaking maple borer: A, adult; B, larva; C, active attacks in red maple saplings; D, galleries partially filled with frass; E, round emergence hole; F, bulging bark scars from previous attacks.*

12 to 17 mm long (figure 179B). Cream colored with head wider than long, one ocellus on each side, and mandibles rounded at apices. Posterior area of pronotum and ampullae covered with fine, but stiff, brownish, velvety pubescence (Craighead 1923, 1950). ***Pupa.*** Dull white with sides of pronotum armed with short chitinous points.

Biology. Adults emerge June to August and deposit eggs singly at rough spots on the trunk but prefer bases of small dead twigs or in and around wounds (Gosling 1973, Knull 1946). Broken bark around scars of old attacks is particularly attractive to females for oviposition. Larvae bore directly into the sapwood and heartwood, often to the center of small stems. During the second year, larvae tunnel upward or occasionally downward in the stem (Craighead 1950). Portions of the galleries may be filled with light brown, tightly packed frass. Galleries are fairly uniform, extending horizontally or obliquely inward, then straight upward or sometimes downward. Completed galleries usually measure 10 to 15 cm long, but galleries up to 31 cm long have been reported (Knight 1968). When mature, larvae construct pupal cells at the end of the burrows by plugging the galleries tightly with frass. New adults chew through the frass plug and gnaw round exit holes at or near gallery entrances. One generation requires 2 years.

Injury and damage. Visible evidence of infestation is swellings or gall-like formations on otherwise smooth stems. Bark begins to break away at the entrance, exposing wood darkened by decay (figure 179C). Fine yellowish frass may be present at gallery entrances. Dissection of infested stems reveals a small cavity under the bark and a gallery 7 to 12 mm in diameter extending 5 to 12 mm horizontally into the stem, then turning 8 to 13 cm straight up (figure 179D). Attack sites sometimes resemble disease cankers. Young saplings 4 to 7 cm in trunk diameter, particularly those in the understory, are most susceptible, but attack sites have been found in trunks up to 10 cm in diameter (Champlain and others 1925, Knight 1968). Attack sites are most common in trunks but sometimes occur in branches of larger trees. Attack sites are prevalent in the lower 2.4 m of trunk but can occur to a height of 5.4 m. The gall-like and cankerlike attack sites are slow to heal, allowing secondary insects and fungi to extend injury. Galleries and/or larvae can often be found by examining saplings broken at attack sites. Adults leave round exit holes, 4 to 5 mm in diameter usually in the galled, distorted bark near entrance sites (figure 179E). Swollen, irregular scars that remain on the stems for several years are evidence of previous attacks (figure 179F). Larvae construct tunnels in the heartwood; repeated attacks often destroy the center of trees. Infested trees are rarely killed outright but may be seriously weakened, becoming subject to breakage (USDA FS 1985). It is common to find 75% of red maples in a neighborhood or local forest stand with borer injuries and many broken off at the point of attack (Craighead 1950). Repeated attacks on young trees leave defective stems that sometimes never recov-

er adequately for desirable crop trees. A low-quality log may be the result of old borer damage (Knight 1968).

Control. Moderate woodpecker predation occurs. Little else is known of the natural and cultural controls. Chemicals applied during oviposition would probably prevent attacks on valuable trees, but none have been evaluated.

Xylotrechus insignis LeConte

[Pacific willow borer] (figure 180)

Host. Willow. Pacific willow specifically mentioned as a host, but other willows undoubtedly attacked (Craighead 1923, Linsley 1964).

Range. Oregon south through California to northern Baja California and east to Arizona and Nevada (Essig 1958, Linsley 1964).

Description. ***Adult.*** Beautiful, cylindrical, reddish brown to black longhorn beetle with yellow markings; 13 to 18 mm long (figure 180A) (Essig 1958, Linsley 1964). Head has conspicuous, V-shaped frontal carina; antennae short and robust, barely reaching base of elytra. Pronotum bordered by narrow, yellow band in front and rear of females. Elytra marked with pale pubescence by a basal patch; an oblique, oval, subbasal spot; a transverse band to apical one-third; and a broad apical marginal patch. Males slightly smaller and less colorful. Legs moderately slender and elongate. ***Larva.*** Elongate and white except for brown head and mouthparts, ampullae covered with velvety pubescence only on perimeter and along median line, and 16 to 24 mm long (figure 180B) (Craighead 1923).

Biology. Adults begin emerging in March and are present until August (Linsley 1964). Females deposit eggs around dead, dying, and broken branches. Larvae make long frass-filled mines under the bark, enter the wood, and complete development. Pupation occurs in chambers in the wood galleries. New adults cut holes directly through the wood and bark to emerge in spring. The life cycle requires 1 or 2 years.

Injury and damage. Initially, injury is difficult to diagnose, but after a few months, the bark begins to loosen in patches. Removing the bark reveals mostly longitudinal larval mines etched in the surface of the sapwood and packed with granular frass (figure 180C). Dissecting the sapwood reveals numerous galleries deep in the wood (figure 180D). In cross section, the galleries are oval, 3 to 4 mm by 6 to 8 mm, and mostly filled with frass (figure 180E). Beetles leave round, 4-to 5-mm-diameter exit holes in the bark (figure 180F). This pest attacks living trees but is found most commonly in dying trees. It can riddle the wood of infested trees, but the host species and condition of host minimize its overall economic impact.

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

Xylotrechus quadrimaculatus (Haldeman)

[birch and beech girdler] (figure 181)

Hosts. Birch, beech, maple, alder, American hornbeam. Birch and beech are

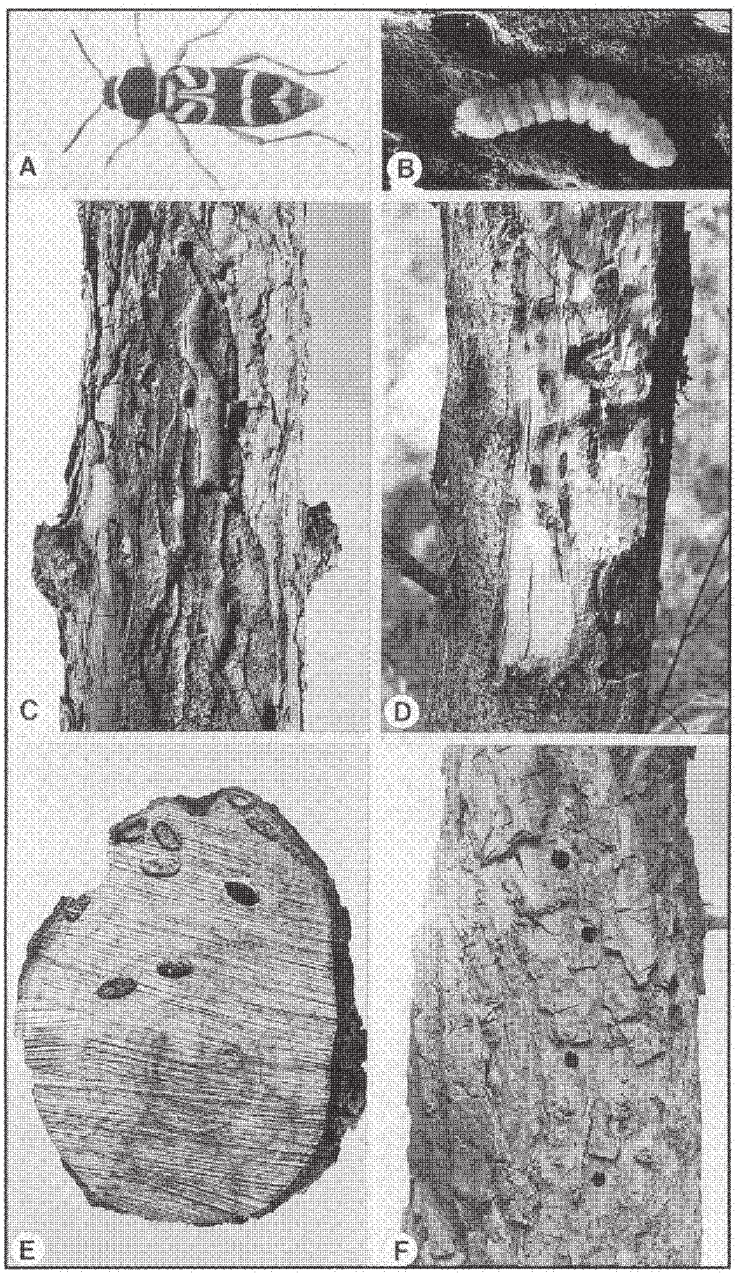

Figure 180—Xylotrechus insignis, *[Pacific willow borer]: A, adult; B, larva; C, longitudinal frass-packed galleries; D, galleries in wood; E, cross section of oval galleries; F, round emergence holes in bark (specimens courtesy F. Hovore and R. Penrose).*

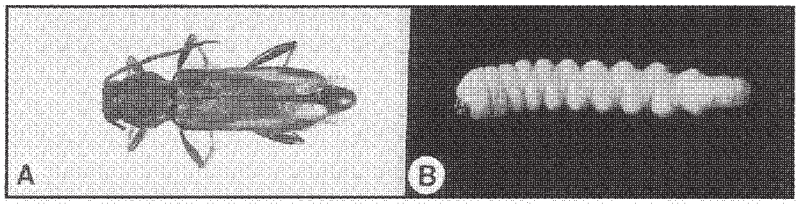

Figure 181—Xylotrechus quadrimaculatus, *[birch and beech girdler]: A, adult; B, larva (specimens courtesy D. Whitehead).*

major hosts (Leonard 1928, Linsley 1964, USDA FS 1985). Pear mentioned, but not confirmed.

Range. Northeastern United States and eastern Canada, but recorded as far west as Michigan (Gosling 1973, Linsley 1964).

Description. ***Adult.*** Elongate, slender longhorn beetle, varying from 7.5 to 15.9 mm long and 2.0 to 3.5 mm wide (figure 181A) (Hopping 1932, Linsley 1964, MacAloney and Ewan 1964). Thorax black with four yellow, pubescent spots. Elytra pale brown and indistinctly marked with pale yellowish white lines. Adults closely resemble sibling species, *X. aceris*, but are distinguished by having fainter spots on thorax and stronger markings on elytra. ***Larva.*** Moderately robust, legless, and creamy white; and slightly larger than adult when fully grown (figure 181B). Larvae distinguished by a single perimeter of ampullae that are velvety pubescent instead of entirely pubescent as in *X. aceris* (Craighead 1923). ***Pupa.*** Dull white with sides of pronotum armed with slender chitinous points.

Biology. Adults emerge from mid-May to mid-June but are collected as late as August (Champlain and others 1925, Linsley 1964). Females deposit eggs in bark crevices and at healed injuries, particularly in the axil of small twigs. Eggs hatch in about 6 days, and larvae begin feeding beneath the bark, usually in straight lines. Larvae begin girdling branches when they reach 6 mm long. Larvae make concentric cuts starting from the mine just under the bark to the stem center, continuing until the branch is almost severed (USDA FS 1985). After completing the girdles, larvae generally tunnel distally into the severed branches. Girdled branches soon fall, and most larvae fall to the ground with the severed branches. A few can be found in the branch stubs remaining on the tree. Occasionally, branches break before the girdle is complete, and the larvae are dislodged and fall freely to the ground and die. Larvae in girdled branches mine beneath the bark for 5 to 10 cm, then bore deeper into the wood, making galleries 15 to 30 cm long. Larvae pack the galleries tightly with granular frass as they advance. During fall, the larvae make simple cells at the ends of galleries to overwinter. In spring, usually in April, mature larvae construct exit tunnels to the outer bark and then pupate. Pupation lasts 12 to 15 days. New adults complete the exit holes and emerge. There is one generation per year.

Injury and damage. Severed branches hanging in the canopy and lying on the ground beneath host trees are evidence of infestation (Champlain and others 1925, MacAloney and Ewan 1964). Pruned branches and branch stubs show a clean, circular cut in the sapwood encircling the stem directly under the bark, extending more or less to the stem center. The bark is not cut, and sometimes, a small portion of the stem center is not severed. Weakened branches break from their own weight or the wind. The girdled end of the severed branch usually contains a small larval hole tightly plugged with frass. Branches from 13 to 50 mm in diameter may be girdled. Infestations are most common on ridge tops of hills and mountains (Craighead

1923). Although forest trees are seldom seriously damaged, valuable shade and ornamental trees may be pruned. Severed branches hanging in the crown and pruned branches littering the ground can reduce esthetic value in residential areas.

Control. Collecting and destroying pruned branches containing the larvae during fall, winter, and early spring help control the borer. Nothing is known of the natural enemies, and direct controls have not been investigated.

Xylotrechus obliteratus LeConte

[poplar-butt borer] (figure 182)

Hosts. Poplar. Quaking aspen is chief host; other poplars and aspens also attacked (Craighead 1950).

Range. Most abundant in the Rocky Mountain region but also found in parts of the eastern United States (Craighead 1950, Linsley 1964).

Description. ***Adult.*** Robust, elongate longhorn beetle 10 to 18 mm long and 3.8 to 5.0 mm wide (figure 182A) (Craighead 1950, Hopping 1932). Body sparsely covered with gray pubescence. Pronotum may or may not be marked with yellow bands at anterior and posterior margins. Gray elytra suffused with white pubescence and crossed by three yellow bands—the first oblique, the middle curved, and the last transverse. Antennae short, barely reaching base of elytra. ***Larva.*** Dull white, legless, and moderately robust (figure 182B). Can be distinguished from larvae of *X. aceris* and *X. quadrimaculatus* by finer velvety pubescence on pronotum and ampullae (Craighead 1923, 1950).

Biology. Adults are present in late summer, particularly during July and August (Craighead 1950, Linsley 1964). Females deposit eggs in bark crevices and surface irregularities or where the wood has been exposed on the lower trunk. Larvae tunnel and feed beneath the bark until fall, then overwinter in their galleries. In spring, they enter the wood, which they work for several years. The larvae generally extend their galleries downward so that the greatest portion of feeding is beneath the surface of the ground. Mature larvae make upward excavations extending outward toward the bark, form pupal chambers, and pupate. New adults gnaw holes through the bark and emerge. Females of successive generations continue to lay eggs on currently and previously infested trees and continue infestation until the tree succumbs or breaks.

Injury and damage. Trees that are weakened, dying, or broken in the basal portion should be examined for infestation (Craighead 1923, 1950). Examination reveals tunnels in the wood around the base of the tree, mostly at or just below the ground line. Sometimes, the burrows extend into the upper roots. Repeated attacks often result in the wood being completely honeycombed. Heavily attacked trees eventually die or break. Fallen trees typically break where tunneled and weakened. Inspection of freshly broken trees reveals open tunnels and larvae. This beetle is a pest in the Rocky Mountains, where it has destroyed extensive areas of aspen growing above 2,134 m in elevation. In many

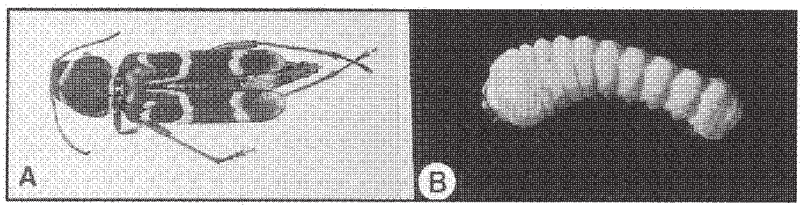

Figure 182—Xylotrechus obliteratus, *[poplar-butt borer]: A, adult; B, larva (specimens courtesy D. Whitehead).*

places, 90% of the trees are attacked each year, some breaking off during winter storms. Stands have been examined following severe ice, snow, and wind storms, and nearly every tree that fell had a hollowed-out butt where it broke (Craighead 1923, Furniss and Carolin 1977).

Control. Little is known of natural and cultural controls. It would be impractical under present forestry conditions to attempt direct control, as stumps and roots would have to be removed to destroy the larvae (Craighead 1950).

Xylotrechus nauticus (Mannerheim)

[nautical borer]

Hosts. Oak, walnut, eucalyptus, peach, willow, madrone. Oaks, walnuts, and willows are favored. Other species are also attacked (Craighead 1923, Linsley 1964).

Range. Occurs along the Pacific Coast from British Columbia (Furniss and Carolin 1977) to California (Linsley 1964). Also recorded from Montana (Essig 1915).

Description. ***Adult.*** Robust, cylindrical longhorn beetle measuring 9 to 16 mm long (Essig 1915, Linsley 1964). Conspicuous, V-shaped ridge on front of head. Integument black, rarely brown, and covered with fine, whitish hairs. Pronotum marked with irregular, sparse patches of whitish gray hairs. Elytra marked with three transverse, zigzag or undulating white lines. Legs moderately elongate. ***Larva.*** Legless, white with brown head and jaws, and about 19 mm long; body slightly wider behind head (Craighead 1923, Essig 1915). Lacks velvety pubescence on pronotum and ampullae present in other *Xylotrechus* species. ***Pupa.*** White to yellow and about 12 mm long.

Biology. Adults emerge and fly from May to July. Newly hatched larvae burrow just beneath the bark for several weeks and complete development deep in the sapwood and heartwood in galleries tightly packed with granular frass. Larvae overwinter in galleries, then pupate just beneath the bark during April and May. The life cycle is 1 year (Linsley 1964).

Injury and damage. Occasionally infests living trees but is commonly found in burned, dying, or dead trees, where it infests branches and trunks (Essig 1915). Circular exit holes are made by newly emerged adults in the outer bark. Peeling back the bark exposes a network of meandering and intersecting galleries made by the smaller larvae on the surface of the sapwood and heartwood. Galleries are firmly packed with granular frass (Craighead 1923, Linsley 1964). On living trees, branches are killed back a meter or more by larvae. Eucalyptus logs cut for lumber have been destroyed. Firewood is commonly riddled, and adults often emerge in homes where firewood is stored (Furniss and Carolin 1977).

Control. Natural controls include one insect predator—*Temnochila virescens* (Fabricius)—and two hymenopterous parasites—*Atanycolus simplex* (Cresson) and *Aulacostelbus montanus* (Cresson) (Linsley 1964). Direct controls are rarely needed in living trees but may be necessary in logs cut for lumber.

***Neoclytus acuminatus* (Fabricius)**
redheaded ash borer (figure 183)

Hosts. Ash, hickory, oak, walnut, birch, beech, maple, eastern hophornbeam, dogwood, persimmon, redbud, holly, hackberry, black locust, honeylocust, yellow-poplar, chestnut, Osage-orange, sassafras, lilac, mountain-mahogany, pear, cherry, plum, peach, apple, elm, basswood, sweetgum. Ash is preferred, followed by oak, hickory, persimmon, and hackberry, and, to a lesser extent, the other species (Barr and Manis 1954, Johnson and Lyon 1988, Linsley 1964, MacAloney and Ewan 1964, Waters 1981).

Range. The Atlantic Coast and Gulf Coast west to Idaho, Colorado, and New Mexico and westward across Canada to Manitoba (Craighead 1950, Furniss and Carolin 1977).

Description. ***Adult.*** Elongate, tapering longhorn beetle, varying greatly in length from 4 to 18 mm (figure 183A) (Linsley 1964, MacAloney and Ewan 1964). Pronotum about as wide as long and broadly rounded at sides; upper surface finely and densely punctured and covered with fine hairs. Anterior and posterior margins of pronotum usually black. Four narrow yellow bands of condensed, fine hairs mark upper surfaces of elytra. Elytra narrower at base than middle of prothorax and sides taper, or narrow, to middle and then more gradually toward apex. Second and third pairs of legs noticeably longer than front pair (Beal and others 1952). ***Egg.*** White, elongate, tapered at one end, and 1.2 by 0.2 mm (Waters 1981). ***Larva.*** Mature larva short, robust, cylindrical, and 10 to 22 mm long (figure 183B) (MacAloney and Ewan 1964). Body surface dull and densely clothed with fine, silky, lemon white hairs. Thoracic legs minute, consisting of one joint and soft spine.

Biology. Adults emerge May to August in the North and February to November in the South (Linsley 1964). In south Alabama, beetles are active March to mid-November, peaking in April, July, and September (Waters 1981). Eggs are most often deposited in bark crevices and cracks, beneath lichens and bark scales, and occasionally at twig nodes. Eggs hatch within 6 days, and young larvae rapidly penetrate the bark. By the 20th day, they have entered the sapwood. During the remainder of development, larvae feed entirely within the sapwood, never entering the heartwood, and pass through six instars. Larval tunnels usually follow the direction of the wood grain, but in smaller trees, the galleries may run horizontally and vertically (Johnson and Lyon 1988). Galleries are always packed tightly with fine, granular frass. Pupation occurs in parallel-sided, frass-free cells either in, or close to, the surface of the sapwood. To emerge, newly formed adults chew circular holes directly through the bark. This borer overwinters most frequently in the larval stage, and the overwintering generation pupates in late winter and early spring. A generation can be completed in 60 to 90 days in Alabama (Craighead 1950, Waters 1981). In Illinois, one generation per year is most common, with a partial second generation during some years (Johnson and Lyon 1988); however, in the South, there are two to three

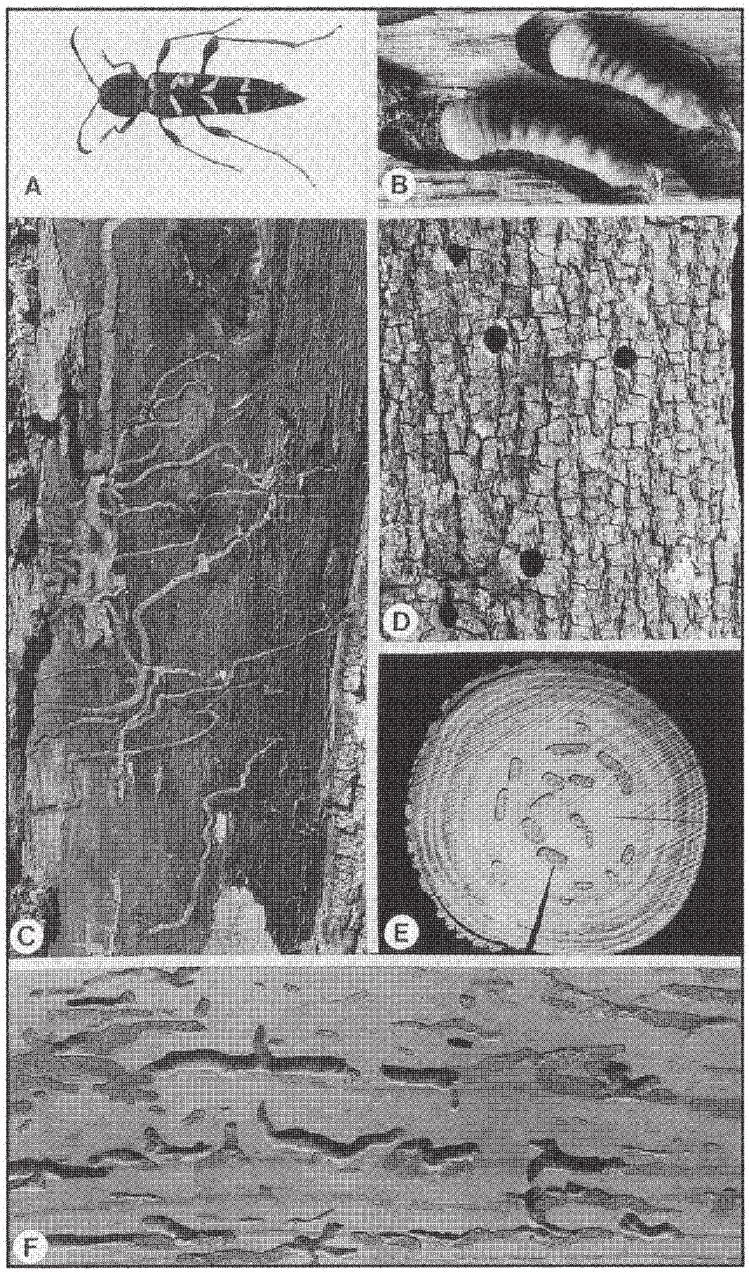

Figure 183—Neoclytus acuminatus, *redheaded ash borer: A, adult; B, larvae; C, narrow, meandering frass-packed galleries beneath bark; D, round emergence holes in green ash; E, cross section of oval, frass-packed galleries in wood; F, ash lumber riddled with galleries.*

generations a year (Waters 1981).

Injury and damage. Initial attacks are difficult to diagnose because there are no open entrance holes and little frass is ejected. However, numerous, long, narrow, frass-packed mines can be observed on the surface of the sapwood when the bark is removed (figure 183C). Later, many round exit holes 2 to 5 mm in diameter appear in the bark (figure 183D). Dissecting infested stems reveals numerous galleries throughout the wood. In cross section, the final galleries are flattened oval, 4 by 12 mm, and packed lightly with granular frass (figure 183E). Injury to recently felled trees and unseasoned logs is often confined to the lower half or shaded undersides (Waters 1981). Infested logs sawn into lumber are often riddled with galleries, making them unmarketable (figure 183F). This pest commonly infests weakened, dead, and dying trees but is most destructive to unseasoned logs containing bark. Over 1 million board feet of ash logs have been completely destroyed in some logging operations (Beal and others 1952, Craighead 1950). This species is also a serious pest of apparently healthy black locust trees in farm woodlots and windbreaks (Barr and Manis 1954). Also, it often attacks recently planted trees.

Control. It is vulnerable to many parasites and predators. Nine species of parasites have been reported (Beal and others 1952, Linsley 1964, Waters 1981). A study in south Alabama revealed that 22% of overwintering larvae were killed by two braconid wasps—*Iphiaulax* sp. and *Wroughtonia ferruginea* (Brues) (Waters 1981). Predators include woodpeckers; nuthatches; two clerid beetles—*Chariessa* sp. and *Thanasimus* sp.; and a trogositid beetle—*Temnochilia* sp. (Waters 1981). Good cultural practices should be followed, because healthy trees are rarely attacked. Recently felled trees and green sawlogs may be infested within 20 days during the warm months, particularly in the South. Therefore, logs should be moved promptly to the sawmill and processed. Direct controls may be needed to protect valuable trees and sawlogs.

Neoclytus tenuiscriptus Fall

[seepwillow borer] (figure 184)

Host. Baccharis. Reared only from mulefat baccharis (Hovore 1983).

Range. Reported from only six counties in southern California and from southwestern Arizona (Linsley 1964).

Description. ***Adult.*** Elongate, moderate-sized longhorn beetle, with subparallel sides and reddish brown integument with lighter markings; 7.5 to 12.0 mm long (figure 184A) (Linsley 1964). Head and pronotum finely to coarsely punctate and without pubescent bands or patches. Antennae extend slightly past base of elytra. Pubescent bands on elytra are dense and appressed and have white or yellowish hairs; pattern consists of narrow transverse band behind elytra base; narrow, median, acutely angulate band near suture; and slightly broader, transverse, subapical band. Legs noticeably slender and elongate.
Larva. White (except for dark head and

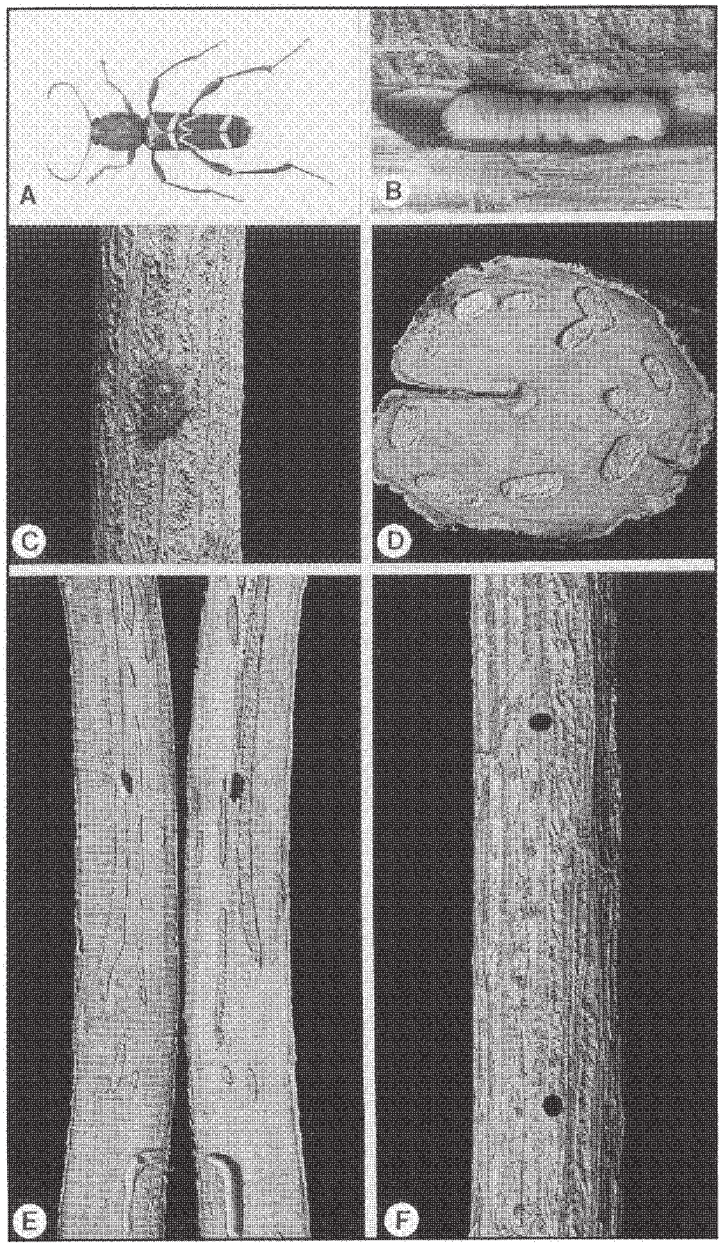

Figure 184—Neoclytus tenuiscriptus, *[seepwillow borer]: A, adult; B, larva; C, resinous exudate on bark indicating attack; D, cross section of frass-packed galleries; E, longitudinal galleries and pupal cell; F, round emergence holes in bark (specimens courtesy F. Hovore and R. Penrose).*

mouthparts) and cylindrical, measuring 10 to 16 mm long (figure 184B).

Biology. Adults emerge and fly from March to June (Linsley 1964). Females apparently deposit eggs mostly on lower stems. Larvae mine the basal portions of stems 15 to 50 mm in diameter, with occasional galleries extending distally into the stem terminus and lateral branches (Hovore 1983). Heavily infested canes may have a dozen galleries, representing both recent and older attacks. Just before pupation, larvae chew exit routes from the simple, elongate pupal cells outward to the inner bark. Based on field observations of larval instars, the life cycle is 2 years.

Injury and damage. Initial attacks are often difficult to detect. In some cases, small dark stains appear on the bark. These spots may contain gelatinous or resinous material (figure 184C). The gelatinous deposits congeal and harden and often mark the site of pupal cells that have been chewed outward to the inner bark surface. Dissection of infested stems reveals that most tunnels are in the wood. In cross section, the galleries are oval, packed with granular frass, and 1.5 to 2.0 mm by 4 to 6 mm (figure 184D). Most galleries extend longitudinally with the stem, and except for pupal cells and exits, are packed with frass (figure 184E). Round holes 3 to 4 mm in diameter in the bark mark the sites of adult emergence (figure 184F). Heavily infested plants frequently succumb (Hovore 1983).

Control. Immature stages are very heavily parasitized by unidentified ichneumonoid wasps. Rearing studies reveal a wasp-to-beetle ratio exceeding 4:1 (Hovore 1983). Direct controls are not needed.

Neoclytus cordifer (Klug)

[mangrove borer]

Hosts. Mangrove, orange, mango, pomegranate. Mangrove preferred, but citrus trees, especially orange, are sometimes heavily attacked (Back 1918, Linsley 1964).

Range. First described as a citrus pest in Cuba in 1836; reported damaging citrus in Florida in 1910 (Back 1918). Reported from Georgia since then (Linsley 1964).

Description. ***Adult.*** Moderately small longhorn beetle, with reddish brown and white markings (Linsley 1964). Elytra about 2.5 times as long as wide, reddish brown with two variable white transverse bands and tipped apically with white. Legs long and slender. Antennae slightly longer in males than females. Beetles range from 7 to 15 mm long.

Biology. Adults emerge April through June (Back 1918). Young larvae feed on inner bark and sapwood where frass-plugged winding burrows stand out in contrast to discolored sapwood. Larvae eventually bore deep into the heartwood. Mature larvae tunnel back to the surface then retreat a short distance beneath the bark to pupate. New adults chew exit holes up to 9 mm in diameter through the wood and bark.

Injury and damage. Borer exit holes 6.4 to 9.7 mm in diameter in the bark are evidence of infestation (Back 1918). Tunnels can be found in the inner bark, sapwood, and heartwood of branches, trunk, crown, and roots. Trees less than 18 cm in

diameter are most apt to be attacked. This borer is a potentially serious pest of the orange industry in Florida.

Control. Badly infested trees should be removed and destroyed in early spring before the new adults emerge. Chemical control may be necessary in some localities to protect commercially grown citrus as well as valuable ornamental trees.

Callona rimosa (Buquet)

[mesquite-huisache borer] (figure 185)

Hosts. Mesquite, huisache. Honey mesquite appears to be favored (Linsley 1962b, Vogt 1949b).

Range. Southwestern species found in southern and central Texas and northern Mexico (Linsley 1962b, Vogt 1949b).

Description. ***Adult.*** Large longhorn beetle with brown integument in male and black in female, reddish orange femora, lustrous metallic green elytra; males 30 to 36 mm long and females 33 to 38 mm long (figure 185A) (Linsley 1962b). Head sparsely punctate with antennae nearly reaching elytral apices in males and reaching only to middle of elytra in females. Pronotum dull in males and shiny in females, densely punctate, and nearly twice as wide as long. Elytra more than twice as long as basal width, with crinkled surface and broadly rounded apices. Legs sparsely pubescent. ***Larva.*** White, moderately robust, with prominent ampullae and accordian-like segments, measuring up to 40 mm long (figure 185B).

Biology. Adults emerge during May and June (Hovore and others 1987, Vogt 1949b). Adults have been taken on several nonhost trees and shrubs. Females apparently deposit eggs on the bark, mostly near the base. Young larvae bore into the bark and sapwood. Galleries often extend down into the roots, especially in small trees. During October, infested trees typically contain one to three larvae, and larvae enlarge the bark openings to form emergence holes but keep them tightly packed with frass. Pupation chambers are formed with wood fibers within galleries, usually below ground. January studies revealed larvae still in the prepupal stage; and studies made in late March and early April found only pupae and teneral adults. These findings indicate one generation per year.

Injury and damage. This pest attacks trees from about 3.8 to 20.0 cm in diameter (Vogt 1949b). Most attack sites occur around the base, but characteristic damage has been observed in branches of large trees. Sap oozing onto the bark from attack sites is the earliest evidence of infestation. Frass is soon pushed through small openings in the bark. Conspicuous quantities of frass, debris, and sap are ejected during July, August, and September. Gallery openings are kept plugged with frass. Dissection of infested trees reveals straight, spacious galleries about 30 cm long and about twice the width of the larvae. Galleries are found in sapwood, mostly at depths less than 2.5 cm beneath the bark. Up to 10% of the trees have been infested in some areas of the lower Rio Grande Valley. However, host trees are hardy, and the vigor of most infested trees seems largely unaffected.

Control. Nothing is known of natural

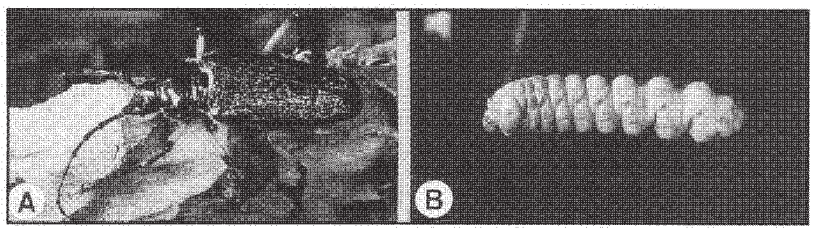

Figure 185—Callona rimosa, *[mesquite-huisache borer]: A, adult; B, larva (A, courtesy F. Hovore; B, specimen courtesy D. Whitehead).*

controls, and direct controls have not been needed.

Crioprosopus magnificus (LeConte)

[Arizona oak borer]

Host. Oak. Arizona white oak, Emory oak, and silverleaf oak are attacked (Hovore 1983).

Range. Southwestern species; Cochise and Pima Counties in southern Arizona and in northern Mexico (Hovore 1983, Linsley 1962b).

Description. ***Adult.*** Large, broad, longhorn beetle measuring 25 to 38 mm long (Hovore 1983, Linsley 1962b). Beetles deep red to yellowish orange (yellowish postmortem) with black markings. Elytra black with two transverse orange bands connected along lateral margin and posterior band not reaching suture. Pronotum with prominent lateral spines. Antennae distinctly longer than body in males and less than body length in females. ***Egg.*** Large, oval, and 2.8 by 4.5 mm.

Biology. Adults emerge in late June or early July and have been collected as late as August 3 (Hovore 1983). Adult emergence appears to be in response to summer "monsoon" rains. Adults are diurnal, with daily activity largely restricted to 9 a.m. to 12 noon. Largest flights occur on warm sunny mornings following rain, with activity decreasing each dry day but increasing again after additional rain. Male beetles fly swiftly over treetops or lazily circle the tree canopy, presumably seeking females. Females are usually on the outer foliage. After mating, females either fly away or crawl down onto the branches or trunk and oviposit. Females deposit eggs singly in fissures of the bark. Egg chorions are coated with a sticky secretion and a layer of fine debris. Larvae tunnel and feed in living trees. Mature larvae pupate at the end of the galleries in elongate-oval chambers plugged to the inner bark surface with wads of excelsior-like frass. New adults chew through the bark to exit. Collections evidence mass emergence in 3-year cycles with few or no specimens collected during intervening years.

Injury and damage. Extensive galleries terminating in pupal cells are found in sapwood and heartwood of living trees (Hovore 1983). Adult emergence holes are cleanly chewed, elliptical openings in the bark up to 20 mm wide. Trunks of small- to medium-sized trees 15 to 30 cm in diameter and lateral branches to 6 cm in diameter may be infested. Limited distribution of the insect makes overall damage minor.

Control. Controls have not been needed. Nothing is known of natural enemies.

Purpuricenus dimidiatus LeConte

[scrub oak borer] (figure 186)

Hosts. Oak, willow. Reared from three species of oaks—California scrub oak, coast live oak, and Dunn oak (Linsley 1962b, Skiles and others 1978).

Range. Throughout California, but more abundant on desert slopes of southern California (Hovore and Giesbert 1976, Linsley 1962b).

Description. ***Adult.*** Moderately robust, black longhorn beetle with reddish markings, measuring 13 to 16 mm long

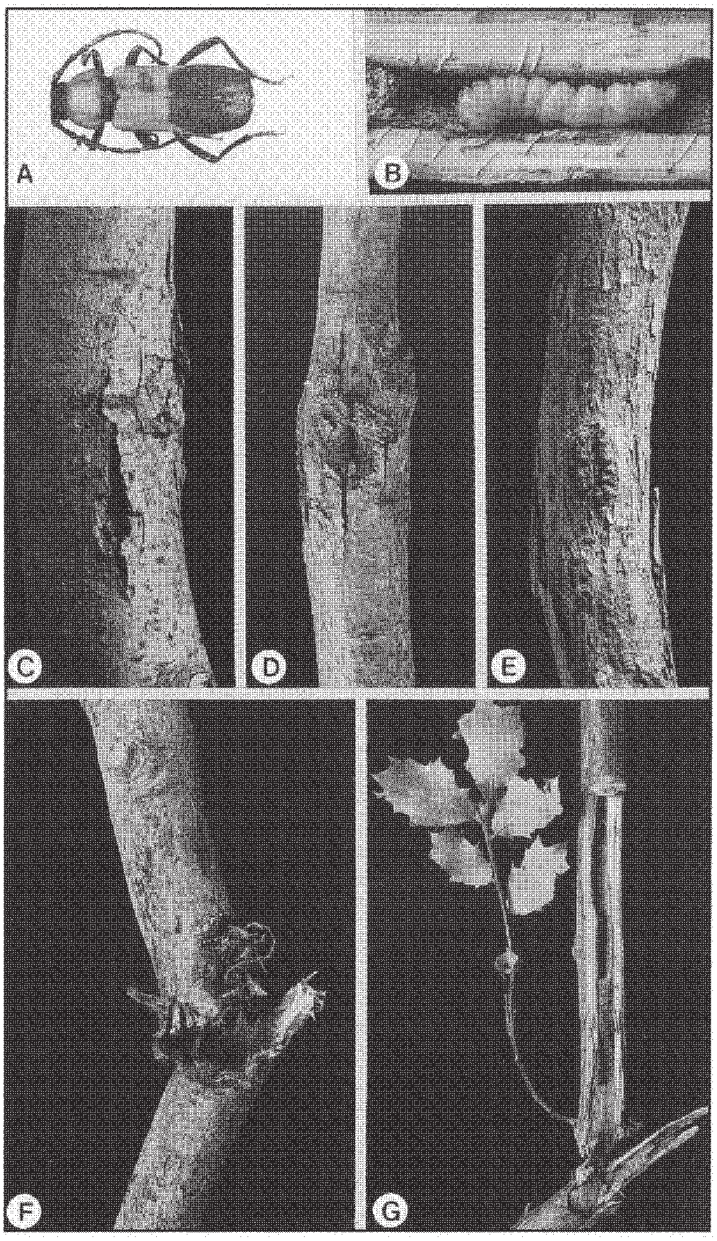

Figure 186—Purpuricenus dimidiatus, *[scrub oak borer]: A, adult; B, larva; C, larval entrance in bark; D, old puckered entrance with frass protruding; E, bulging bark scar over old attack; F, stem broken at girdled site; G, gallery in stem center (specimens courtesy F. Hovore and R. Penrose).*

(figure 186A) (Linsley 1962b). In males, disk of pronotum and base of elytra typically reddish, but some specimens entirely black; in females, entire pronotum and basal half of elytra red. Pronotum wider than long, and antennae reach middle of elytra in females and slightly longer in males. ***Larva.*** Moderately robust, cylindrical, white except for brown head and mouthparts, measuring 15 to 20 mm long (figure 186B).

Biology. Adults emerge May to July (Linsley 1962b). Larvae tunnel into the woody portion of stems, making elongate openings in the bark at entrance sites, which they enlarge as they grow. Although some frass is ejected through the bark entrances, small amounts may be packed tightly within portions of the galleries. As the larvae mature, they plug bark openings with fibrous frass. Pupation occurs in the galleries, and new adults emerge through the frass-plugged entrances. The life cycle requires at least 2 years (Hovore and Giesbert 1976).

Injury and damage. Weakened hosts with faded foliage and dying, dead, and girdled branches indicate infestation (Hovore and Giesbert 1976). Elongate openings occur at entrance sites (figure 186C); entrances may later appear slightly swollen and puckered, with frass protruding (figure 186D). Later, the opening is plugged with fibrous frass. After the site is vacated, the opening heals and forms a puckered bulging scar (figure 186E). Small trunks and branches may be infested, but the pest prefers the basal portion of stems arising from the root collar. Infested stems are typically partially girdled and break (figure 186F). Dissection of infested plants reveals galleries usually in the center of the stem (figure 186G). Damage might be considered negligible in noncommercial hosts, but these species are important as cover in arid habitats and as browse for sheep, goats, deer, and other wildlife.

Control. Nothing is known of natural, cultural, or direct controls.

Purpuricenus axillaris Haldeman

[white oak branch girdler]

Hosts. Oak, hickory, chestnut. Oaks (particularly members of the white oak group) are preferred. Recorded from swamp white oak, chestnut oak, post oak, black oak, pignut hickory, and American chestnut (Champlain and others 1925, Linsley 1962b, Lugger 1884).

Range. Eastern United States from New York and Massachusetts south to Virginia and west to Mississippi and Indiana (Linsley 1962b).

Description. ***Adult.*** Robust, subcylindrical longhorn beetle measuring 12 to 29 mm long (Blatchley 1910). Beetles black with dorsal third of elytra yellow or yellowish orange (Linsley 1962b). Head and pronotum densely punctate. Antennae in females reach slightly beyond tips of elytra and slightly longer in males.

Biology. Adults emerge May to July, but beetles have been taken alive as late as August (Kirk and Knull 1926, Linsley 1962b). Eggs are deposited singly on selected branches (Champlain and others 1925). Larvae bore into branches, then

tunnel downward toward the trunk. They often mine smaller branches along main branches and sometimes prune them. Galleries, which are packed tightly with frass, often extend downward 61 cm or more before the larvae mature and sever the branches. Larvae are usually in the pruned portions of branches but sometimes may be in branch stubs on the tree. They occasionally mine into the main trunk at the base of the branches. The life cycle appears to require 2 years.

Injury and damage. Living branches severed and hanging from the tree or lying on the ground confirm infestation. Branches are mined and tunneled and eventually cut off. Damage is similar to that of *Anelaphus villosus* except that *P. axillaris* prunes larger branches, often up to 50 mm in diameter. The lowest branches on the tree seem to be preferred. This pest was reported to cause considerable damage to lower branches of swamp white oak near Hummelstown, Pennsylvania (Champlain and others 1925).

Control. Collecting and burning fallen branches destroy larvae before adults emerge. Little else is known about natural or direct controls.

Amannus pectoralis LeConte

[saltbush borer] (figure 187)

Host. Saltbush. Fourwing saltbush is only reported host (Linsley 1962b). Adults have been collected on rush bebbia, but it is doubtful that this species is a larval host.

Range. Southwestern species ranging from southern Nevada, Arizona, and southern California to northern Baja California in Mexico (Linsley 1962b).

Description. ***Adult.*** Moderately small, slender, dark brown to blackish longhorn beetle with brownish gray pubescence, and 7 to 10 mm long (figure 187A) (Linsley 1962b). Head irregularly punctate with antennae barely attaining middle of elytra in females and exceeding elytral apices by about three and a half segments in males. Pronotum wider than long and thinly clothed with pale hairs denser on sides. Elytra three times as long as wide and densely punctate with dark stripe down middle of each elytron and inner margins narrowly bordered in black. ***Larva.*** Elongate, cylindrical, and yellowish with tiny thoracic legs, measuring 11 to 16 mm long (figure 187B).

Biology. Adults emerge and fly April to June (Linsley 1962b). Based on the location of galleries and emergence holes, females deposit eggs on stems with a range of diameters, although few emergence holes are found in smaller stems. In small stems, the larvae move downward, but in large stems, they may tunnel in either direction. Pupation most often occurs with the head upward in the gallery. The life cycle is unknown but, based on collection of larvae and adults, 1 or 2 years seem likely.

Injury and damage. Main stems and branches from 4 to 30 mm in diameter are infested. Some stem dieback may be observed. Examination reveals scattered tiny openings 0.5 to 1.0 mm in diameter in the bark where some frass is ejected. Adult emergence holes 2 to 4 mm in diameter,

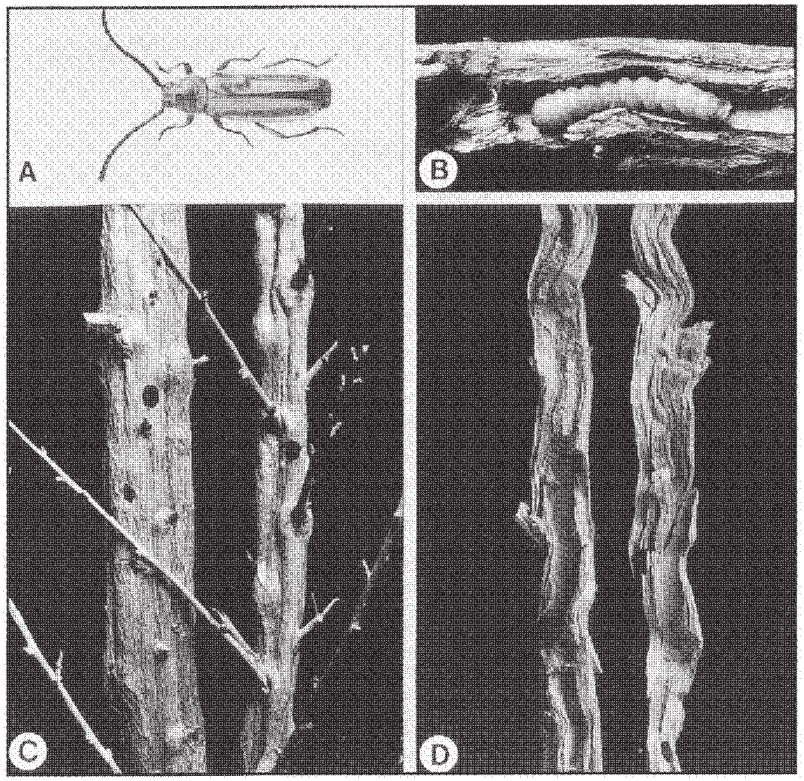

Figure 187—Amannus pectoralis, *[saltbush borer]: A, adult; B, larva; C, emergence holes in stems; D, galleries partially packed with fine frass (specimens courtesy F. Hovore and R. Penrose).*

varying from nearly round to oval to irregular, are scattered along the stem (figure 187C). As many as 10 emergence holes in a 30-cm stem section have been observed. Dissection reveals oval to flattened-oval galleries, portions of which are tightly packed with fine, powdery, yellowish frass (figure 187D). Small diameter stems may be completely hollow, leaving only thin shells. Although some infested plants may die, damage is minor.

Control. One unidentified insect parasite was reared from infested bolts. Direct controls have not been needed.

Family Brentidae—Timber Worms or Primitive Weevils

Members of this family are mostly tropical; only one species is covered here. The adults are greatly elongate, slender, and cylindrical (Arnett 1968, Craighead 1950). The head of the female is prolonged into a slender snout, whereas that of the male is short, broad, and flat with large jaws. The straight snout directed forward and non-elbowed antennae help to distinguish this family from other weevils. Larvae are elongate, cylindrical, and white with scattered setae.

Genus and Species

Arrhenodes minutus (Drury) *476*

Arrhenodes minutus (Drury)

oak timberworm (figure 188)

Hosts. Oak, elm, poplar, beech. Attacks trees in red and white oak groups (Solomon and others 1987). Upland oaks, especially black and scarlet oaks, are particularly susceptible (Buchanan 1960). Elm, poplar (Shenefelt and Benjamin 1955), beech, and aspen (MacAloney and Ewan 1964) have also been mentioned. Clusters of adults found under loose bark of boxelder and honeylocust suggest that other hardwood species are probably susceptible.

Range. Southeastern Canada throughout the eastern United States to the Gulf Coast (Sanborne 1983, Solomon and others 1987).

Description. ***Adult.*** Shiny, very elongate snout beetle, varying from 7 to 25 mm long (figure 188A) (Buchanan 1960, Shenefelt and Benjamin 1955, Solomon and others 1987). Reddish brown to brownish

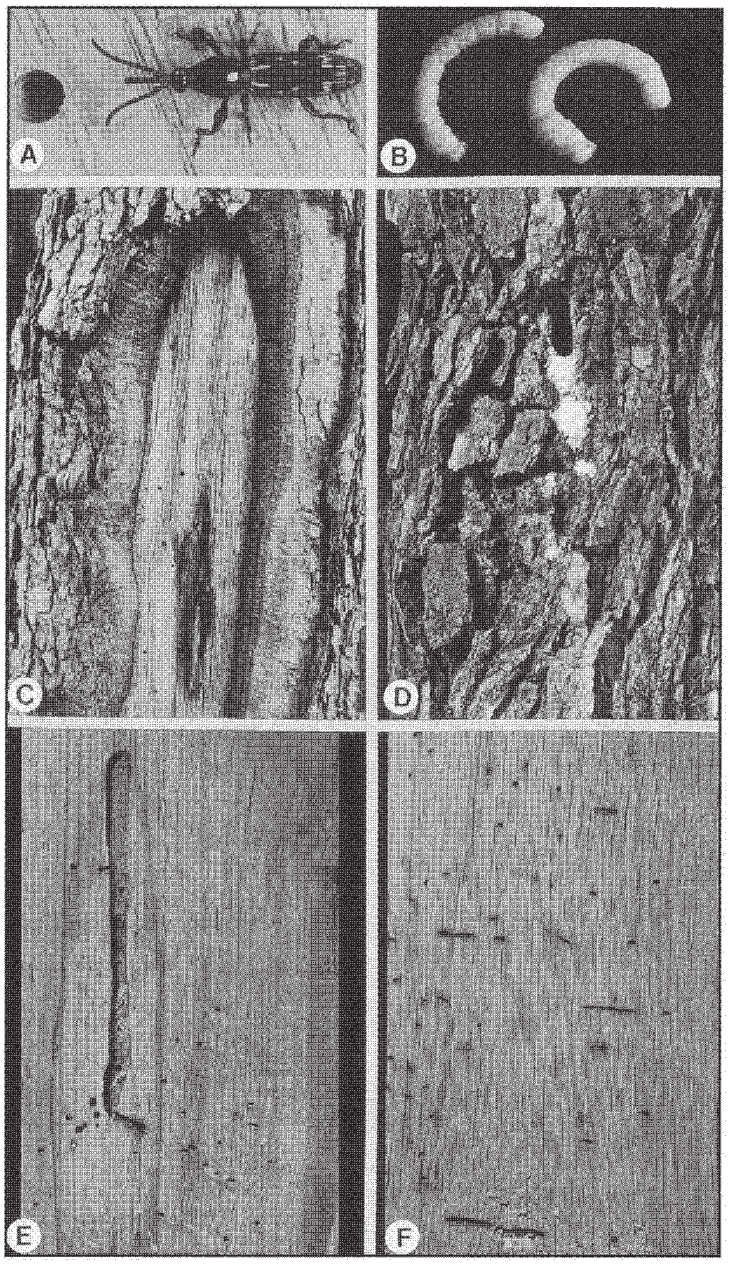

Figure 188—Arrhenodes minutus, *oak timberworm: A, adult; B, larvae; C, sapwood infestation site; D, white frass at old borer tunnel; E, cluster of holes associated with red oak borer gallery; F, oak timberworm holes in oak lumber.*

black with elongate yellowish spots on elytra. Females have long slender snouts; male mouthparts are broad and flattened and noticeably larger than those of females. ***Egg.*** Round, less than 1 mm in diameter, and translucent initially, but gradually becomes opaque. ***Larva.*** White, elongate, cylindrical, and curved with three pairs of two jointed, thoracic legs, and one pair of prolegs at end of abdomen (figure 188B). Full-grown larvae 12 to 24 mm long.

Biology. Adults present from early May to August over most of its range (Buchanan 1960); attracted to sap spots for feeding and sometimes congregate under loose bark at wound sites (Sanborne 1983). Fresh wounds are most attractive for oviposition, but some as old as 2 years are chosen. To oviposit, females chew cylindrical hair-sized holes in large wood vessels on wood surfaces shaded from direct sunlight. One egg is deposited in each hole; most holes are plugged with a sticky secretion and frass. In Ontario, there are two periods of oviposition, from mid-June to late July and from early to mid-September (Sanborne 1983). Egg incubation requires from a few days to 3 weeks, depending on temperatures. Newly hatched larvae bore directly into the wood. The diameter of the tunnels at first is sufficient for movement of the larvae through them but is enlarged in time (Hopkins 1903). Typically, tunnels are bored nearly straight across the wood grain with little up or down slope. Tunnels go almost to the opposite side of the tree, make a sharp U-turn, and go back across the wood grain toward the entrances. Larvae keep the tunnels clean by pushing the frass outside. Pupation occurs near the tunnel exit from which the adults emerge. The life cycle is generally 3 years, but some individuals develop in 2 years and a few require 4 years (Buchanan 1960).

Injury and damage. Attacks are usually associated with previous injuries. Most attack sites are at wounds that expose sapwood (figure 188C) (Buchanan 1960). White, powdery frass at egg sites on exposed wood or at large vacated borer entrances provide evidence of infestation (figure 188D) (Donley and Terry 1977). Holes are often found around large red oak borer galleries (figure 188E). Small round tunnels 0.2 to 4.0 mm in diameter lead from the egg sites into the wood. In sawn lumber, damage is characterized by mostly horizontal tunnels extending in many directions (figure 188F). Dying trees and green fresh-cut logs are sometimes attacked. Economically damaging losses are primarily to standing timber grown for wood products (Hopkins 1903). In particular, losses result from the small wormholes made by feeding larvae. Lumber cut from infested logs may be unfit for special uses such as tight cooperage or flooring (MacAloney and Ewan 1964). Factory grade lumber is sometimes substantially reduced in grade. Also, this borer has been reported to attack fresh-cut stave bolts, large pieces of unseasoned lumber, and squared timbers, resulting in substantial losses (Hopkins 1903). During peak larval activity from spring to midsummer, incidence of attack in blazed trees in the Missouri Ozarks ranges from 50 to 78%

(Buchanan 1960). Defects are most prevalent in upland forests of the central United States, east to Kentucky, Ohio, and West Virginia. Oak timberworm can also vector the oak wilt fungus (Buchanan 1957).

Control. Trees should be protected against wounds and injuries, including those caused by large borer species (Solomon and others 1987). In areas with a history of serious timberworm damage, extra precautions during harvesting and other woods operations are needed to minimize bark injuries to residual crop trees. Infestation can also be minimized by promptly removing dying and felled trees (Hopkins 1903). No natural enemies have been reported. Chemical and other direct controls have not been investigated.

Family Curculionidae—Weevils or Snout Beetles

The curculionids are typical snout beetles with the head being prolonged downward into a well-defined and usually curved beak (Arnett 1968, USDA FS 1985). The antennae are inserted on the snout, and they are usually elbowed and club shaped. Many are wonderously disguised with cryptic colors and forms to mimic other insects, bird droppings, or buds; this characteristic is enhanced by their feigning death and dropping to the ground. Larvae are usually C-shaped, subcylindrical, and fleshy, with a few scattered hairs. They feed in buds, shoots, stems, roots, bark, and wood. They are sometimes troublesome to nursery operators, foresters, and landowners, but only a few are serious pests.

Genus and Species

Conotrachelus
- *aratus* (Germar) *480*
- *schoofi* Papp *482*
- *elegans* (Say) *485*
- *juglandis* LeConte *485*
- *retentus* (Say) *489*
- *anaglypticus* (Say) *490*

Cryptorhynchus
- *lapathi* (Linnaeus) *492*

Magdalis
- *aenescens* LeConte *495*
- *armicollis* (Say) *497*
- *barbita* (Say) *499*

Ampeloglypter
- *sesostris* (LeConte) *500*
- *ampelopsis* LeConte *502*

Conotrachelus aratus (Germar)

[hickory shoot curculio] (figure 189)

Hosts. Hickory, pecan. Hickory appears to be favored with bitternut, shagbark, mockernut, and pignut hickories specifically listed (Brooks 1922). Pecan is commonly attacked in the Southeast. (Payne and others 1979). Walnut is mentioned but not confirmed.

Range. Throughout the eastern United States from Massachusetts south to Florida and west to Texas and Kansas (Brooks 1922, Phillips 1964, Schoof 1942).

Description. ***Adult.*** Snout beetle with short, stout snout that is slightly curved and about one-third body length with breast grooved for reception of beak (figure 189A) (Brooks 1922, Payne and others 1979, Schoof 1942). Beetles dull grayish to reddish brown with indistinct, broad band of yellowish pubescence behind middle of elytra and narrow line of same color on each side of thorax. Adults average about 5 mm long and 2 mm wide. ***Egg.*** Oval to oblong, creamy white, semitransparent; and averages 1.1 mm long and 0.7 mm in diameter. ***Larva.*** Yellowish white with brown head and black jaws with scattering of short but noticeable setae (figure 189B). Larvae are legless and slightly curved or crescent shaped and average about 6.0 mm long and 1.5 mm in diameter.

Biology. This weevil overwinters in the adult stage in litter, trash, or debris on the ground near host trees (Brooks 1922, Payne and others 1979, Schoof 1942). Adults emerge from hibernation in early spring as buds begin unfolding and shoot growth begins. Feeding begins in late March and April in the Deep South and 2 to 4 weeks later in the North. After feeding for a short time, females deposit eggs singly in puncture niches in the tender shoots and leaf petioles just above the enlarged petiole base. Eggs hatch in about a week, and the larvae begin feeding and tunneling within the tender new growth where they complete their larval development. By early to midsummer, mature larvae vacate their galleries, drop to the ground beneath the tree, and burrow 12 to 50 mm into the soil where they form unlined, earthen cells for pupation. Pupation lasts 2 to 3 weeks. Adults emerge from the ground mostly during August and September. Emerging adults are comparatively inactive, feeding lightly before entering hibernation in autumn. There is one generation a year.

Injury and damage. Soon after tree growth begins in spring, feeding and oviposition puncture marks made by adult curculios on the tender shoot tips and leaf petioles may be noticeable (Brooks 1922, Payne and others 1979, Phillips 1965b). Egg punctures are characterized by dark, triangular or V-shaped marks or spots about 3 mm long. Dark puncture marks occur in series of 3 to 10, typically one just above each leaf axil. Favorite feeding sites of the larvae are in the bulblike swellings at the base of leaf petioles, but they also burrow in succulent new shoots and cause slight to moderate swellings (figure 189C). Egg puncture openings become the entrance to the larval tunnels and ejection holes for the frass. Active larval galleries usually have small amounts of dark frass at the entrances and darkened areas of tissue encircling the openings (figure 189D).

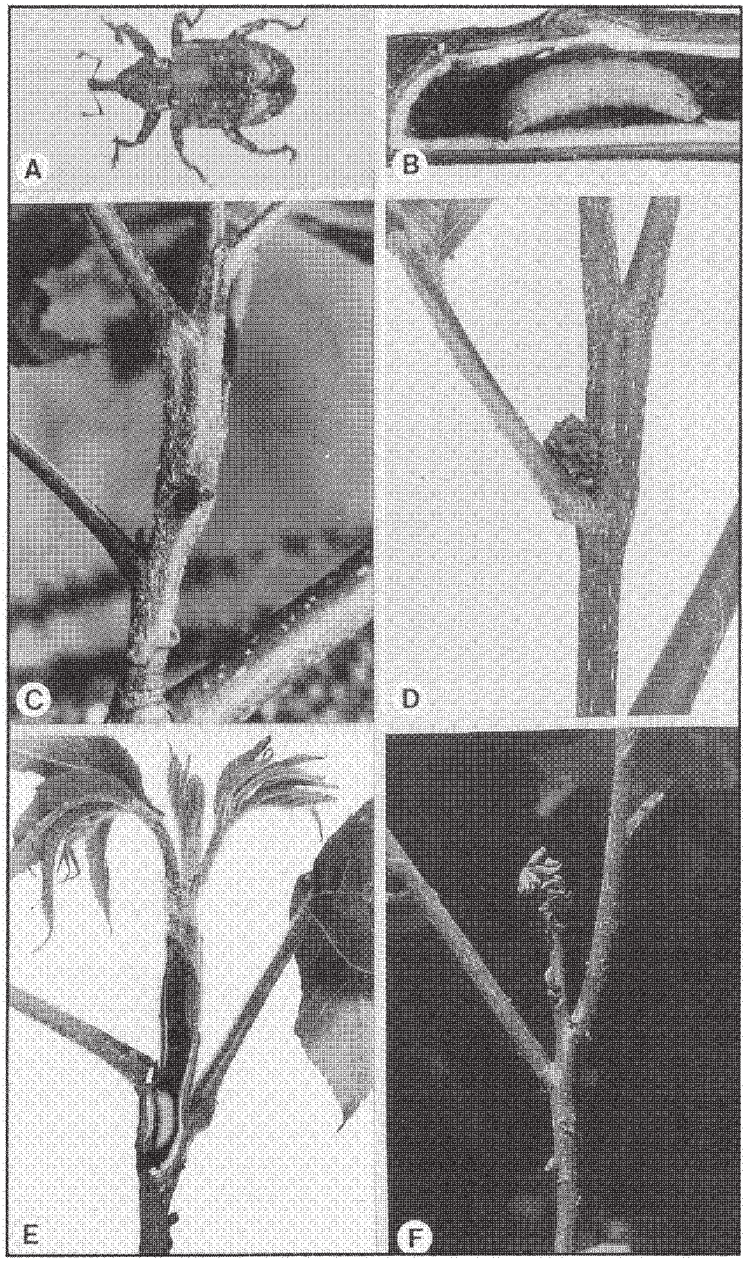

Figure 189—Conotrachelus aratus, *[hickory shoot curculio]: A, adult; B, larva; C, shoot with swelling and gallery entrance; D, dark frass expelled at entrance; E, gallery in hickory shoot; F, infested shoot stunted and overtopped.*

Frass is not tied together with silken threads and less is present than is typical for *Acrobasis* shoot borers attacking the same hosts. Dissection reveals the crescent-shaped larvae. The burrows and galleries range from 25 to 51 mm long (figure 189E). Affected shoot tips and leaves usually become yellowish to brown and wither on the tree or drop away (figure 189F). Heavily tunneled shoots sometimes break and drop without turning yellow and withering. Adult and larval feeding causes injury. Adult feeding punctures cause some dieback of buds and new leaflets and occasionally of the apical portion of new tender shoots, but damage is usually negligible. Injury by the larvae tunneling within the new shoots and leaf petioles results in premature foliage loss and weakening or killing nut-producing shoots. Loss of terminals in young trees intended for timber production can result in forking and abnormal trunk development. Heavy damage has occurred most commonly on unmanaged trees or in groves adjacent to woodlands containing native pecan and hickory (Payne and others 1979). Fifty percent or more of the shoots can become infested.

Control. Natural enemies are generally effective in holding the insect to levels that do not cause economic loss. Half or more of the larval population may be destroyed by parasites (Brooks 1922). Three species of dipterous parasites have been identified from the larvae—*Myiophasia globosa* Townsend, *Cholomyiae longipes* Fabricius, and *Chaetochlorops inquilina* Coquillett. An unidentified hairworm nematode parasite has been reared from larvae. New plantings should be established away from heavily infested woodlots. Sanitation and cultural practices such as clipping, collecting, and destroying infested shoots can help to reduce populations when only one or a few high-valued trees isolated from surrounding hosts are involved. Elimination of trash and debris can also help to eliminate hibernation sites. Chemical control is occasionally necessary when jarring the tree indicates that many adults are present or when there is a history of damage (Brooks 1922, Payne and others 1979, Phillips 1965b). Up to three spray applications beginning in early spring, when unfolding buds have 6 to 25 mm of new growth, may be necessary to control the adults before they lay their eggs.

Conotrachelus schoofi Papp

[pecan shoot curculio] (figure 190)

Hosts. Hickory, pecan. Mockernut, shagbark, and pignut hickories have been listed specifically as hosts and seem to be favored; but pecan is also readily attacked (Schoof 1942, Tedders and Payne 1986).

Range. Throughout the eastern United States from Massachusetts to Florida and west to Texas, Kansas, and Iowa (Buchanan 1947, Papp 1978, Schoof 1942).

Description. ***Adult.*** Small snout beetle with mixture of reddish and black tones, 4.5 to 5.7 mm long (figure 190A) (Schoof 1942). Beak stout, curved, and slightly longer than prothorax and sparsely covered with tan and white hairs. Antennae elbowed, with small, oval club at tips. Prothorax distinctly wider than long with sides usually rounded and distinctly bulging near apical third. Elytra about 1.3 times longer than wide and sides

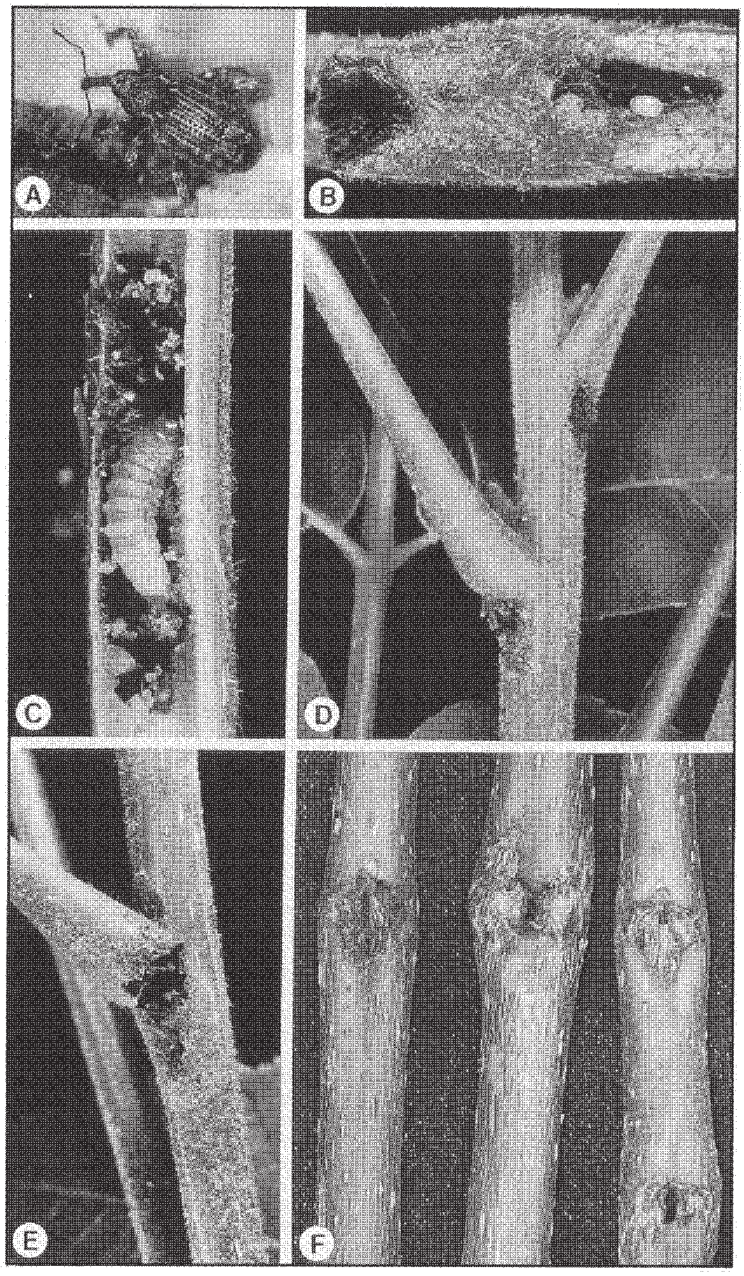

Figure 190—Conotrachelus schoofi, *[pecan shoot curculio]: A, adult; B, egg and egg niches on shoot; C, larva; D, frass at gallery entrance at base of rachises; E, hollowed and broken leaf rachis; F, shoots with healing injuries (courtesy W. Tedders).*

gradually converging toward apex. ***Egg.*** Oval, creamy white, semitransparent, averaging 0.7 mm wide and 1.1 mm long (figure 190B) (Tedders and Payne 1986). ***Larva.*** Legless, curved to nearly crescent shaped, and about 6 mm long (figure 190C). First- and second-instar larvae, clear white to dirty white; mid-instars, light yellow; fifth instars, orangish yellow with light brown beaks.

Biology. Adults overwinter in leaf litter beneath host trees (Schoof 1942). They emerge in late March and April in the Deep South and 2 to 4 weeks later in the northern range. Adults feed on immature foliage and shoots (Tedders and Payne 1986). Damaged leaflets usually curl, and adults use these as protected resting places. Females commence oviposition when new shoots are about 50 mm long. Eggs are deposited singly beneath the epidermal layer opposite the crescent and separated from the crescent by a partition of masticated plant material. Eggs hatch in about 6.5 days. New larvae feed initially in the bulb-like swelling of the rachis base but soon tunnel into the shoot and pass through five instars. In Georgia, mature larvae exit the shoots between May 11 and June 22 and burrow 12 to 50 mm deep in the soil for pupation. The pupal period lasts about 7 days, and adults emerge, move back onto the trees, and begin feeding. During autumn, the adults return to the leaf litter for hibernation. There is one generation a year.

Injury and damage. Earliest signs of attack are circular punctures 1.5 to 2.0 mm in diameter on the shoots and leaf rachises (Tedders and Payne 1986). Swelling of infested rachises (and sometimes shoots) soon follows. Oviposition injuries (figure 190D) are at the lower base of leaf rachises rather than above the base as occurs for *C. aratus*. Oviposition injuries initially are crescent-shaped excavations about 4 mm long, but they gradually darken, becoming necrotic and V-shaped. Usually, larvae chew a second hole to the outside of the shoot between the upper base of the leaf rachis and the shoot, often destroying the buds. Slight winds cause injured compound leaves to break from the shoot (figure 190E), leaving 1.5- by 4.0-mm exit holes. Dark frass is pushed from the openings. Galleries in the shoots may extend in either direction from the leaf rachis and average 4 mm in diameter and 24 mm long. Broken shoots are usually associated with feeding by several larvae, feeding at the base of the shoot, and leverage by long shoots. Shoots that do not break or die usually heal by the end of the following year (figure 190F). Adult feeding and oviposition punctures cause some injury, but larval feeding causes the major damage. Heavy infestations can cause moderate breakage and loss of petioles and shoots. In the past, serious infestations have rarely been reported, but during the early 1980's, numerous outbreaks caused extensive damage to immature trees in commercial pecan orchards in Georgia (Tedders and Payne 1986).

Control. Natural enemies are two hymenopterous egg parasites—*Anaphes* sp. (most abundant) and *Fidiobia* sp., two hymenopterous larval parasites—*Nealiolus rufus* Riley (most abundant) and *Perilam-*

pus sp., and two dipterous larval parasites—*Cholomyia inaequipes* Bigot and *Myiophasia globosa* (Townsend) (Tedders and Payne 1986). Culturally, locating new orchards away from heavily infested hickories, early pruning, destroying infested shoots, and removing leaf litter to eliminate hibernation sites can help to reduce infestations. Two applications of insecticide timed to correspond to the egg and early larval stages have provided excellent control in grower trials in Georgia.

Conotrachelus elegans (Say)

[pecan gall curculio] (figure 191)

Hosts. Pecan, hickory. Pecan seems to be favored in southern range, but hickories are also readily attacked (Buchanan 1947, Schoof 1942).

Range. New York west to Nebraska and south to Florida and Texas (Papp 1979, Schoof 1942).

Description. ***Adult.*** Reddish black snout beetle from 3.8 to 5.1 mm long (figure 191A) (Schoof 1942). Head with dense semicoarse punctures covered with tan and white setae. Prothorax rounded from base to near apex and then constricted. Elytra about 0.7 times as wide as long and blackish basally and reddish apically. Abdominal sternites (one to four) more densely punctate than those in related species. ***Larva.*** White, legless, and crescent shaped, measuring 5 to 6 mm long at maturity (figure 191B and C).

Biology. Based on labeled specimens, adults have been taken from May to August (Buchanan 1947, Schoof 1942). Eggs are deposited mainly in galls, where the larvae feed and develop. Mature larvae exit the galls and drop to the soil for pupation. Little else is known of the insect's life and seasonal histories.

Injury and damage. Larvae are found mostly in *Phylloxera* leaf and shoot galls but apparently burrow occasionally in succulent shoots. Pecan phylloxera populations (and galls) have increased markedly in the South during recent years, providing an abundance of preferred feeding sites. Larvae feeding within galls are often difficult to recognize without dissecting the galls. Sometimes, small amounts of brown frass can be seen as it is pushed from openings in the galls. Opening the galls usually reveals one larva along with varying amounts of dark frass (figure 191B and C). When larvae burrow into succulent shoots, dieback and breakage occur. Overall damage has been minimal because most larvae feed within leaf and shoot galls rather than in the shoots.

Control. One hymenopterous parasite—*Eurytoma tylodermatis* Ashmead—has been reported (Krombein and others 1979). Direct controls have not been needed.

Conotrachelus juglandis LeConte

butternut curculio (figure 192)

Hosts. Butternut, walnut. Butternut is preferred native host; black walnut is much less susceptible (Britton and Kirk 1912, Brooks 1922). Among introduced walnuts, favors Japanese over English walnuts. Hybrid trees having Japanese parentage were among the most susceptible in Michigan tests (Wilson and Corneil 1978).

Range. Wisconsin southward to Texas

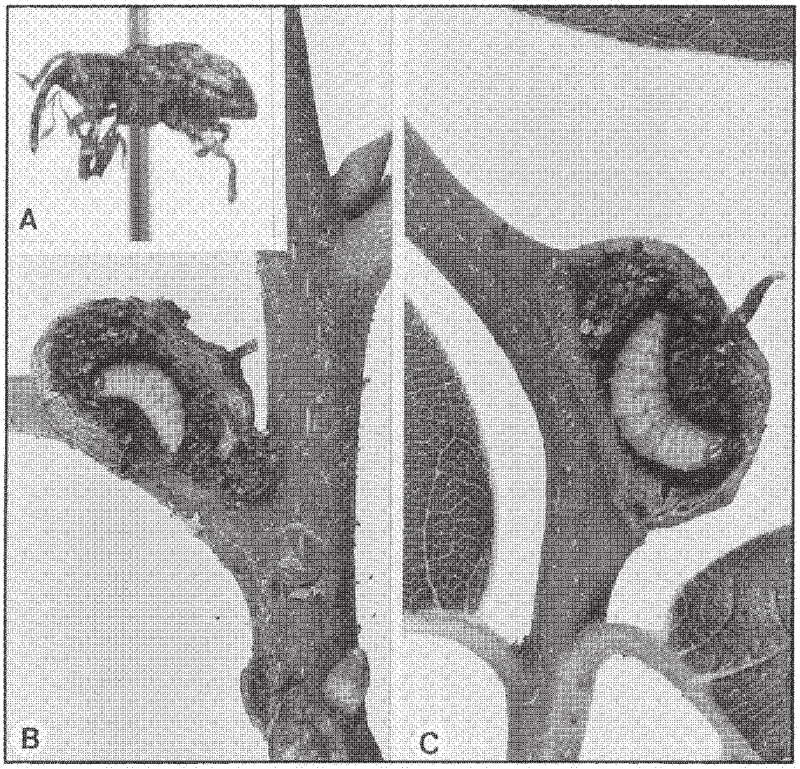

Figure 191—Conotrachelus elegans, *[pecan gall curculio]: A, adult; B, larva in gall on rachis; C, closeup of larva and gall (A, specimen courtesy D. Whitehead).*

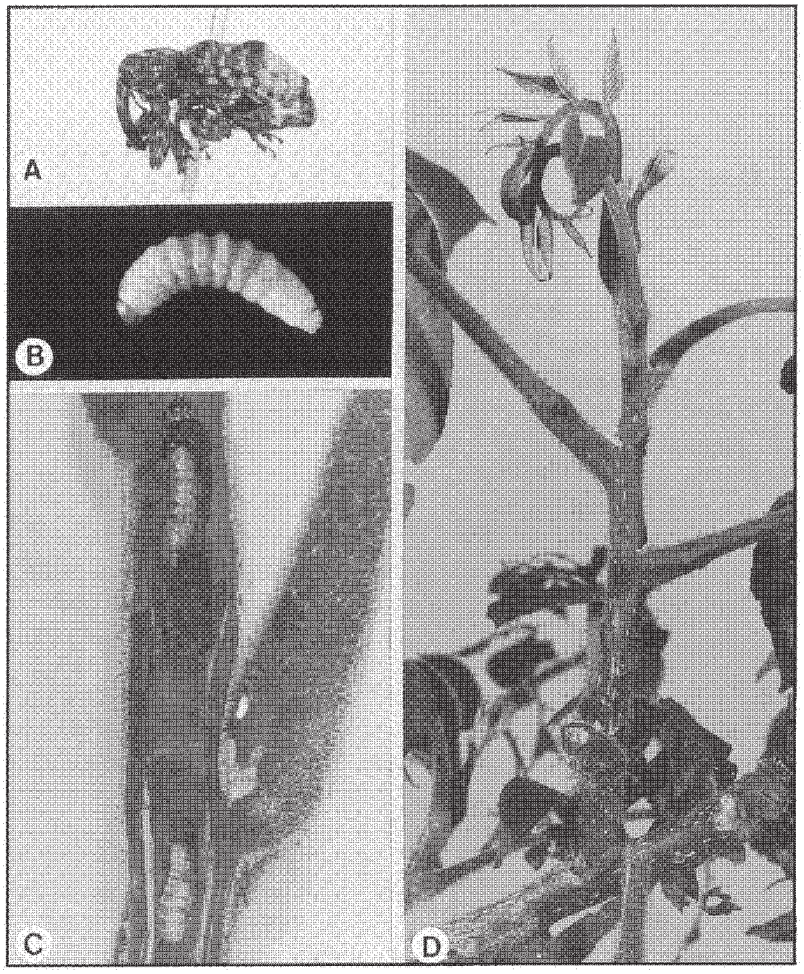

Figure 192—Conotrachelus juglandis, *butternut curculio: A, adult; B, larva; C, tunneled shoot with larvae; D, entrance sites on black walnut shoot (A & B, specimens courtesy D. Whitehead; C & D, courtesy W. Johnson).*

and eastward to the Atlantic Coast; also found in south central Canada (Johnson and Lyon 1988). Range closely approximates that of butternut.

Description. ***Adult.*** Predominantly dark brown to black snout beetle measuring 5 to 7 mm long (figure 192A) (Blatchley and Leng 1916, Brooks 1922). Grayish yellow hairs form line along each side of dorsum of prothorax and broad band behind middle of elytra. Beak shiny and sparsely punctured. Prothorax broadly constricted in front and basal two-thirds rounded at sides. ***Egg.*** Oblong to oval, creamy white with soft shiny surface and measures 0.95 by 0.75 mm. ***Larva.*** Dirty white when young, becoming yellowish white with dark brown head with age (figure 192B). Full-grown larvae legless, crescent shaped, and about 12 mm long.

Biology. Adults hibernate in leaf litter during winter, resume activity in spring when walnut catkins are fully developed, and commence feeding upon shoots and leaf veins (Schoof 1942). Females oviposit first on new growth and later in the immature nuts. Females deposit one egg in each niche chewed in young shoots, usually concealed under a flap of tissue and frass (Wilson and Corneil 1978). In Michigan, oviposition begins in mid-May and continues until early August; adults may live a year or longer (Wilson and Corneil 1978). First-instar larvae appear in mid-May in Connecticut, about 6 to 12 days after oviposition (Britton and Kirk 1912). Young larvae bore into the pith and feed up or down shoots or into the bases of leaf petioles (Wilson and Corneil 1978). Oldest larvae are nearly always found toward the shoot base where pith diameter is widest. Partially hollowed-out shoots that do not break off usually survive but may be stunted. During larval development, the egg niche opening becomes the larval tunnel entrance and an ejection hole for frass. Larvae pass through five instars and complete development in 4 to 6 weeks. Mature larvae exit galleries and drop to the ground, usually by late August in Michigan. Larvae burrow 5 to 8 cm into the soil and construct earthen pupation cells. Pupation lasts 15 to 20 days. New adults begin to emerge in late July in Michigan with complete emergence by mid-September. After feeding on shoot tips and leaflets, they hibernate in leaf litter.

Injury and damage. The most noticeable signs of infestation are wilting and dying of tender shoots and leaves. Dissection of shoots reveals burrows in the center together with some brown frass (figure 192C). Close inspection reveals slight swellings on shoots and petioles with associated openings (figure 192D). During active attacks, varying quantities of brown frass are pushed from gallery entrances. Dark tissue usually surrounds the openings (Wilson and Corneil 1978). Shoots may be so badly tunneled that they break. Infested shoots are frequently girdled near the base, so that most or all of the season's growth is lost. Infested shoots that survive are often stunted. In the early 1900's in Connecticut, nearly complete destruction of new shoot growth on seedlings in nurseries and trees in young plantations and heavy nut losses were reported (Britton and Kirk 1912). Injury by larvae to terminals and branches can be so severe that new

shoots are killed back to the woody growth of the previous season (Johnson and Lyon 1988). Injury deforms the main stem and prevents natural crown development (Wilson and Corneil 1978).

Control. The following dipterous parasites help regulate butternut curculio populations—*Chaetochlorops inquilina* Coquillett, *Cholomyia inaequipes* Bigot, *C. longipes* Fabricius, *Maeophasia aenea* Wied., *Metadexia basalis* G. T., and *Sigalphus curculionis* Fitch (Brooks 1922). Host species and hybrid crosses vary considerably in susceptibility (Wilson and Corneil 1978). Thus, in areas with a history of heavy damage, the least susceptible species—black walnut, English walnut, and butternut—should be selected for planting. Collecting and destroying immature fallen nuts weekly before the larvae leave them may help protect individual trees and small plantings (Brooks 1922). Carefully timed insecticide applications have controlled other shoot curculios and should be effective (Gibson and Kearby 1975).

Conotrachelus retentus (Say)

black walnut curculio

Hosts. Walnut, butternut. Black walnut preferred host; butternut rarely attacked (Brooks 1922, Schoof 1942).

Range. New Jersey and Pennsylvania south to North Carolina and westward through Mississippi to Kansas and Missouri (Schoof 1942). Occurs commonly, and injury appears to be most severe, at the latitude of Maryland and West Virginia and throughout the southern range of black walnut (Brooks 1922).

Description. ***Adult.*** Snout beetle 5.7 to 7.2 mm long with beak somewhat longer than prothorax (Schoof 1942). Adults dull reddish brown and covered with grayish pubescence. Light, indistinct, broad band behind middle of elytra and similar broken line on each side of prothorax (Brooks 1922). Prothorax slightly wider than long with sides rounded and strongly constricted in front. Elytra oblong oval. ***Egg.*** Oval to oblong and creamy white with surface delicately granulose like ground glass, measuring about 1.0 mm by 0.7 mm (Brooks 1922). ***Larva.*** Legless, creamy white with brown head sparsely clothed with short stiff hairs; about 11 mm long at maturity. Body usually held in curved position. ***Pupa.*** White, about 9 mm long; abdomen, thorax, and wing pads sparsely covered with short stiff hairs.

Biology. Adults overwinter in soil or under litter beneath hosts (Blair and Kearby 1978, Brooks 1922, Gibson and Kearby 1975). In Missouri, weevils emerge for several weeks beginning in mid-April and feed largely on leaves, staminate flowers, and leaf rachises of black walnut. Females deposit eggs singly in nuts and developing shoots. Eggs hatch in 5 to 7 days. Several eggs may be laid in a shoot or nut, but larvae cannibalize one another so that usually only one survives. Mature larvae vacate the shoot or nut and enter the soil, where they construct smooth-walled, earthen cells below the surface in which to pupate. Pupation is 2 to 3 weeks. Summer adults emerge in mid-July and into August. Adults feed on foliage until

leaves drop in fall, then overwinter in duff and litter beneath infested trees.

Injury and damage. Earliest evidence of infestation is feeding damage by adults on the base of the leaf rachis (Blair and Kearby 1978). Adult feeding injuries are small, darkened areas and cause some leaflets to break or dieback. Crescent shaped, oviposition punctures can be found in small nutlets and tender shoots. Brown frass may be found at gallery entrances. Heavily infested shoots may be largely hollowed. Dissection exposes shoot galleries and larvae. This pest primarily destroys nut crops on black walnut, but it may cause light to moderate damage to new shoots early in the year (Blair and Kearby 1978, Brooks 1922).

Control. Large numbers of three dipterous parasites—*Chaetochlorops inquilina* Coquillett, *Cholomyia longipes* Fabricius, and *Fannia canicularis* L.—were reportedly reared from the larvae and pupae (Brooks 1922). Two hymenopterous parasites—*Thersilochus conotracheli* (Riley) and *Triaspis curculionis* var. *rufus* (Riley)—were reared in small numbers. Good sanitation beneath trees and frequent collection of fallen infested nutlets help reduce infestations (Brooks 1922). A spray program that coincides with adult emergence, feeding, and oviposition has been effective in black walnut plantations (Gibson and Kearby 1975).

Conotrachelus anaglypticus (Say)

[cambium curculio] (figure 193)

Hosts. Apple, pear, peach, pecan, hickory, beech, birch, chestnut, oak, yellow-poplar, maple, tupelo, dogwood, serviceberry, sourwood, hornbeam. Apple, pear, and pecan seem to be preferred; however, this pest readily attacks a wide range of hosts (Brooks 1924).

Range. Throughout eastern North America from Ontario and Maine west to Michigan and Texas and south to Florida. One report from Montana (Schoof 1942).

Description. ***Adult.*** Compactly shaped snout beetle with body length 3.5 to 5.0 mm (figure 193A) (Schoof 1942). Body brownish black to dark reddish brown. Upper body thinly covered with short hairs that form two narrow, whitish lines on each side of thorax; broad, yellowish, oblique stripe at base of each elytron, and broad grayish band behind middle of elytra. Femora of legs marked with whitish bands of short hairs (Brooks 1924). Beak scarcely as long as head and thorax (Blatchley and Leng 1916). ***Egg.*** Oval, translucent white with touch of yellow, slightly wrinkled surface, and about 0.7 by 0.4 mm (Brooks 1924). ***Larva.*** Mature larva (figure 193B) white with yellowish brown head, fleshy, legless, almost cylindrical but slightly flattened ventrally, and 7 to 9 mm long. ***Pupa.*** White, about 5 mm long, with many spine-like setae on abdomen, prothorax, and wings.

Biology. Adults from overwintering generation emerge in late February and early March in the central peninsula of Florida, in mid- to late April in central Georgia, and by mid-May in West Virginia (Brooks 1924, Phillips 1965a, Schoof 1942). Second generation adults emerge from early July through early August. Adults are long lived, sometimes 5 to 6 months, and in most areas are active most of the summer. Adults are large-

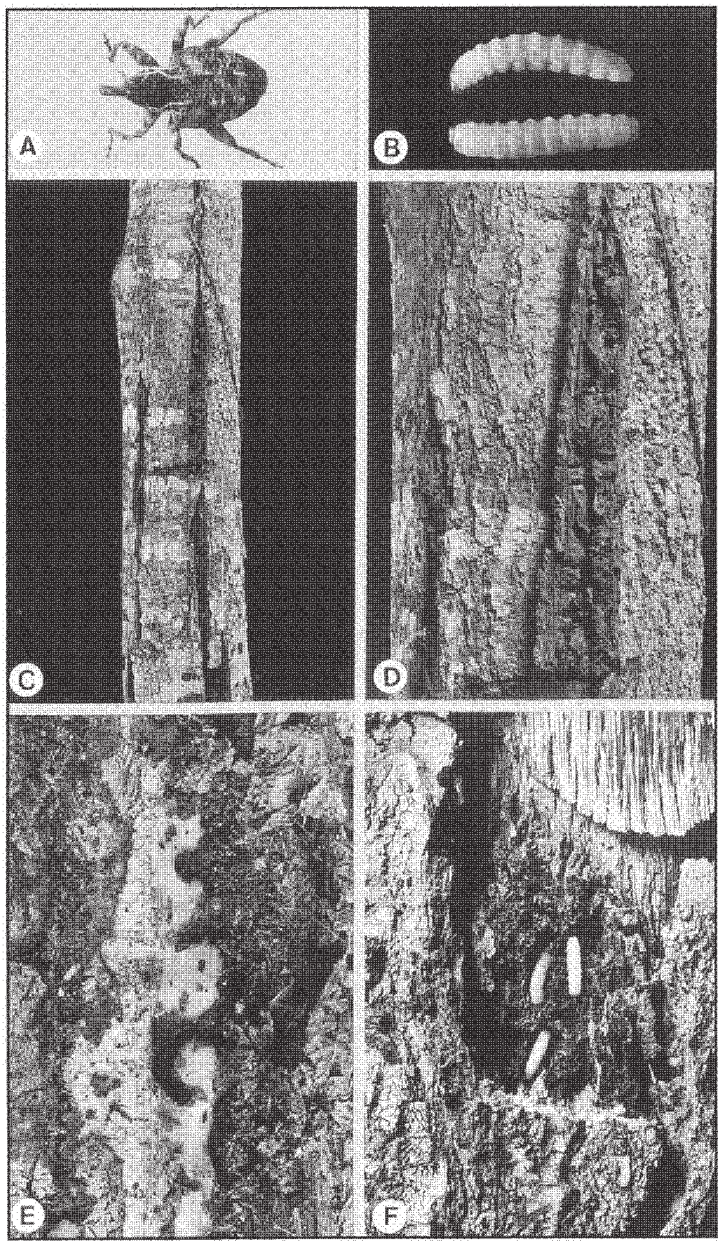

Figure 193—Conotrachelus anaglypticus, *[cambium curculio]: A, adult; B, larvae; C, infested wounds on Nuttall oak; D, closeup of infested wounds with bulging callus tissue; E, bark removed to expose mines and tunnels extending into live tissue; F, tunneling larvae beneath bark.*

ly nocturnal, and oviposition reportedly can last 52 days in north Georgia. Females deposit 25 to 30 eggs each, usually partially embedded in the moist, fibrous, inner bark around fresh wounds and in injured fruits. Eggs hatch in 2 to 4 days. When feeding in fruits, such as peach, plum, and apple, the larvae mature in 11 to 33 days, but take slightly longer to develop in bark. When disturbed, mature larvae have the unusual habit of curling their bodies so that the anal segment hooks under the head; then, by suddenly straightening their body, they jump about 25 mm vertically and 75 to 100 mm horizontally. After feeding, larvae drop to the soil and construct spherical, smooth-walled, earthen cells 2.5 to 5.0 cm deep in which to pupate. In north Georgia studies, 17 to 29 days elapsed between the time larvae entered the soil and new adults emerged. In West Virginia, larvae enter the soil in mid-July and are found as newly formed adults in mid-September. Adults emerge from the soil in fall and presumably overwinter under leaf litter. This curculio has one generation a year at latitudes of West Virginia and northward, two per year in central Georgia, and possibly more than two generations in its extreme southern range.

Injury and damage. Slow-to-heal wounds should be inspected. Favorite sites for attack are fresh wounds (figure 193C and D) (Brooks 1924, Phillips 1965a). Fresh-cut stumps and ends of green logs are commonly infested. Small amounts of brown to black frass can sometimes be observed on wounds. Lifting the bark at wound sites reveals the larval burrows (figure 193E), frass, and sometimes white larvae, often in large numbers (figure 193F). Typically, a feeding band 2.5 to 5.0 cm wide around the edge of wounds with burrows extending into the live tissue can be observed. Although not a tree killer, this insect can cause serious injury. Injuries caused to fruit and ornamental trees are often attributed wrongly to other insect borers. In Florida nurseries, this pest has destroyed up to 50% of the grafts on pecan trees during some years (Phillips 1965a).

Control. One hymenopterous larval parasite—*Tersilochus conotracheli* (Riley)— and one dipterous parasite—*Myophasia globosa* Townsend—have been reared, but little is known of their effect in controlling this pest. Practices that prevent or reduce bark wounds help to minimize injuries. Injuries should be smoothed and wound edges promptly treated with tree wound paint. Budded and grafted trees can be protected 2 to 4 weeks with one application of insecticide (Phillips 1965a). Clean cultivation and sanitation in orchards and beneath ornamental trees help control adult populations by destroying overwintering sites.

Cryptorhynchus lapathi (Linnaeus)

poplar-and-willow borer(figure 194)

Hosts. Willow, poplar, alder, birch. Willow is preferred (Furniss 1972, Harris and Coppel 1967). Poplars vary widely in susceptibility. Balsam poplar and black cottonwood are generally attacked, but quaking aspen rarely. Hybrid poplars also vary greatly in susceptibility. Preliminary studies of hybrid poplars in Ontario revealed infestation rates of 0 to 50% (Morris 1981). This borer rare-

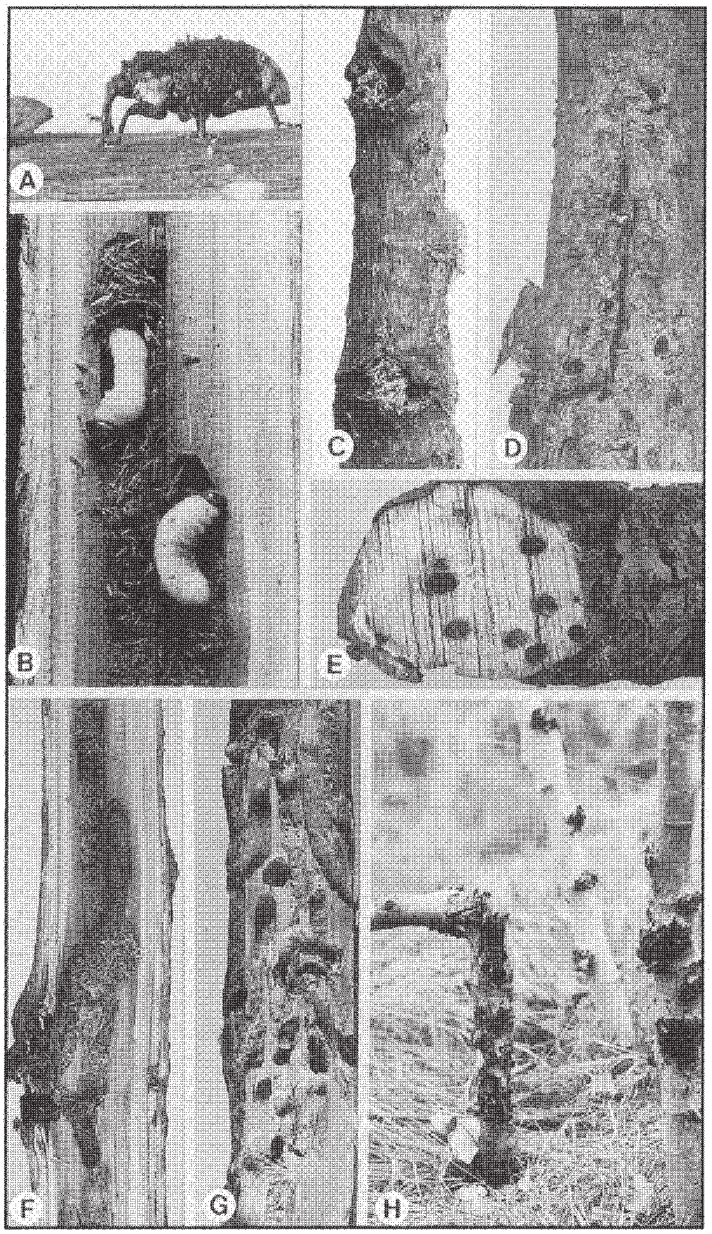

Figure 194—Cryptorhynchus lapathi, *poplar-and-willow borer: A, adult; B, larvae; C, entrance holes with frass; D, cracked bark and round exit holes; E, cross section of round galleries; F, gallery with frass; G, stem riddled by galleries; H, infested saplings galled and broken (H, courtesy J. Harris).*

ly attacks alder and birch. Adults occasionally feed on the bark and fruit of other deciduous trees but do not reproduce in them (Harris and Coppel 1967).

Range. Introduced from Europe or Asia. First reported in New York in 1882 (Furniss 1972). Now found throughout southern Canada and in the northern half of the United States from northern California eastward to the Carolinas.

Description. ***Adult.*** Snout beetle about 8 mm long, black and mottled with black and either gray or pink scales (figure 194A) (Furniss 1972, Harris 1966). Oval body appears rough and hard. Head small, largely hidden by thorax extending into slender beak that can be placed into groove between legs. ***Egg.*** Soft, white, and oval, measuring 1.1 by 0.8 mm. ***Larva.*** Subcylindrical, slightly curved or C-shaped, legless, white with shiny reddish brown head; less than 1 mm long when newly hatched to nearly 13 mm when mature (figure 194B). ***Pupa.*** White, 7 to 9 mm long.

Biology. Adults and larvae overwinter in Canada (Harris 1966, Harris and Coppel 1967), but only larvae overwinter successfully in New York (Matheson 1917). Adult weevils emerge from galleries mostly during summer and fall and feed on bark of new shoots on the main stem (Harris 1966). They are active in evening and morning but inactive during the day if temperatures exceed about 26 °C (Furniss 1972). When disturbed, adults feign death by folding their legs and dropping to the ground. Adults seldom fly and are sedentary (Harris 1966). Weevils mate and begin laying eggs about 2 to 10 days after emergence. Eggs are laid in lenticels, scars, bases of branches, and injured areas of the bark. Females chew into the bark, making round holes the depth of their beaks. One to four eggs are deposited in the hole and packed with bits of wood. There are two peak egg-laying periods: the first in March and April by adults that overwinter, the second from July through September by newly emerged adults. Eggs hatch in 18 to 25 days (Furniss 1972). After overwintering between the bark and wood, young larvae mine partly around the stem, and then usually upward in the wood for about 6 cm (Furniss 1972). Frass is initially expelled from holes in the stem, but later the frass is allowed to accumulate within the gallery. Larvae pupate behind a fibrous frass plug at the end of the tunnel (Harris 1966). They turn headfirst toward the tunnel entrance before pupation, which occurs mostly from mid-July through September (Furniss 1972). Pupal period lasts about 2 to 3 weeks. Development from egg to adult takes about 1 year, but adults may live and continue to lay eggs for up to 2 years.

Injury and damage. Attack sites occur on stems 1.3 to 15.0 cm in diameter but are most common on those 2.5 to 10.0 cm in diameter (Furniss 1972, Gautreau 1963). Attack sites are concentrated on the lower trunk, mostly near the root collar, but occasionally are up to 4 m above ground (Morris 1981). Current attack sites are indicated by irregular holes in the bark, usually with a mixture of sap and moist, reddish brown and white frass at entrances, in bark crevices, and on the ground below (figure 194C) (Harris 1966). Irregular splits usually develop in bark, and round exit holes may be

present (figure 194D). Dissection reveals 4- to 8-cm-long galleries, round in cross section (figure 194E), packed with coarse and fibrous frass (figure 194F). Repeatedly attacked trunks are often honeycombed with tunnels, some of which may be darkened and weathered (figure 194G). Some stems become deformed, with many callused areas, gall-like swellings, and dead bark. Trees that sustain extensive tunneling may be girdled and die or break (figure 194H). When populations are heavy, adults sometimes cause noticeable feeding injuries to newly developing shoots. This borer is an important pest of ornamental and plantation trees. In some northern areas, damage from heavy infestation is only by deformities in the attacked trees (Harris and Coppel 1967). In Alberta, mortality in willow stands has been estimated at 40% (Gautreau 1963). Infestations often persist in the same stems or plants several years. In infested stems, various fungi and insects commonly increase damage (Furniss 1972).

Control. Natural control includes parasitism by two wasps—*Bracon cryptorhynchi* (Muesebeck) and *Dolichomitus irritator* (Fabricius) (Krombein and others 1979). Ants and birds also feed on adults and larvae. Natural flooding during snowmelt and runoff may be a control in some areas (Furniss 1972). Because the adults are sedentary and seldom fly, cultural and sanitation practices can minimize damage. Searching out, cutting, and destroying all infested stems around the periphery of new plantings should prevent or delay infestation. In special situations, new valuable plantings can be temporarily protected by wrapping the trunks with paper or burlap. Various insecticides have been used with only moderate success (Harris 1966). Also, fumigation may be used to treat infested cuttings and transplants.

Magdalis aenescens LeConte

bronze appletree weevil (figure 195)

Hosts. Apple, hawthorn, plum, cherry, alder. Apple is favored; alder is an important native host (Essig 1929, Fall 1913, Moznette 1919).

Range. Alaska southward through British Columbia, along the Pacific Coast to California (Essig 1929), east to Montana and southward through the Rocky Mountains to New Mexico (Fall 1913).

Description. ***Adult.*** Metallic bronzy black, elongate, slender snout beetle, 4 to 6 mm long (figure 195A) (Chittenden 1900a, Essig 1929). Head, beak, and prothorax densely and finely punctured, and elytra distinctly striate. Beak cylindrical and about same length as prothorax. Posterior angles of prothorax prominent and produced over base of elytra. Elytral striae contain small punctures and interspaces finely roughened. Broad femoral leg segments acutely toothed and claws distinctly toothed near bases. ***Egg.*** Ovoid, smooth, shiny, yellowish white, measuring about 0.5 by 0.25 mm. ***Larva.*** Curved to C-shaped, strongly wrinkled, white except for dark brown mouthparts; reaches about 4 mm long (figure 195B). Prothoracic region enlarged as in bostrichid larvae, but these legless and less hairy in this species. ***Pupa.*** Soft and white with snout bent down

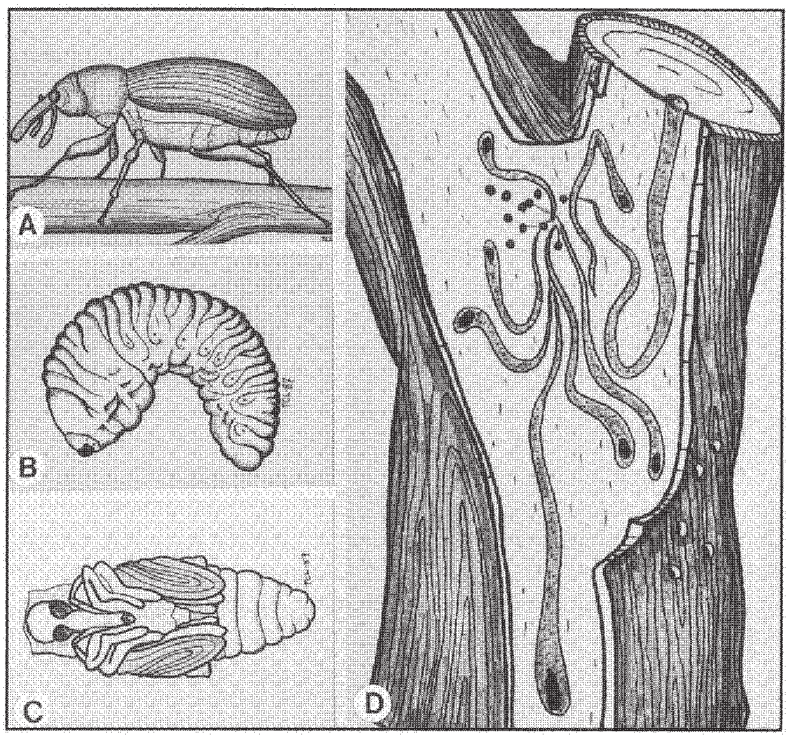

Figure 195—Magdalis aenescens, *bronze appletree weevil: A, adult; B, larva; C, pupa; D, cluster of small egg punctures with radiating larval galleries (sketches after Chittenden [1900]).*

against underside of abdomen between legs (figure 195C).

Biology. Adults emerge early April to August and feed on foliage of young fruit trees, particularly on the upper surface, sometimes riddling them with small punctures (Slingerland and Crosby 1919). Females seek roughened bark, especially cankered areas, sunscald spots, and edges of mechanical wounds on trunks and branches for oviposition. Females chew deep holes into the bark, depositing one egg in each, then pushing the eggs deeply into the holes with their beaks, and plugging the holes with frass. Circular clusters of egg punctures range from 4 to 21. Adults die soon after mating and oviposition. Egg incubation is about 2 weeks. Young larvae make 0.5-mm-wide tunnels in the inner bark. They then gradually extend the tunnels between the bark and wood, etching both surfaces, to a width of about 2 mm and length of 25 to 64 mm (Moznette 1919). Oblong to oval pupal cells 6 mm long are constructed under the bark at the end of larval galleries (Chittenden 1900a). Larvae overwinter in and under bark and transform to pupae in spring and summer. Newly formed adults bore round holes 1 to 2 mm in diameter through the bark to emerge.

Injury and damage. This weevil will attack wounds and dead areas on healthy trees but most commonly attacks weakened, neglected trees (Chittenden 1900a, Essig 1929, Mote 1944). Inspection of dead bark reveals a small circular cluster of egg punctures (figure 195D). Usually, the egg punctures are in sunken, discolored bark (Mote 1944). Under the bark, and engraved into the surface of the sapwood, are meandering larval galleries. Larger circular holes show that the new weevils have emerged. This pest is particularly destructive to young fruit trees, especially in neglected, deteriorating orchards (Moznette 1919).

Control. A hymenopterous parasite—*Cheiropachus quadrum* (Fabricius)—has been reared (Krombein and others 1979). Up to 50% of the larvae and pupae are reportedly destroyed by parasites (Moznette 1919). Good cultural practices help to minimize attacks. Infestations can be greatly reduced by destroying pruned branches, removing dying and recently dead trees, and by prompt treatment of injuries with tree wound paint (Essig 1929). Prunings, dead trees, and other debris should be destroyed before April to kill the developing weevils in the wood.

Magdalis armicollis (Say)

red elm bark weevil (figure 196)

Hosts. Elm. American elm listed as specific host, but other elms probably serve as hosts (Goeden and Norris 1963, Kondo and Thomas 1979).

Range. Georgia north to the New England States and southeastern Canada and west to the Dakotas and Texas (Fall 1913, USDA FS 1985).

Description. ***Adult.*** Elongate, wedge-shaped, robust snout beetle and 3.5 to 6.0 mm long (figure 196A) (Blatchley and Leng 1916, Fall 1913). Females reddish brown; males blackish brown with reddish or yellowish brown elytra. Antennae slender and slightly shorter than thorax. Elytra deeply striate and coarsely punctured. ***Egg.*** Ellipti-

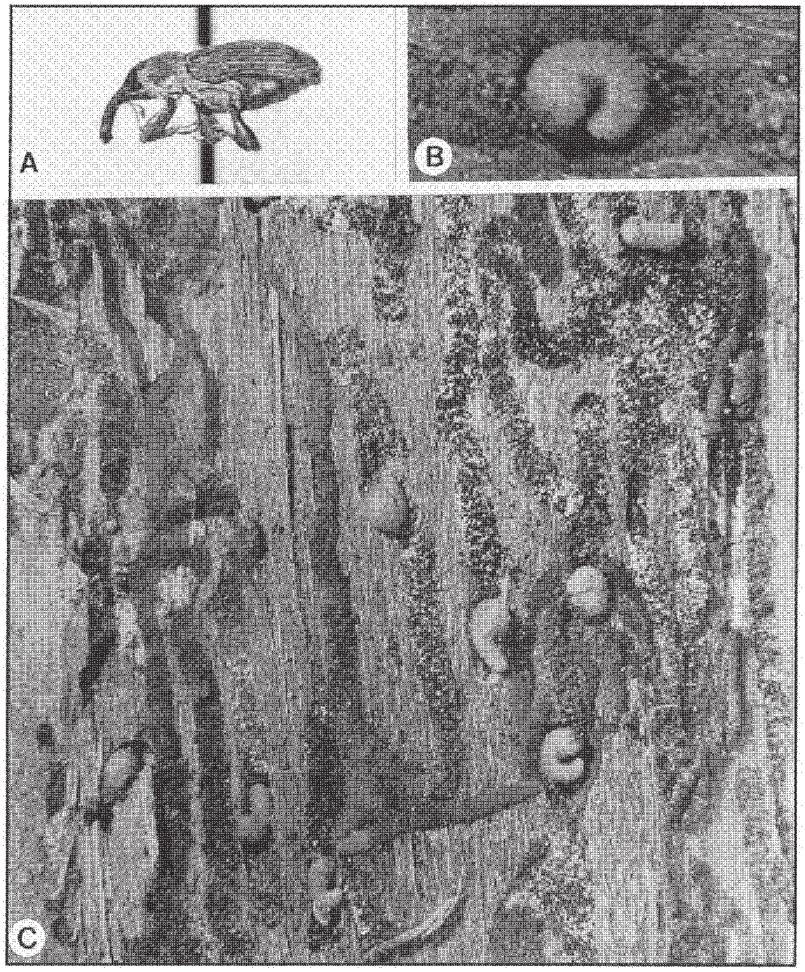

Figure 196—Magdalis armicollis, *red elm bark weevil: A, adult; B, larva; C, galleries, frass, and larvae under bark of elm (A, specimen courtesy D. Whitehead; B & C, courtesy J. Stein).*

cal, white to yellow, and about 0.6 by 0.36 mm (Hoffman 1939). ***Larva.*** Yellowish white, C-shaped with thoracic segments largest (figure 196B).

Biology. Adults emerge April to October with peak from late spring to midsummer (Fall 1913, Hoffman 1939, Kondo and Thomas 1979, McDaniel 1936). Newly emerged adults move to the crowns, feed on the leaves and succulent twigs, and then mate. Before oviposition, females make many test punctures, then deposit one or more eggs deep in the inner bark, sealing with brown frass and adhesive secretions. Eggs hatch in about 9 days, and larvae make convoluted tunnels in the cambium that radiate out from the oviposition site but generally run parallel with the wood grain and score both inner bark and wood surfaces. Larval tunnels gradually increase in size as the grubs develop, eventually terminating in cells where they pass the prepupal and pupal stages. The pupal stage requires 9 to 11 days. There is one generation per year.

Injury and damage. Puncture marks (often clustered on the bark) may be noticeable, especially when populations are heavy (Hoffman 1939). Removing the bark reveals larvae in galleries that radiate out from a group of oviposition punctures (figure 196C). The bark of heavily infested trees may be peppered with small circular emergence holes. Foliage with a shothole pattern indicates adult feeding. This pest prefers weakened, dying, and recently dead trees but occasionally attacks healthy trees (Hoffman 1939, Kondo and Thomas 1979). Small suppressed trees with one or more dead branches are particularly susceptible. Young transplanted trees are also frequently attacked and may be girdled. This insect is a proven transmitter of Dutch elm disease, but incidence of transmission is low.

Control. Recently transplanted trees and young trees suffering from stress can be protected by wrapping with fine wire screen or paper or by spraying the bark with an approved insecticide (McDaniel 1936). Populations can be reduced by removing and burning infested materials in fall, winter, or spring before the adults emerge (Hoffman 1939).

Magdalis barbita (Say)

black elm bark weevil

Host. Elm. Elms, especially American elm, are preferred (McDaniel 1936, USDA FS 1985). Hickory, oak, and alder have been mentioned as hosts but may be misidentifications (Blatchley and Leng 1916, Fall 1913).

Range. Texas and Georgia northward into southern Canada; best known in its northern range (Blatchley and Leng 1916, Herrick 1935, USDA FS 1985).

Description. ***Adult.*** Black, elongate, wedge-shaped snout beetle, and 4 to 6 mm long (Blatchley and Leng 1916, Fall 1913). Elytra slightly broader posteriorly, deeply striate, and coarsely punctured. ***Larva.*** Yellowish white, C-shaped, thoracic segments noticeably enlarged.

Biology. Adults appear May to July and feed on foliage and tender twigs (Blatchley and Leng 1916, Herrick 1935, McDaniel 1936). Females chew deep punctures in bark to oviposit. Young larvae feed and

burrow in inner bark and sapwood of small and large branches and sometimes trunks, constructing galleries 38 mm long or longer. Pupation occurs in oval cells just beneath the outer bark. This weevil has one generation per year.

Injury and damage. Close examination of susceptible trees may reveal clusters of tiny round puncture marks. Larvae feed under the bark of unhealthy, weakened, dying, and recently dead trees. The C-shaped larvae and galleries can be exposed by lifting the bark. Mature beetles leave perforated emergence holes (Herrick 1935). The weevil is a carrier of Dutch elm disease, but does not seem to be important in disease transmission (Goeden and Norris 1963, Kondo and Thomas 1979).

Control. Maintenance of strong, healthy trees by mulching, fertilization, and watering is important in preventing attacks on ornamentals in heavily infested areas (Herrick 1935). Infested branches should be cut and burned to destroy broods. Trunks and branches of newly transplanted trees can be wrapped with crepe paper to prevent oviposition.

Ampeloglypter sesostris (LeConte)

grape cane gallmaker (figure 197)

Hosts. Grape. Concord and other cultivated varieties and wild varieties serve as hosts (Blatchley and Leng 1916, Slingerland and Crosby 1919, Webster 1900a).

Range. West Virginia west to Michigan and south to Missouri (Blatchley and Leng 1916, Slingerland and Crosby 1919).

Description. ***Adult.*** Elongate oval, moderately convex and shiny snout beetle, pale reddish brown and 2.7 to 3.0 mm long (Blatchley and Leng 1916, Slingerland and Crosby 1919). Beak rather slender, strongly curved near base, and about 1 1/2 times as long as thorax. ***Larva.*** Yellowish white with brown head and dark jaws, legless, and about 10 mm long.

Biology. Adults emerge from hibernation in May (Blatchley and Leng 1916, Slingerland and Crosby 1919, Webster 1900a). Females start laying eggs when new canes have sufficient growth, usually in May and June. To oviposit, females select a spot directly above the lowest joint that does not bear fruit, then bore holes into the heart of the cane and deposit an egg in each hole. Females fill the hole with bits of bark and make 8 to 14 puncture holes above the oviposition site. Eggs hatch in 7 to 10 days. Larvae feed principally in the pith, working up or down for distances of several centimeters and causing elongate galls to form. Larvae mature in 8 to 10 weeks and pupate within the galls. Adults emerge in August and overwinter under leaves or in other suitable shelters. This pest has one generation a year.

Injury and damage. Examination of infested canes reveals elongate swellings or galls 25 to 38 mm long and about twice the diameter and a row of punctures around the stem causing ugly scars (figure 197A) (Blatchley and Leng 1916, Slingerland and Crosby 1919). Dissection of galls reveals tunnels, brown frass, and sometimes larvae (figure 197B). Galls sometimes cause the canes to die back, but the pest is of minor importance.

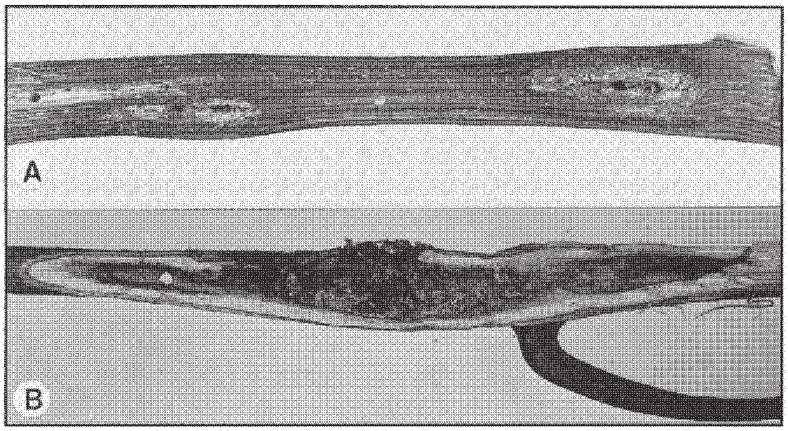

Figure 197—Ampeloglypter sesostris, *grape cane gallmaker: A, entrance holes with slight swellings on canes; B, cane split to show tunnel and frass (specimens courtesy D. Whitehead).*

Control. Pruning out and burning infested canes during July and early August destroy the larvae and reduce the population (Slingerland and Crosby 1919, Webster 1900a). Chemical sprays directed at the adults in late May and June have provided protection.

Ampeloglypter ampelopsis LeConte
[grape cane girdler]

Hosts. Virginia creeper, grape. Principal wild host is Virginia creeper; attacks grape less frequently (Blatchley and Leng 1916, Slingerland and Crosby 1919).

Range. Eastern United States from New England and West Virginia west to Michigan and south to Indiana (Blatchley and Leng 1916, Slingerland and Crosby 1919).

Description. ***Adult.*** Small, oblong, moderately convex snout beetle, measuring about 2.7 to 3.0 mm long (Blatchley and Leng 1916, Slingerland and Crosby 1919). Shiny black with reddish brown antennae and tarsi; beak robust, strongly curved, and slightly longer than thorax. ***Larva.*** White, footless, and curved.

Biology. This species overwinters in the adult stage, and weevils emerge from hibernation in May (Blatchley and Leng 1916, Slingerland and Crosby 1919). Females deposit one egg per puncture in the growing canes and then girdle the stem below the egg site with a series of holes. Eggs hatch in about 10 days, and larvae feed in the pith of the cane. Larvae mature in July and pupate within their burrows, and the new adults emerge in August. Adults from this brood overwinter in plant debris.

Injury and damage. Withered tips and tender leaves near the ends of shoots give the vines a noticeably ragged appearance (Blatchley and Leng 1916). Examination of withered canes reveals gall-like swellings and puncture marks where the shoots were girdled. Dissection reveals burrows and white, C-shaped larvae.The insect kills shoots of growing canes, causing minor damage in some commercial vineyards.

Control. Cutting and burning infested canes during late summer destroy the larvae (Slingerland and Crosby 1919).

Family Scolytidae—Bark Beetles and Ambrosia Beetles

The family Scolytidae comprises a large, diverse, and important group of beetles (Arnett 1968, Furniss and Carolin 1977, USDA FS 1985). Adults are small, stout, compact to moderately elongate, and cylindrical. The antennae are elbowed, and the outer segments are enlarged and clublike. Most are brown to black; some have variegated markings of gray. The head is partially to completely hidden from above by the thorax. Larvae are grublike, thick bodied, legless, broadly C-shaped, and white to cream colored. Species are divided into two groups: the **true bark beetles** and the **ambrosia beetles**. Bark beetles burrow either entirely in the inner phloem or at the juncture of the bark and sapwood and feed on the inner phloem. Ambrosia beetles burrow in the sapwood and feed both in the larval and adult states on fungi, known as ambrosia, that they cultivate within their tunnels. The ambrosia beetles (usually females) possess specialized structures called **mycetangia** that store the fungi and introduce it into new galleries during the burrowing process. The specific ambrosia fungi are included here for only a few ambrosia beetle species because of the difficulty workers have had in isolating, identifying, and agreeing on the fungus species involved. Brood burrows of scolytids are of a variety of different types, but those made by the same species are so characteristic that the responsible species can be readily identified without seeing the insect. Although some scolytids attack healthy trees, most prefer weakened, injured, or dying trees and fresh-cut logs. Some bark beetles can kill or hasten the death of weakened trees, and others are important vectors of tree diseases. Ambrosia beetles are important chiefly because of the degrade of sawed lumber that results from their invasion of trees and logs.

Genus and Species

Scolytus
- *quadrispinosus* Say *504*
- *rugulosus* (Muller) *506*
- *multistriatus* (Marsham) *509*

Hylurgopinus
- *rufipes* (Eichhoff) *512*

Hylesinus
- *aculeatus* (Say) *514*
- *californicus* Swaine *517*
- *criddlei* Swaine *519*

Phloeotribus
- *liminaris* (Harris) *521*
- *frontalis* (Olivier) *524*
- *dentifrons* (Blackman) *526*

Alniphagus
- *aspercollis* (LeConte) *527*

Trypophloeus
- *populi* Hopkins *529*

Dryocoetes
- *betulae* Hopkins *532*

Pseudopityophthorus
- *minutissimus* (Zimmermann) *534*
- *pruinosus* (Eichhoff) *536*
- *pubipennis* (LeConte) *539*

Corthylus
- *columbianus* Hopkins *541*
- *punctatissimus* (Zimmermann) *543*

Monarthrum
- *mali* (Fitch) *546*

fasciatum (Say) *548*
Xyloterinus
politus (Say) *551*
Trypodendron
retusum (LeConte) *553*
betulae (Swaine) *556*
Xyleborus
celsus Eichhoff *556*
affinis Eichhoff *560*
ferrugineus (Fabricius) *561*
xylographus (Say) *563*
dispar (Fabricius) *564*
sayi (Hopkins) *565*
Xyleborinus
saxeseni (Ratzeburg) *566*
Xylosandrus
compactus (Eichhoff) *569*
germanus (Blandford) *572*
crassiusculus (Motschulsky) *575*

Scolytus quadrispinosus Say

hickory bark beetle (figure 198)

Hosts. Hickory, pecan, butternut. Prefers hickories, with shagbark and bitternut hickories listed most often in the literature (Goeden and Norris 1964, Hopkins 1912, McDaniel 1936). Pecan and butternut are less susceptible.

Range. Quebec south throughout the eastern half of the United States to the Gulf Coast and westward to Wisconsin and Texas (USDA FS 1985, Wood 1982).

Description. ***Adult.*** Short, stout, thickly cylindrical, black to reddish brown, almost hairless bark beetle, 2.9 to 5 mm long (figure 198A) (Goeden and Norris 1964, McDaniel 1936, USDA FS 1985, Wood 1982). Front tibiae have a short curved spine or hook. In males, venter deeply excavated; third abdominal segment armed with three spines, fourth with one large median spine. In females, venter less deeply excavated and without spines. ***Egg.*** Ellipsoidal, cream colored, and barely visible to naked eye. ***Larva.*** Short, curved or slightly C-shaped, legless, yellowish white, wrinkled, and 5 to 8 mm long when mature (figure 198B). ***Pupa.*** Very compact, fragile, and white.

Biology. This bark beetle overwinters in various larval stages (Goeden and Norris 1964, 1965; McDaniel 1936). During spring, the oldest larvae transform to pupae in elliptical chambers, terminating each larval tunnel just beneath the bark surface. Beetles begin to emerge in May and continue through late August. Beetle populations and seasonal activity reach maximum during July and early August. Newly emerged beetles fly to the crowns of host trees where they feed mainly in terminal and twig growth for 10 to 15 days. Sexually mature beetles are then attracted to low-vigor trees, where they bore into the bark of trunks and branches. Here, females excavate 12- to 50-mm-long longitudinal upright egg galleries (without nuptial chambers) between the bark and wood. Mating on the bark surface and egg laying within the gallery continue throughout summer, with each female depositing 20 to 60 eggs singly in small niches along either side of the egg gallery. They cover the eggs with a plug of macerated frass. Eggs hatch in 10 to 12 days. Larvae mine outward and parallel to each other at first, but as they become larger, they diverge until the complex of mines resembles an

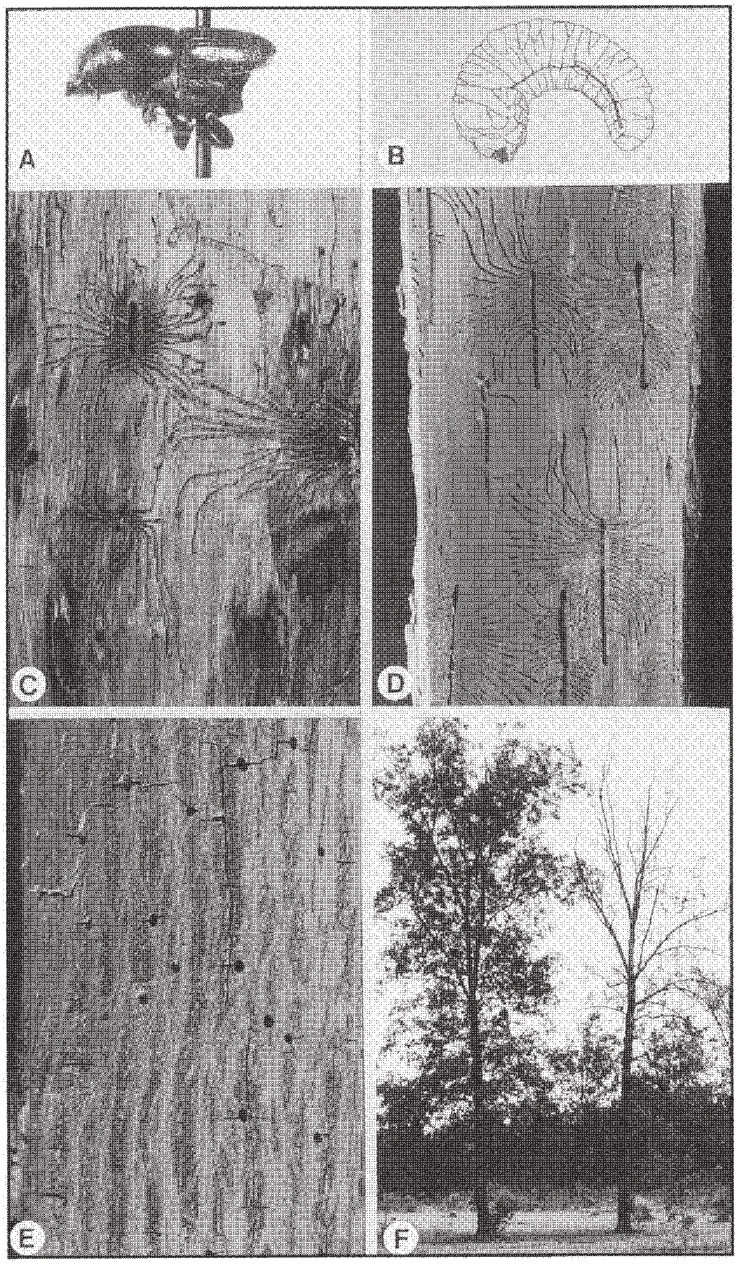

Figure 198—Scolytus quadrispinosus, *hickory bark beetle: A, adults; B, larva; C, vertical egg tunnel with radiating larval galleries engraved on sapwood; D, centipede-like engravings in bark; E, round exit holes in bark; F, hickory killed by beetle attack.*

engraving of centipede legs. Larval mines may extend 75 mm or more outward from egg galleries, thus severing the food and water conducting tissues of the tree. Mature larvae leave the cambium and bore into the outer bark where they pupate in cells. This beetle has one generation per year in its northern range and two in its southern range.

Injury and damage. Reportedly, this bark beetle is the most destructive insect of hickory (Wood 1982). Adults feed in terminal growth, and larvae tunnel in trunks and large branches and cause greatest damage (figure 198C and D) (Goeden and Norris 1965). Newly emerged adults feed on twigs in the tree crown throughout summer. They make short food tunnels, about body length or less, in twigs, mainly at the base of axillary buds and leaf of current year and 1-year-old growth. Heavy twig feeding may cause yellowing and premature dropping of leaves and broken twigs scattered over the crown but rarely seriously weakens the tree. In fall and winter after initial attack, numerous round entrance holes 3 mm in diameter in the bark are often the only outward sign of attack (figure 198E). During winter and spring, woodpecker holes in the bark are good indicators of bark beetle infestation. In spring, sparse or yellowed foliage also indicates attack. Removing the perforated bark reveals the engraved peculiar designs of centipede-like galleries (figure 198C and D). When attacks are numerous, the galleries can girdle the tree. The foliage of heavily infested trees turns yellow and then red within a few weeks of attack, and finally brown as the tree succumbs (figure 198F). Trees stressed and weak from drought, fire, storm damage, disease, or other causes are most susceptible. Healthy trees are seldom attacked except when beetle populations are high. Although large infestations usually kill a tree, light ones may only girdle branches or a part of the trunk, causing top dieback.

Control. Five species of hymenopterous parasites—*Coeloides scolytivorus* (Cresson), *Ecphylus hickoriae* Rohwer, *Heterospilus scolytidae* (Ashmead), *Spathius trifasciatus* Riley, and *Trigonura ulmi* Burks—help to reduce populations (Krombein and others 1979). Hickory bark beetles rarely attack healthy trees, so good cultural practices such as thinning, pruning, fertilization, and irrigation are important for orchard, ornamental, and other valuable trees (Goeden and Norris 1964, Hopkins 1912). The most effective control is to destroy trees harboring overwintering larvae during winter and spring. Infested trees can be cut and burned or submerged in water. An alternative is to peel the bark or spray with an insecticide before emergence begins in May or June. To protect valuable trees during epidemics, trunks and large branches should be thoroughly sprayed with an insecticide during early July.

Scolytus rugulosus (Muller)

shothole borer (figure 199)

Hosts. Apple, peach, pear, plum, cherry, quince, apricot, nectarine, loquat, serviceberry, wild cherry, chokecherry, mountain-ash, hawthorn, elm. Prefers cultivated fruit trees, but occasionally infests wild and uncultivated species (Brooks 1916).

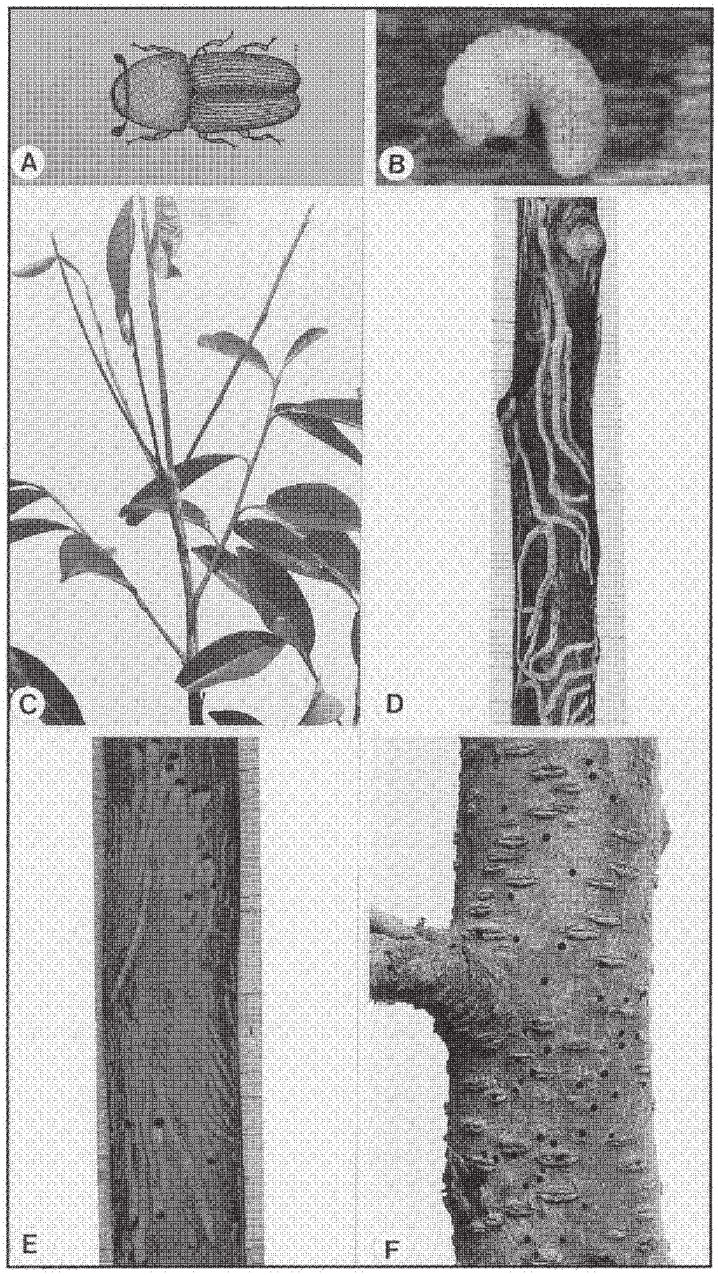

Figure 199—Scolytus rugulosus, *shothole borer: A, adult; B, larva; C, branch dying from attack; D, irregular larval tunnels on small stem; E, uniform galleries with pupation holes in sapwood; F, shot-sized exit holes in bark (B & C, courtesy W. Johnson).*

Range. Introduced in the United States (discovered first near Elmira, New York) from Europe in mid-1870's. Now common in fruit-growing areas throughout the United States, southern Canada, and northern Mexico (Bright 1976, Slingerland and Crosby 1919, Wood 1982).

Description. ***Adult.*** Dark reddish brown to grayish black bark beetle, 1.5 to 2.9 mm long (figure 199A) (Blackman 1934, Brooks 1916, Wood 1982). Body about twice as long as wide. Head barely visible from above and sparsely clothed with fine, moderately long setae. Antennae yellowish, clubbed at tips. Pronotum slightly wider than long, shiny surface with coarse, rather close, elongate punctures more dense on front and sides. Elytra about equal in width to pronotum, and each elytron rounded posteriorly. Ventral abdominal segments ascend strongly and obliquely toward elytra, but not excavated. ***Egg.*** Oval, 0.50 by 0.36 mm, milky white when deposited, but translucent at maturity (Gossard 1913). ***Larva.*** Legless grub, white to pink, cylindrical, and transversely wrinkled, 3.5 to 4.0 mm long (figure 199B). Head yellowish with rusty red jaws. Thoracic segments enlarged considerably. Abdomen tapers gradually toward tip and bends downward, giving larva a C-shape. ***Pupa.*** White to pink when formed, gradually turning yellow and darkening, 3.0 to 3.5 mm long.

Biology. Adults emerge from March to June, but adults may be found throughout much of the growing season (Bright 1976, Brooks 1916, Gossard 1913). Adults fly to susceptible trees, bore into the bark, and construct egg galleries 30 to 60 mm long, mainly in the inner bark, but also etching the surface of the sapwood. Egg galleries are more or less parallel with the stem, but sometimes curve, and occasionally branch or are Y-shaped. Eggs are deposited in small, closely spaced niches along both sides of the gallery. Eggs hatch in 3 to 10 days, and larvae tunnel at right angles to the gallery but sometimes turn and follow the wood grain; larval galleries vary in length from 2.5 to 10.0 cm. When larvae are numerous and crowded, their feeding galleries intertwine. Mature larvae burrow into the sapwood about 16 mm, then turn up or down along the grain and pupate in small oval cells. Some summer generation larvae pupate in the bark, but overwintering larvae are found almost exclusively in the wood. Development from egg to adult during summer is about 1 month. After the spring emergence of the overwintering generation, distinct generations are impossible to distinguish. This borer has one to two generations per year in its North range; and up to four generations per year in the South.

Injury and damage. Twigs, branches, and trunks, particularly of trees weakened from drought, disease, injury, or age, are most subject to attack (Gossard 1913, Slingerland and Crosby 1919). Active attacks are often indicated by small amounts of boring dust in bark crevices. On peach and other stone-fruit trees, small masses of clear, gummy exudate accumulate at beetle entrances. The more vigorous the tree, the more gumlike exudate accumulates. Wilting, yellowing, and browning of foliage on twigs

(figure 199C) and other stems are evidence of attack. Entrance holes are usually found at lenticels and other roughened areas of the bark. Galleries are often more irregular than those made by other scolytids on small branches and stems (figure 199D). On larger branches and trunks, both the egg (mostly vertical) and larval galleries (initially transverse, becoming oblique to vertical) are relatively uniform (figure 199E). Emerging beetles leave through many small shot-sized holes—hence the pest's common name (figure 199F). Because it prefers injured, weakened, and dying trees, this species is of minor importance in forest operations. However, it can be a serious horticultural pest in poorly maintained fruit orchards.

Control. Studies in 1965 (Bushing 1965) recorded 20 species of hymenopterous parasites, whereas later studies (Krombein and others 1979) list only 11 species. Woodpeckers excavate many of the larvae, especially during winter (Brooks 1916). Infestations and losses can be minimized by keeping trees healthy. All dead and dying limbs and trees should be removed promptly and destroyed to eliminate breeding sites. Insecticides may sometimes be required to protect fruit trees.

Scolytus multistriatus (Marsham)

smaller European elm bark beetle (figure 200)

Hosts. Elm. All native and introduced species of elm as well as Japanese zelkova (USDA FS 1985).

Range. Introduced from Europe, presumably in either burl elm logs sent to veneer plants or in elm crates used to carry cargo (Whitten 1960). First recorded near Boston, Massachusetts, in 1909 and since reported from every state except Alaska and Hawaii; occurs across southern Canada from Nova Scotia to British Columbia (Schreiber and Peacock 1979, USDA FS 1985, Wood 1982).

Description. ***Adult.*** Small bark beetle with shiny upper surface; pronotum nearly black, elytra dark reddish brown, length 1.9 to 3.1 mm (figure 200A) (Blackman 1934, USDA FS 1985, Whitten 1960, Wood 1982). Head of male flattened in front between eyes; that of female, convex. Antennae clubbed at extremity. Face covered with many, fine, long, incurved, yellow hairs, except near median line. Pronotum slightly wider than long. Elytra slightly wider than pronotum; about 1.3 times as long as wide. Posterior underside of abdomen concave, second sternite nearly vertical and armed with noticeable stout spine projecting from anterior margin. ***Egg.*** Small, globular, shiny, pearly white. ***Larva.*** White, legless grub with brown head, C-shaped, 2.8 to 3.2 mm long (figure 200B). ***Pupa.*** White initially, gradually darken, wings folded under abdomen, about 3 mm long.

Biology. Larvae overwinter in pupal chambers in bark (Schreiber and Peacock 1979, USDA FS 1985, Whitten 1960). They pupate in spring, and adults emerge through "shot holes" they chew through the bark at about the time the first elm leaves fully expand (late March to early June, depending on latitude). Emerging adults fly directly to weakened or diseased elms to breed in the inner bark or to healthy elms to feed on the

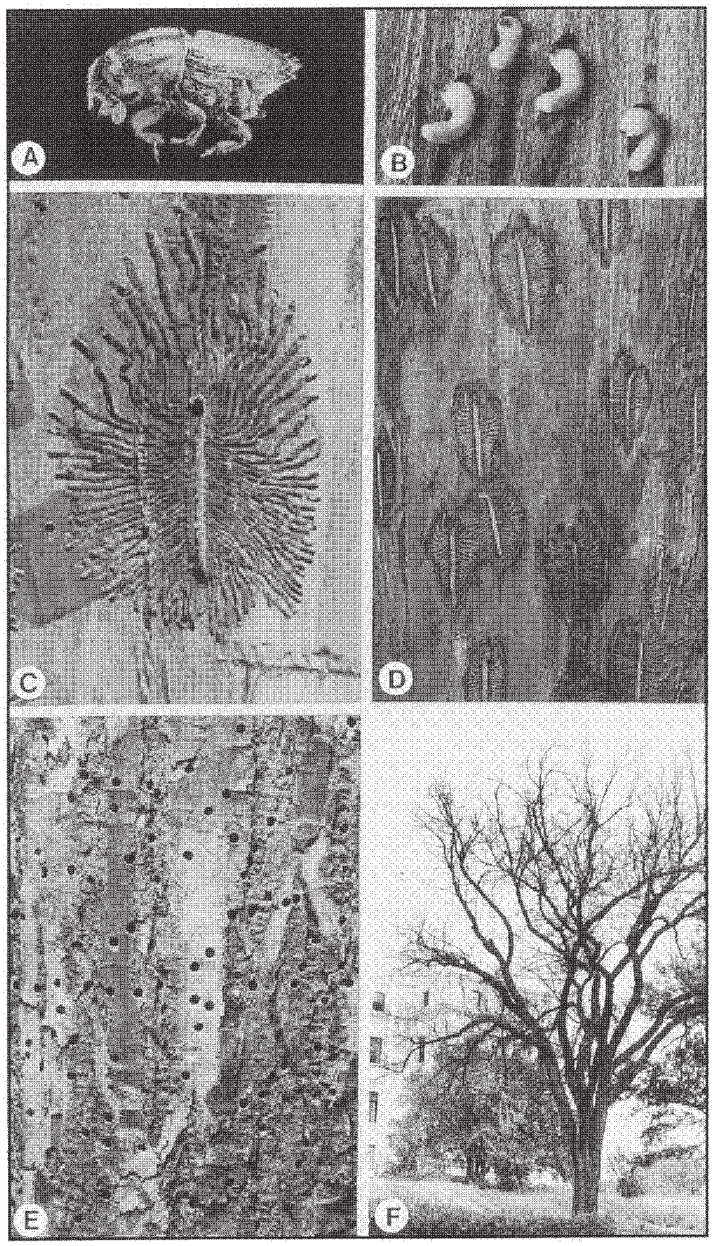

Figure 200—Scolytus multistriatus, *smaller European elm bark beetle: A, adult; B, larvae; C, closeup of vertical egg tunnel and radiating egg galleries; D, numerous galleries under bark; E, beetle exit holes in bark; F, large elm killed by beetles (C-E, specimens courtesy J. Simeone).*

bark in the crotches of 2- to 4-year-old twigs. Beetles that emerge from trees with Dutch elm disease become contaminated with the fungus *Ceratocystis ulmi* (Buisman) C. Moreau and in feeding often transmit it to healthy trees. Breeding attacks typically begin in weakened trees. Females initiate the attack and release an aggregating pheromone that attracts both sexes to the breeding site. After mating near entrance holes in the bark, females bore egg galleries in the inner bark 2.5 to 8 mm long and parallel with the grain. Eggs are deposited in closely spaced niches along the sides of the egg gallery. Larvae feed in the inner bark and surface of the wood. Their parallel galleries radiate at right angles to the egg gallery, but larvae often turn and follow the wood grain as they mature. Larval galleries are 8 to 20 cm long. Pupation occurs largely in the bark, and adults emerge through individually excavated holes. Development from egg to adult during summer is about 6 weeks. This bark beetle has two generations per year in the Midwest; three generations per year are common in the South.

Injury and damage. By midsummer, many healthy elms that experienced twig-crotch feeding by newly emerged beetles will develop symptoms of Dutch elm disease: wilting, drying, yellowing, and browning of foliage followed usually by defoliation and death. Symptoms can occur on scattered branches, or the entire crown may wilt and die suddenly. In the inner bark and etched into the surface of the sapwood are the characteristic gallery patterns of adults and larvae (figure 200C and D). Egg galleries are straight and run vertically along the wood grain. Closely spaced larval galleries radiate perpendicularly from both sides of the egg gallery but then turn and follow the wood grain. Galleries often overlap and frequently girdle the tree. Bark appears perforated by numerous small shot-sized emergence holes, 0.7 to 1.1 mm in diameter (figure 200E). This pest is the principal vector of Dutch elm disease in the United States and annually contributes to the death of thousands of valuable street, shade, and park trees (figure 200F) (Schreiber and Peacock 1979, Shenefelt and Benjamin 1955). The United States Government has spent huge sums of money to control this beetle (USDA FS 1985).

Control. Eight species of hymenopterous parasites have been identified (Bushing 1965, Krombein and others 1979). Four disease-causing pathogens—including three entomogenous bacteria (*Aceobacter scolyti* Presson, *Escherichia klebsiellaeformis* Presson, *Serratia marsescens* Bizio (Vago 1963)) and one fungus, *Beauveria bassiana* (Balsamo) Vuillemin—have been reported. Studies show that 92% of overwintering larvae in damp habitats are killed by *B. bassiana*, but only 4% mortality occurs in dry habitats (Madelin 1963). Low temperatures and overcrowding of broods in the bark have also been reported as natural controls (Shenefelt and Benjamin 1955). Losses caused by this pest and the accompanying Dutch elm disease can be minimized by concerted community efforts to (1) reduce beetle populations by eliminating breeding materials through sanitation

and tree care, (2) protect healthy trees with insecticidal sprays, (3) prevent underground disease transmission by destroying natural root grafts between diseased and healthy trees, and (4) plant trees that are resistant to Dutch elm disease (Schrieber and Peacock 1979). Pheromones can be used to detect and monitor beetle populations and to time chemical controls (Birch and others 1981).

Hylurgopinus rufipes (Eichhoff)

native elm bark beetle. (figure 201)

Host. Elm. Elm species are the major hosts, but also attacks basswood, ash, and wild cherry (USDA FS 1985).

Range. Throughout the eastern United States north of Alabama and Mississippi (USDA FS 1985) west to Nebraska and North Dakota (Furniss and Carolin 1977); in Canada, from New Brunswick to Manitoba (Bright 1976).

Description. ***Adult.*** Brownish black bark beetle, sparsely clothed with stiff, short, yellow hairs, and measuring 2.0 to 3.5 mm long (figure 201A) (Bright 1976, USDA FS 1985). Head convex, thickly punctured, and barely visible from above. Antennal club almost twice as long as wide. Pronotum narrows toward front; entire surface densely punctured; posterior margin reddish. Longitudinal striae on elytra deep and contain deep punctures and erect bumps. Distinguished from *S. multistriatus* (Marsham) (also in elm) by color, shape, and the absence of a concave abdomen and prominent spine. ***Egg.*** Globular, shiny, white (figure 201B) (Whitten 1960). ***Larva.*** Legless, C-shaped, fat, wrinkled, white with brown head, 3 to 5 mm long when mature (figure 201C).

Biology. Adults emerge from mid-April to mid-May and fly to healthy elms to feed in the bark of large branches for brief periods (Hildahl and Jeffrey 1980, USDA FS 1985, Whitten 1960). After feeding, beetles fly to dying and recently dead trees for oviposition. They bore into bark crevices, or under bark scales, and tunnel to the inner bark where females construct egg galleries. Egg galleries extend horizontally across the grain and usually consist of two branches diverging from the point of penetration in the bark. Eggs are deposited along sides of the egg galleries, and developing larvae feed in closely spaced, parallel galleries that run mostly perpendicular to the egg galleries with the wood grain. Larvae pupate in small, oval-shaped cells in the bark at the ends of feeding tunnels. Larvae and adults overwinter in the bark. If the host has Dutch elm disease, emerging beetles will transmit fungal spores to healthy elms during the spring and fall adult feedings. There are two generations a year in the beetle's southern range but only one to one and one-half generations in its northern range.

Injury and damage. Red dust in bark fissures of living trees in spring and fall indicates overwintering beetles (Hildahl and Jeffrey 1980). Accurate identification is best made by examining the adult and larval gallery patterns found in the inner bark and slightly etched into the sapwood surface (figure 201D and E). The egg gallery of *H. rufipes* is horizontal or slightly inclined,

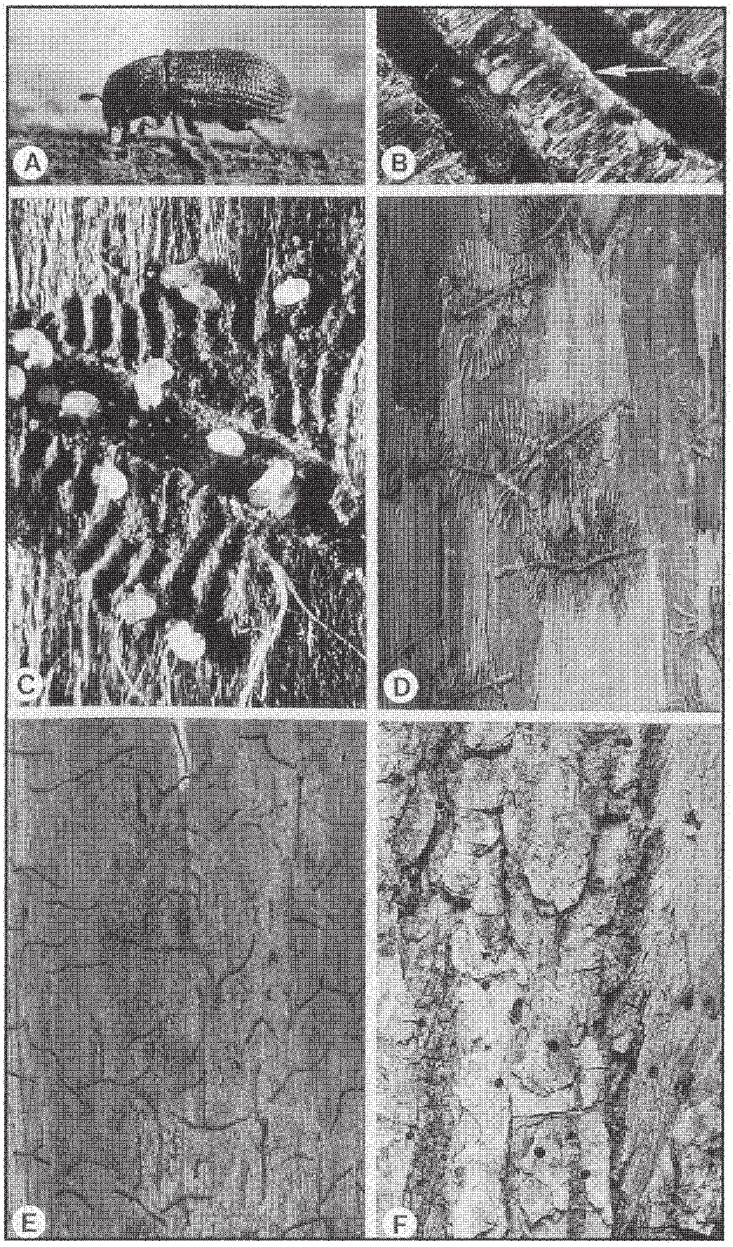

Figure 201—Hylurgopinus rufipes, *native elm bark beetle: A, adult; B, eggs in niches along tunnel; C, larvae; D, horizontal egg tunnels with radiating larval tunnels; E, egg tunnels etched in sapwood; F, adult exit holes in bark (A-C, courtesy C. Jeffery and V. Hildahl; D, courtesy W. Johnson).*

distinguishing it from the egg gallery of *S. multistriatus*, which runs vertically with the wood grain. Larval galleries of *H. rufipes* run along both sides of the egg gallery perpendicular to the wood grain. Larvae, pupae, and callow adults may be found in small galleries and small cells. Emerging adults leave numerous small, round holes about 1 mm in diameter in the bark (figure 201F). Before Dutch elm disease was introduced in the United States, the native elm bark beetle was of little importance because it primarily attacked weakened, dying, and recently dead trees (McDaniel 1936). Now it is a major vector of Dutch elm disease, particularly in New England and Canada, where the species is more abundant than *S. multistriatus* (USDA FS 1985). *Hylurgopinus rufipes* populations can grow large during prolonged drought, when the beetles aggressively attack healthy trees (McDaniel 1936).

Control. Ten species of hymenopterous parasites, predaceous birds, and disease are natural enemies (Bushing 1965, Whitten 1960). Woodpeckers capture many overwintering larvae and adults. Low winter temperatures and competition for food caused by larval overcrowding often cause high rates of mortality. Many communities emphasize prevention through good tree maintenance and strict sanitation as opposed to control (Hildahl and Jeffrey 1980). Infested and diseased elms should be removed and destroyed within 30 days of being diagnosed. Insecticidal sprays and injected fungicides have been used with some success in protecting valuable yard and street trees. However, for sanitation cutting and chemical treatment to be effective, the effort requires communitywide cooperation. Controls are rarely feasible in forests.

Hylesinus aculeatus (Say)

[eastern ash bark beetle] (figure 202)

Host. Ash. White and green ash, but other ash species also probably serve as hosts (Beal and Massey 1945, Blackman 1922, Chamberlin 1939).

Range. Eastern United States west to the Rocky Mountains and eastern Canada west to Manitoba (Blackman 1922, Furniss and Carolin 1977, Ives and Wong 1988).

Description. ***Adult.*** Small, elongate, cylindrical bark beetle, 2.2 to 3.4 mm long (figure 202A) (Blatchley and Leng 1916, Ives and Wong 1988, USDA FS 1985). Dark brown; distinct light and dark patterns occur due to dense covering of flattened, whitish gray scales (Blackman 1922). Light scales on pronotum outline a diamond-shaped patch of dark, reddish brown scales. Brown and gray scales on elytra form a variable herringbone pattern. Elytra slightly wider than pronotum and serrate along anterior margin. Rear of elytra convex and gradually sloped (Beal and Massey 1945). ***Larva.*** White with brown mandibles, legless, C-shaped; thoracic segments moderately larger than abdominal segments (figure 202B).

Biology. Adults emerge from hibernation as early as late March in Mississippi (Blackman 1922) but as late as May or June in the northern range (Ives and Wong 1988). Adults fly to limbs and trunks of

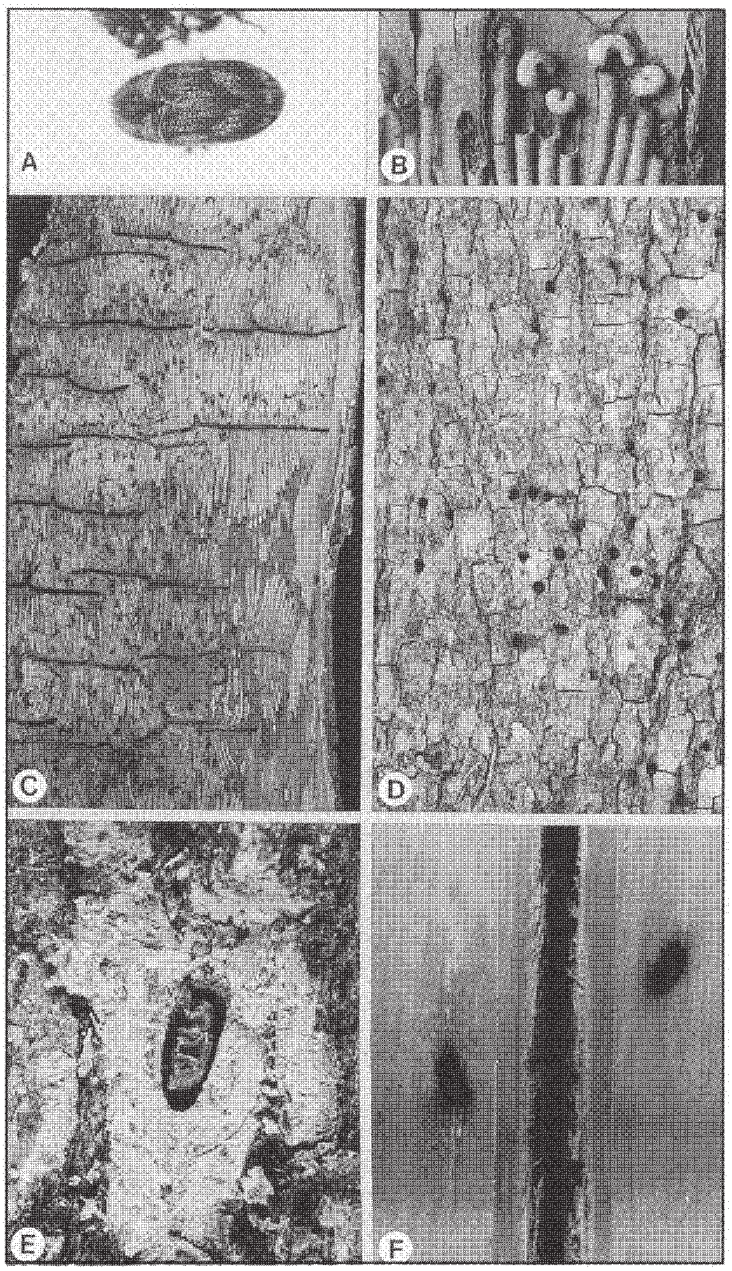

Figure 202—Hylesinus aculeatus, *[eastern ash bark beetle]: A, adult; B, larvae; C, horizontal egg tunnels with vertical larval galleries; D, round adult exit holes in bark, E, adult in hibernation cell in bark; F, hibernation chambers extending through bark to cambium.*

seriously weakened, dying, and felled trees to reproduce (USDA FS 1985). Females make large transverse egg galleries beneath the bark and deposit eggs singly in niches on opposite sides of the gallery. Larvae tunnel perpendicular to the egg gallery with the wood grain and pupate at the ends of the feeding galleries in oval cells. Adult and larval galleries and pupal cells deeply etch the sapwood surface and inner bark (Chamberlin 1939, USDA FS 1985). Newly formed adults rarely disturb the beautiful design of the galleries (figure 202C) because they burrow straight out from their pupal cells to the bark surface to emerge. In fall, adults construct short feeding tunnels in the bark of living or recently felled trees and overwinter (Beal and Massey 1945). This bark beetle has one generation per year in Minnesota, with new adults leaving hosts in midsummer to seek winter hibernation sites (Dodge 1938); two generations occur in North Carolina (Beal and Massey 1945). In Mississippi, beetles develop from egg to adult in 2 to 2.5 months; thus, three generations seem possible (Blackman 1922).

Injury and damage. Bark on susceptible trees and fresh-cut logs may be peppered with small round entrance holes. Fine frass may accumulate in bark crevices. Removing bark reveals typical galleries and white tunneling larvae. The prominent egg galleries are characterized as biramous and transverse, with two arms connected by a very short slightly enlarged tunnel below the entrance hole, which serves as a turning niche and nuptial chamber (figure 202C) (Beal and Massey 1945, Blackman 1922). Egg galleries range from 2 to 6 cm long. Larval galleries are packed with frass and radiate outward nearly perpendicular from the transverse egg galleries. Larval engravings are further characterized as longitudinal, regularly and closely spaced, and short and uniform (2 to 5 cm). Few other bark beetles produce more uniform galleries (Chamberlin 1939). Beetles leave many tiny round exit holes about 1 mm in diameter in the bark (figure 202D). When populations are high, hibernating niches can be found in the inner bark of healthy trees (figure 202E). Hibernating niches often extend through the bark to the cambium and cause small defects in the wood (figure 202F). Although the beetle can hasten the death of trees weakened by fire, disease, injury, and other stresses, it is seldom important from an economic standpoint (Beal and Massey 1945). Occasionally, it is an economic pest to producers of "rustic" (bark still on) ash products (USDA FS 1985).

Control. Six species of parasites have been listed (Bushing 1965). In New Jersey studies, 32% of the larvae were killed by a hymenopterous parasite—*Coeloides scolytivorus* (Cresson) (Hoffman 1938). In another study in Mississippi, parasitism by an unidentified wasp ran as high as 90% (Blackman 1922). A clerid beetle—*Enoclerus quadriguttatus* Olivier—sometimes destroys large numbers of beetles. Direct controls are rarely warranted but, should they be necessary, felling and debarking infested trees and limbs before broods emerge control the insect (Beal and Massey 1945). Logs intended for "rustic"

uses should be promptly removed from woodlands and stored in beetle-free areas or sprayed to prevent infestation.

Hylesinus californicus Swaine

[western ash bark beetle] (figure 203)

Hosts. Ash, olive. White, green, and Oregon ash, and olive recorded and probably other ash species (Chamberlin 1939, McKnight and Aarhus 1973, Vernoff 1980).

Range. Washington south to California into Mexico and east to North Dakota, Colorado, and Oklahoma (Furniss and Carolin 1977), and in southern Alberta, Saskatchewan, and Manitoba (Ives and Wong 1988).

Description. ***Adult.*** Small, cylindrically oval bark beetle, 2.3 to 3.0 mm long (Chamberlin 1939, Essig 1917, Ives and Wong 1988). White scales (plumose hairs) on pronotum form an irregular elongate pattern around patch of black scales (sometimes diamond shaped). Antennae and legs reddish brown. White and black scales on elytra produce gray blending, but a variable herringbone pattern is evident. ***Larva.*** White with dark mandibles, C-shaped thoracic segments larger than those of abdomen, slightly longer than adult.

Biology. Adults emerge from hibernation in late May and early June in North Dakota and Oregon (McKnight and Aarhus 1973, Vernoff 1980). Beetles attack twigs, branches, and sometimes boles of living trees. Females select the host; males join them. Short entrances are slightly longer than the bark thickness, and when they reach the junction of the inner bark and outer sapwood, they are enlarged somewhat to form a nuptial chamber and turning niche for adults. Two egg galleries are constructed opposite each other and originate at the nuptial chamber. Egg galleries are straight or only slightly curved, deeply engrave the sapwood, and often completely girdle small stems; they are invariably stained black by a *Ceratocystis* fungus. Eggs are deposited singly in niches along the sides of the egg galleries, and larvae tunnel at more or less right angles to the egg gallery following the wood grain. As larvae grow, their galleries occasionally cross. Mature larvae pupate at the ends of the galleries in small elliptical cells. In North Dakota, new adults emerge through August. They fly to boles of living trees and burrow obliquely upward into the outer bark and construct winter hibernation chambers that may contain one or more beetles. There is one generation per year (Furniss and Carolin 1977).

Injury and damage. Small, round entrance and exit holes in the bark, sometimes with fine frass in bark crevices, may be found. The most characteristic evidence of attack is a row of ventilation holes about 1 mm in diameter and about 4 mm apart directly over the egg gallery (figure 203A) (McKnight and Aarhus 1973). Bark along the row of holes and slightly to either side of the egg gallery on twigs and branches becomes sunken and discolored. Removing the bark reveals typical egg galleries that often nearly encircle twigs and branches (figure 203B). Both the transverse egg gallery and perpendicular larval galleries

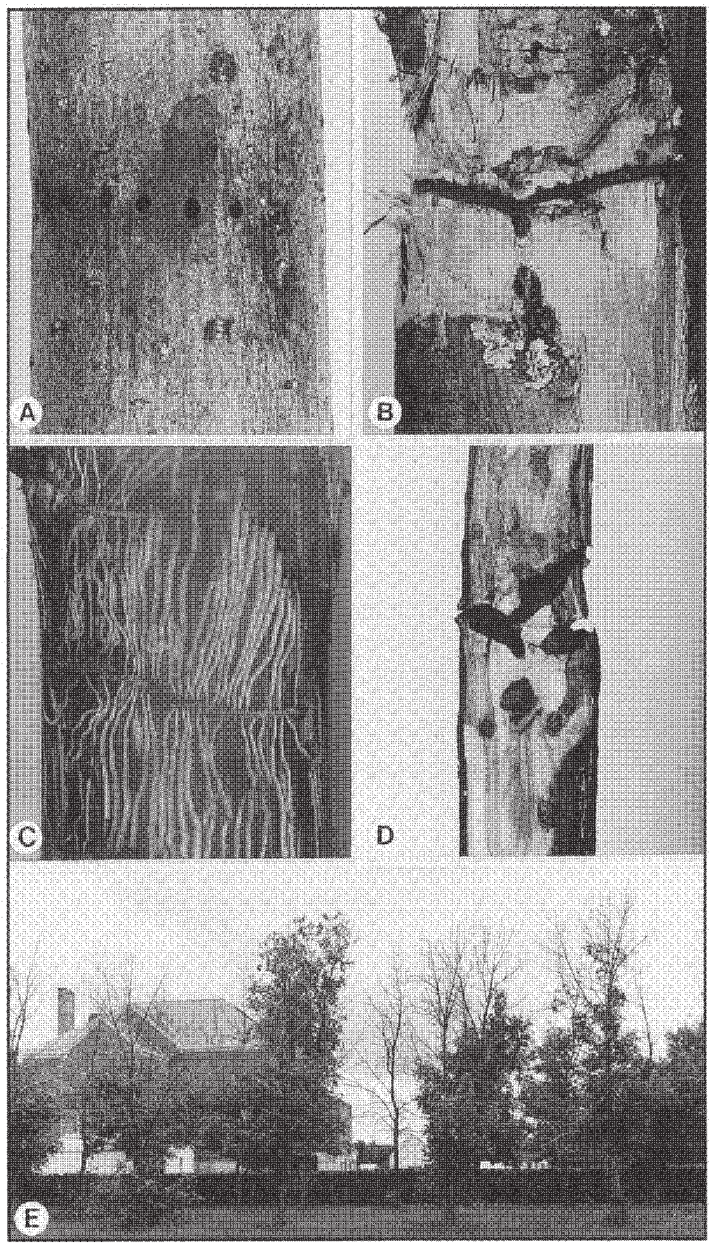

Figure 203—Hylesinus californicus, *[western ash bark beetle]: A, ventilation holes in bark over egg tunnel; B, transverse egg tunnel in bark; C, egg tunnel with vertical larval galleries; D, small ash stem girdled by egg tunnel; E, green ash killed by beetle attacks (courtesy M. Dix).*

are in the inner bark and on the surface of the sapwood (figure 203C). Twigs and small branches may be girdled and killed by one beetle (figure 203D). Leaves on girdled branches turn bright yellow then brown, especially during July and August. Crown dieback and tree mortality occur especially when infested trees are weak from drought or other stresses (figure 203E). In the Great Plains, where green ash is prized as a shade and windbreak tree, this pest sometimes causes noticeable branch and top kill and some tree mortality.

Control. Four insect parasites—*Coeloides scolytivorus* (Cresson), *Ecphylus schwarzii* (Ashmead), *Habrocytus* sp., and *Spathius benefactor* Matthews—have been recorded (Bushing 1965, Vernoff 1980) but apparently they have little effect on beetle populations. An entomogenous nematode—*Omemeea maxbassiensis* Massey—has been collected from beetle galleries (McKnight and Aarhus 1973). Direct controls are rarely needed.

Hylesinus criddlei Swaine

[northern ash bark beetle] (figure 204)

Hosts. Ash. White and green ashes have been attacked (Swaine 1918).

Range. A northern species reported from Minnesota (Dodge 1938), North Dakota (McKnight and Aarhus 1973), Wyoming, Colorado (Furniss and Carolin 1977), Manitoba, and Quebec (Doane and others 1936).

Description. ***Adult.*** Very small, oval bark beetle, 2.0 to 2.6 mm long (Chamberlin 1939). Pronotum with numerous roughened, rasplike ridges that extend from anterior margin to middorsal area; also with submarginal row of ridges that are elongate and nearly pointed. Elytra with grooves and punctures almost entirely hidden by dense covering of scales. Wing covers slope gradually toward posterior margin. ***Larva.*** White C-shaped body; with brown mandibles and enlarged thoracic segments (figure 204A).

Biology. Adults hibernate in chambers in the outer bark, most commonly around the root collars of trees 10 to 15 cm in diameter at breast height (McKnight and Aarhus 1973). In North Dakota, adults emerge from hibernation in mid-May and fly to susceptible hosts. Trees felled the previous year are especially attractive to beetles. Females bore into the bark and are soon joined by the males (figure 204B). The beetles make two-branched egg galleries and deposit eggs in niches along both sides of the gallery. Larvae feed in closely spaced tunnels, mature, pupate, and produce adults that emerge from late July through August. This species has one generation a year.

Injury and damage. Removing the bark reveals the characteristic galleries (figure 204C). The gallery system is a slightly enlarged, nuptial chamber with nearly straight egg galleries about 1 mm in diameter extending transversely across the wood grain and sometimes encircling twigs and small branches (Doane and others 1936, McKnight and Aarhus 1973). Larval galleries are symmetrical, close together, and filled with frass; they radiate from the empty, larger egg galleries. Egg galleries are often so close together that pupal chambers of

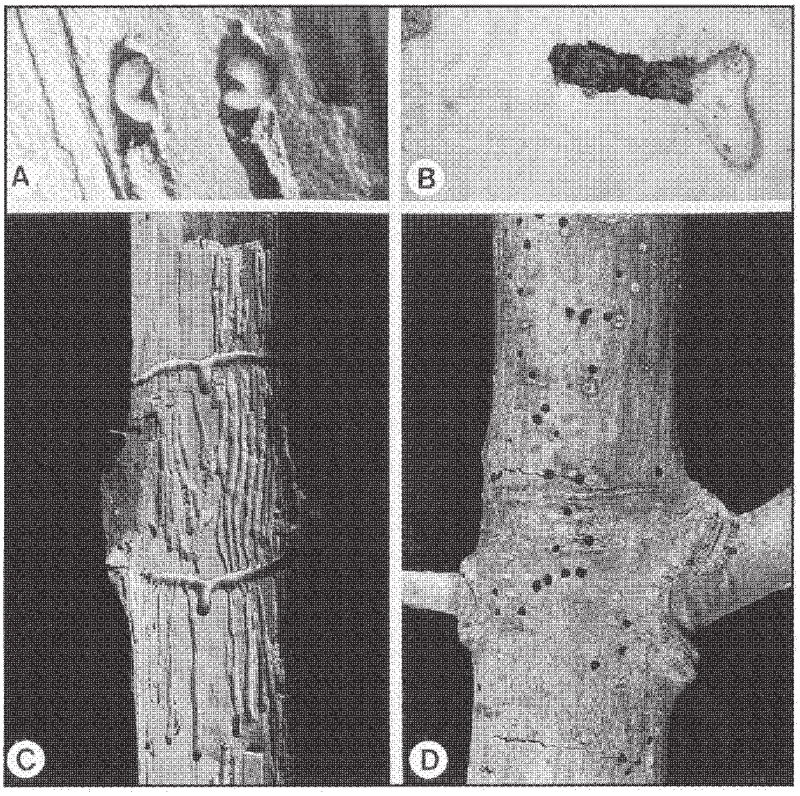

Figure 204—Hylesinus criddlei, *[northern ash bark beetle]: A, larvae; B, pair of adults initiating egg tunnel in bark; C, nuptial chamber, lateral egg tunnels, and vertical larval galleries; D, numerous adult exit holes in bark (A, courtesy M. Dix).*

neighboring broods nearly touch. The egg galleries deeply engrave the outer sapwood but exhibit little or none of the dark staining that occurs with other ash bark beetles. There are no ventilation holes over the egg galleries as with *H. californicus*. The bark may be peppered with numerous round holes slightly less than 1 mm in diameter made by the emerging beetles (figure 204D). Trees may be attacked along their entire lengths from groundline upwards, but attack sites are most common on upper stems and branches above and beyond the attack sites of *H. californicus*. Trees girdled or partially girdled by rodents during winter, trees infested by other bark beetle species, those cut the previous year, and branches broken by winter and spring windstorms are preferred. Thus, the beetle is only of minor importance.

Control. The following parasitic wasps have been reared from infested branches and trunks—*Dinotiscus* sp., *Eurytoma crassineura* Ashmead, *Mesopolobus* sp., and *Rhaphitelus maculatus* Walker. (McKnight and Aarhus 1973). Direct controls are rarely needed.

Phloeotribus liminaris (Harris)

peach bark beetle (figure 205)

Hosts. Peach, cherry, plum, black cherry, elm, mulberry, mountain-ash. Peach preferred, but cherry, black cherry, and other stone fruit trees also commonly attacked (Gossard 1913, USDA FS 1985).

Range. Primarily an eastern species, from the Atlantic Coast west to Arkansas, south to the Gulf Coast, and north to Manitoba (USDA FS 1985, Wood 1982). Particularly troublesome in Ohio, West Virginia, New York, and other northeastern areas (Rexrode 1981, Schultz and Allen 1977).

Description. ***Adult.*** Oblong, subcylindrical bark beetle, light brown to nearly black, 1.5 to 2.2 mm long (figure 205A) (Beal and Massey 1945, Blackman 1922, Wood 1982). Segments of antennal club greatly elongated. Pronotum entirely reticulate, containing moderately large, shallow punctures and abundantly clothed with long, fine, whitish hairs. Elytra broader than pronotum, anterior margin slightly elevated and serrate, striae deep, punctures coarse, surface clothed with long, fine hairs. Declivity of elytra armed with small, blunt granules. ***Egg.*** Elliptical, opaque, milky white, 0.46 by 0.37 mm (Gossard 1913). ***Larva.*** White with yellowish head and brown mandibles, 2.8 to 3 mm long (figure 205B). Body C-shaped, very wrinkled, and clothed with numerous short spines. ***Pupa.*** White, turning to brown at maturity, about 2.5 mm long and 0.75 mm wide; end of abdomen bears one pair of brown-tipped spines (figure 205B) (Gossard 1913).

Biology. This bark beetle overwinters in larval and adult stages (Brooks 1916, Rexrode 1982, Slingerland and Crosby 1919). Adults emerge as early as March and early April in peach orchards but not until early May in black cherry stands in forests. Confusion over the number of generations a year arises because spring broods are produced by both the overwintering parent adults and by their adult progeny, which develop from overwintering larvae. It is

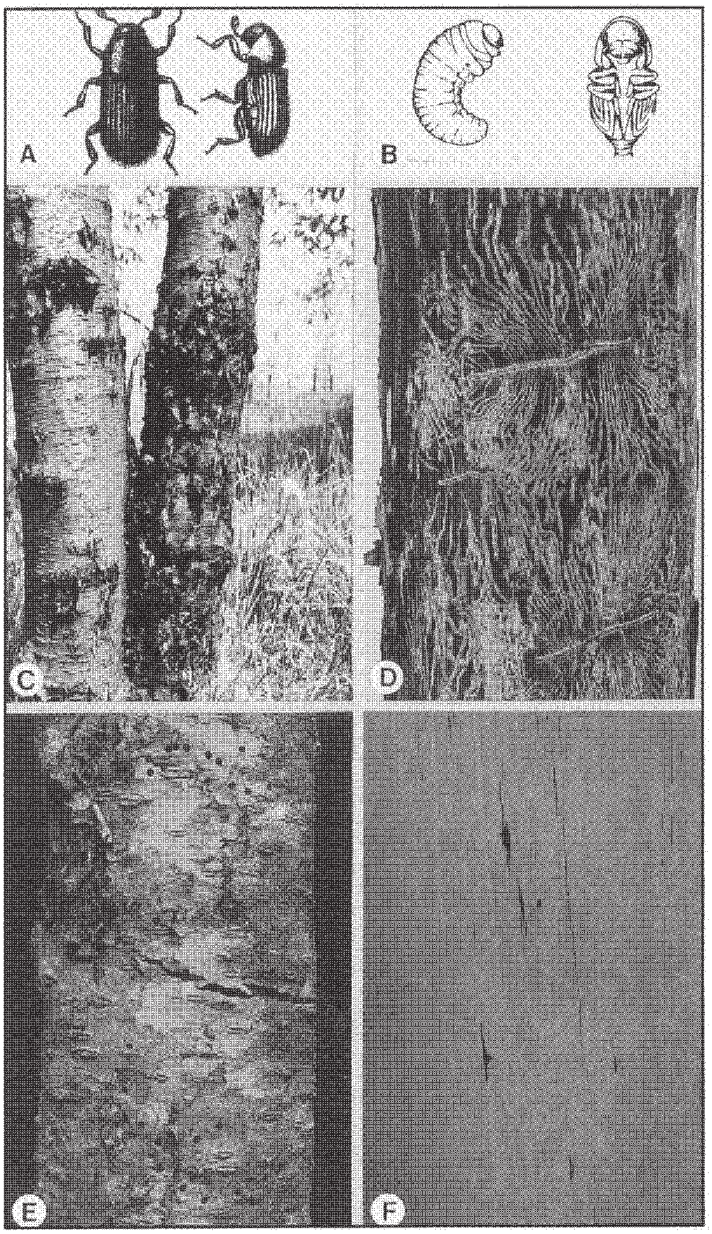

Figure 205—Phloeotribus liminaris, *peach bark beetle: A, adults; B, larva and pupa; C, roughened bark with gum and frass exudates; D, lateral egg tunnels with radiating larval galleries under bark; E, adult exit holes in bark of black cherry; F, gum-spot defects in lumber (A-D, courtesy C. Rexrode).*

common for half of the primary progeny adults to emerge, attack, and lay eggs two or three times in the same or new hosts throughout summer and fall. Reemerging parent adults attack in the gaps between those by progeny beetles; thus, when susceptible hosts are available, adults are continually on the attack. Identification of specific broods is further complicated by the great variation in the duration of each life stage. Eggs can last 7 to 110 days, larvae 25 to 332 days, pupae 17 to 181 days, and adults 7 to 217 days (the long periods include overwintering time). Attacks are initiated by females, which are soon joined by males. Mating occurs in the short entrance tunnel. Females construct an egg gallery, then deposit 80 to 100 eggs singly in separate niches along the sides of the gallery, covering each with a small plug of frass. Young larvae feed in short galleries that radiate at right angles to the egg gallery. Pupae develop in the inner bark at the ends of the larval galleries. New adults emerge through separate holes in the bark, often producing a shot hole pattern. On peach trees, hibernating beetles form small chambers in the inner bark that result in gum exudation on the bark surface. Hibernation chambers on wild black cherry are constructed in the outer bark under bark scales and rarely result in gum flow.

Injury and damage. The most characteristic evidence of attack is small globules of gummy sap, mixed with frass, at entrance holes on the bark surface (figure 205C) (Brooks 1916, Gossard 1913, Rexrode 1981). Gummosis may occur on limbs and trunks; occasionally, gum flows so prolifically that it puddles at the base of trees. The gallery system (figure 205D) consists of a short entrance tunnel that extends to the succulent inner bark and outer sapwood where egg galleries are 25 to 65 mm long and cut transversely across the grain; the short entrance tunnel and the egg gallery often form a Y. Egg galleries are distinguishable from those of the shothole borer, which are mostly parallel with the grain. Larval galleries 38 to 70 mm long run mostly at right angles to the egg gallery but occasionally turn slightly across the grain and sometimes intersect. Emerging beetles leave many round holes about 1 mm in diameter in the bark (figure 205E). This beetle prefers weakened and dying trees but habitually constructs short hibernation galleries (causing gummosis) in healthy trees, thus predisposing such trees to further infestation (Gossard 1913). A well-known enemy in peach orchards, it sometimes causes serious mortality in natural stands of black cherry weakened by insect defoliators (Schultz and Allen 1977). Aborted attacks on healthy black cherry trees result in ingrown gum pockets, black spots, and streaks that degrade wood for lumber and veneer (figure 205F) (Rexrode 1981).

Control. Natural enemies include a hymenopterous parasite (*Cheiropachus obscuripes* Brues) (Bushing 1965), an unidentified nematode, and mites (Gossard 1913). Although direct control measures sometimes may be required, emphasis in commercial fruit orchards should be given to maintaining vigorous trees and control of

other insects and diseases (Chandler 1939). Removal and destruction of severely weakened and dying trees and branches to eliminate breeding must be practiced continually. Chemicals have given control when direct measures are required (Brooks 1916, Chandler 1939).

Phloeotribus frontalis (Olivier)

[mulberry bark beetle] (figure 206)

Hosts. Mulberry. Red mulberry is preferred, but other native and exotic species are also attacked (Blackman 1922, USDA FS 1985). There is one questionable record of occurrence in hackberry (Beal and Massey 1945).

Range. East of the Rocky Mountains from Pennsylvania and Georgia west to Kansas and Texas (Wood 1982). Probably occurs throughout the range of its chief host, red mulberry (Blackman 1922).

Description. ***Adult.*** Very small, somewhat elongate, cylindrical bark beetle; dark brown, 1.8 to 2.2 mm long (figure 206A) (Beal and Massey 1945, Blackman 1922). Front of female's head convex and shallowly, densely punctured; male's head, front slightly concave, densely punctured, with a pair of spines at base of antennae. Pronotum slightly broader than long, roughened along sides and in front, coarsely punctured on posterior dorsal half. Elytra broader than pronotum; anterior margins arcuate and serrate. Elytral striae deeply impressed with rows of coarse, closely spaced, shallow punctures; spaces between striae granulate and bear short, erect setae. ***Larva.*** White with brown mandibles, and slightly enlarged thoracic segments; curved to C-shaped body and 2.0 to 2.4 mm long (figure 206B). ***Pupa.*** White, gradually darkening, 1.8 to 2.3 mm long (figure 206C).

Biology. Adults hibernate in galleries in the bark of host trees (Beal and Massey 1945, Blackman 1922). Adults emerge during spring and fly to susceptible trees to reproduce. Branches and trunks of considerably weakened trees, freshly felled trees, and fresh stumps are most susceptible. The monogamous females initiate the attack and construct the slightly enlarged nuptial chamber. After mating, females make egg galleries and deposit 30 to 93 eggs each in tiny niches along the gallery walls. Larvae feed and burrow outward from the egg gallery and pupate at the ends of larval galleries. New adults exit the bark directly above the pupal cells and fly to living trees to feed. The insect has two generations per year. Adults burrow into the inner bark of living trees to feed and overwinter. This tunneling causes irritation and stimulation of thickened callus tissue. Beetles are frequently found in trees infested by the cerambycid species *Dorcaschema wildii* and *D. alternatum*.

Injury and damage. Initially, numerous short strings of yellow frass extrude from attack sites on the bark (figure 206D). Frass becomes fine and powdery as the stems dry. Leaves may yellow and soon brown on individual branches or over the entire crown. Removing bark reveals the characteristic galleries (Beal and Massey 1945, Blackman 1922). The gallery system consists of a short, enlarged entrance tunnel

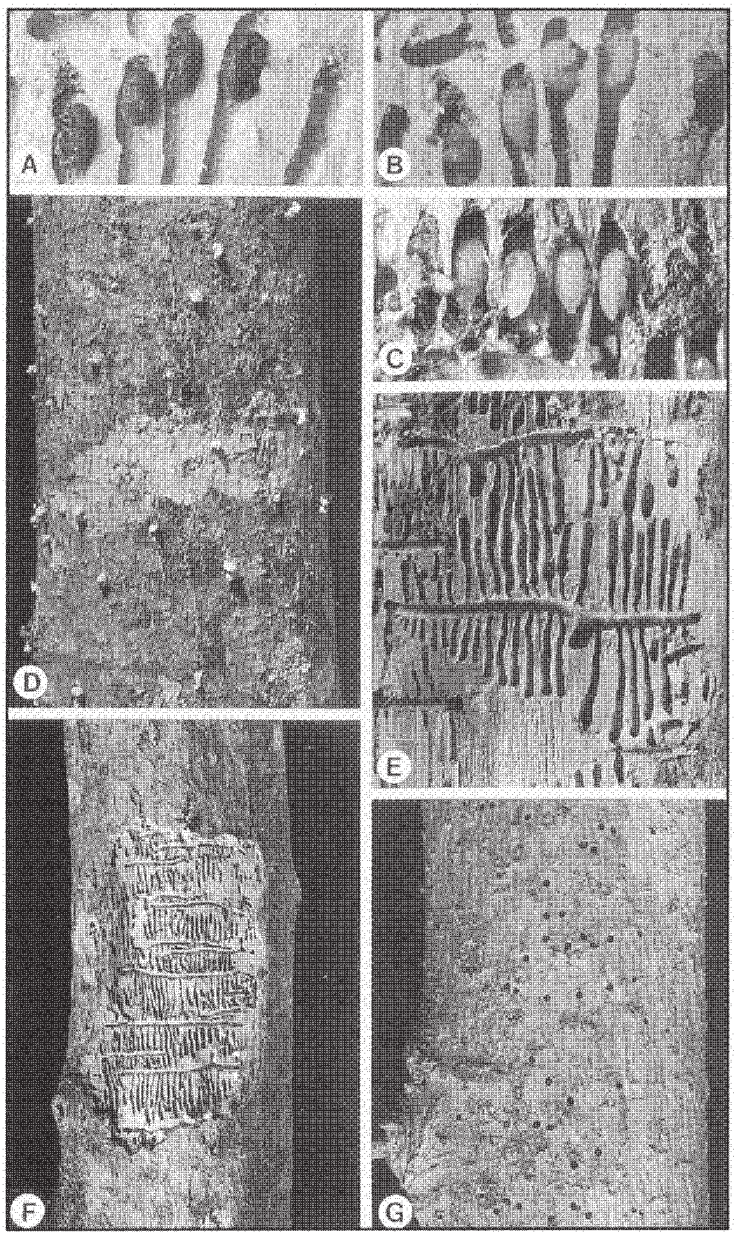

Figure 206—Phloeotribus frontalis, *[mulberry bark beetle]: A, teneral adults; B, larvae; C, pupae; D, yellow frass clumps extruding from entrance holes in bark; E, closeup of nuptial chamber, lateral egg tunnels, and vertical larval galleries; F, overlapping galleries under bark; G, adult exit holes in bark.*

through the bark to the inner phloem and sapwood, from which two egg galleries originate and extend transversely across the grain in opposite directions (figure 206E). Transverse egg galleries engrave the sapwood surface and vary from 30 to 85 mm long. Larval galleries are generally straight, extend mostly perpendicular away from the egg galleries, usually following the grain of the wood. Few other bark beetle species exceed the uniformity of this species' gallery pattern (figure 206F). Many tiny round holes are left in the bark by emerging beetles, often giving the bark a "peppered" appearance (figure 206G). Living, apparently healthy trees sometimes exhibit roughened abnormal swellings, blackened bark, and scars caused by the feeding and overwintering beetles. Shaving the bark at swollen sites reveals numerous short overwintering burrows in the inner bark, sometimes penetrating to the cambium. The burrows can be so concentrated that patches of bark are killed, causing "cat facing" or sloughing of the bark. Repeated attacks by large numbers of overwintering beetles can seriously weaken trees.

Control. Nine hymenopterous parasites and one clerid predator have been listed as natural enemies (Beal and Massey 1945, Bushing 1965). Culturally, cutting infested mulberry trees in spring and fall to destroy the early and late broods has been recommended (Blackman 1922). Chemical controls may be needed occasionally to protect valuable ornamental trees.

Phloeotribus dentifrons (Blackman)

[hackberry bark beetle]

Hosts. Hackberry, sugarberry. Favors hackberry (Beal and Massey 1945, USDA FS 1985).

Range. Occurs throughout the natural range of hackberry in the eastern United States; specifically recorded from Minnesota, Kansas, Mississippi, and North Carolina (Beal and Massey 1945, Blackman 1922, Dodge 1938, USDA FS 1985) and as far west as New Mexico (Furniss and Carolin 1977).

Description. ***Adult.*** Tiny, oblong, cylindrical bark beetle, dark brown to black, 1.2 to 1.6 mm long (Beal and Massey 1945, Blackman 1922). Front of female's head convex; front of male's, deeply concave with pair of spines at lower margin of concavity. Pronotum broader than long, roughened on sides, and punctured on upper central portion. Anterior margins of elytra raised and serrate. Punctures in elytral striae coarse and shallow. Smaller body clothed with short, coarse, gray to white, scalelike hairs distinguish this species from the closely related *P. frontalis*, which is clothed with nearly erect, yellowish hairs.

Biology. Adults emerge from hibernation quarters from March to June (Blackman 1922). Beetles attack seriously weakened and dying trees, green logs, and broken branches (Beal and Massey 1945). They make an entrance, nuptial chamber, and transverse egg gallery with perpendicular larval galleries. Females deposit eggs along the walls of the egg gallery; larvae feed outward and pupate in the inner bark.

New adults emerge through holes in the bark. Adults hibernate in the same hosts from which they develop. Large populations are sometimes found in last year's engravings at any time during winter and early spring. There are two generations a year.

Injury and damage. This bark beetle mostly attacks branches less than 38 mm in diameter, but trunks and logs up to about 15 cm are also attacked (Beal and Massey 1945, Blackman 1922). Removing the bark reveals a gallery system resembling that of *P. frontalis* in mulberry, that is, a nuptial chamber, transverse egg gallery, and perpendicular larval galleries. But the galleries are smaller and shorter than those of *P. frontalis*. Emerging adults leave tiny, round exit holes in the bark. This species differs markedly in habits from *P. frontalis* by overwintering in last season's engravings and obliterating part of the characteristic gallery system. It is far less aggressive than other *Phloeotribus* species and of little or no economic importance.

Control. Eight species of hymenopterous parasites have been listed (Bushing 1965), but subsequent studies suggest that only one—*Eurytoma phloeotribi* (Ashmead)—has been established definitely as a parasite (Krombein and others 1979). Direct controls are not needed.

Alniphagus aspericollis (LeConte)

alder bark beetle (figure 207)

Host. Alder. Red alder, white alder, and Oregon alder; other western alders are probably susceptible (Doane and others 1936, Furniss and Carolin 1977).

Range. Occurs mainly along the Pacific Coast from California north through Washington and British Columbia and presumably into Alaska (Furniss and Carolin 1977). Found east to Idaho and eastern Utah (Wood 1982).

Description. ***Adult.*** Elongate, cylindrical, blackish brown bark beetle, 2.6 to 5.0 mm long (figure 207A) (Borden 1969, Bright 1976, Chamberlin 1939). Pronotum scarcely wider than long, slightly rounded at sides, gradually narrowed, finely and densely punctured. Elytral striae deeply impressed and coarsely punctured, and interspaces moderately convex and minutely granulate. Elytral declivity distinctly elevated with large, acute granules and short and sparse pubescence. Members of genus *Alniphagus* readily distinguishable from other bark beetles by seven-segmented antennal funicle and conical, slightly flattened antennal club. ***Egg.*** Opaque white to light brown, elliptical, about 0.9 by 0.5 mm (figure 207D). ***Larva.*** White with brown mandibles, curved, 3 to 5 mm long (figure 207B). ***Pupa.*** White, wing pads folded under abdomen, 3 to 5 mm long (figure 207C).

Biology. Adults are active throughout the growing season but emerge mainly in May and from mid-July to August. This species prefers trees weakened by other agents and slash caused by windthrow, snow breakage, or logging. Females initiate attack and bore through to the inner bark to construct egg galleries, slightly etching the sapwood. Females deposit up to 69 eggs (figure 207D) in niches about 1 mm apart on both sides of the egg galleries. Larvae

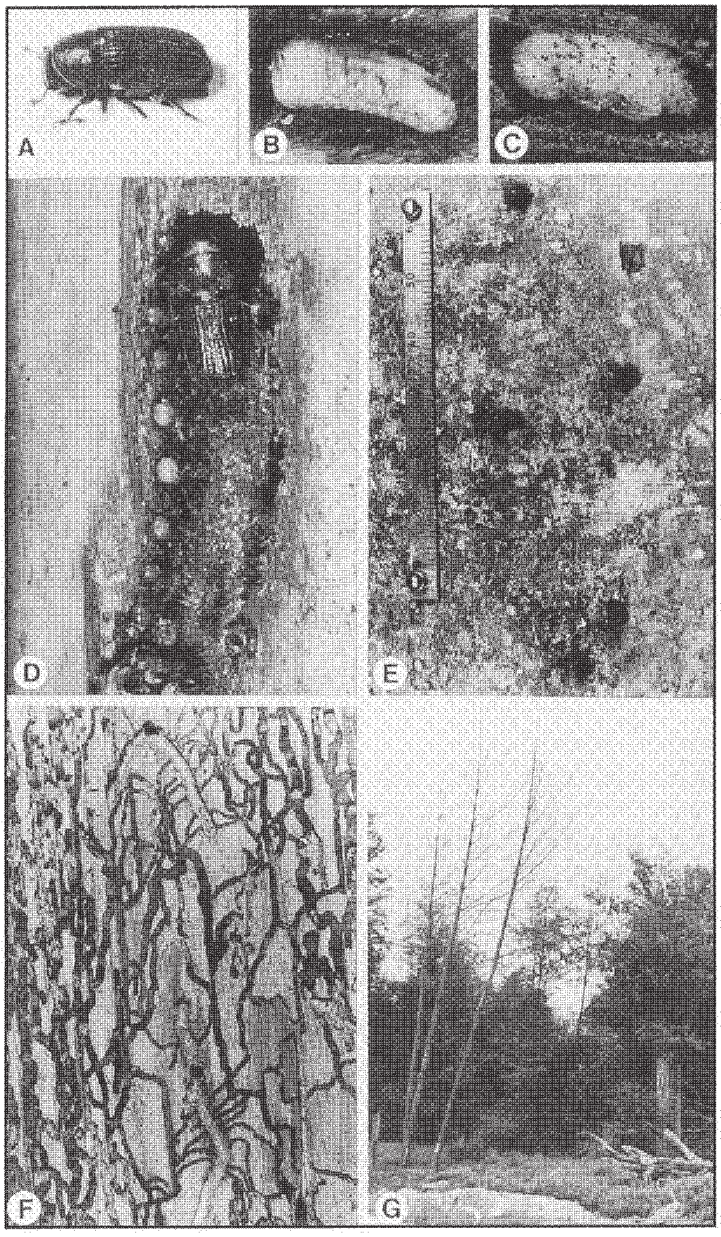

Figure 207—Alniphagus aspericollis, *alder bark beetle: A, adult; B, larva; C, pupa; D, eggs in niches along egg gallery; E, adult entrance holes in bark; F, V-shaped egg tunnels with meandering larval galleries; G, alder trees killed close to pile of debris where beetle population developed (courtesy J. Borden).*

mine a short distance at right angles to the egg gallery and turn to follow the wood grain. Head capsule measurements suggest three larval instars. Mature larvae pupate in the inner bark in small cells at the ends of the larval mines; the pupal stage lasts 2 to 3 weeks. Beetles of the summer generation that do not mature by September overwinter as larvae, pupae, or callow adults; beetles that emerge in the fall fly to healthy trees and construct hibernation chambers 2 to 3 cm long in the outer bark. There are two generations per year (Anderson 1960, Bright 1976).

Injury and damage. Infestation is externally evident by entrance holes bordered by a tightly packed rim of frass and often blocked by the elytral declivity of a resident beetle (Borden 1969, Bright 1976). Bark surrounding each entrance hole becomes darkly stained with sap and small amounts of loose, granular frass (figure 207E). Entrance holes are commonly found under lichens and in bark crevices but more frequently at the base of branches. Attack density of entrance holes varies from about 45 to 377 per m^2. The inner bark may be riddled with egg tunnels and larval mines (figure 207F) and may eventually drop and pull away from the sapwood. Egg galleries are of four types: an elongate gallery up to 8 cm long; a wide, irregularly shaped, cavelike gallery; a two-branched form with tunnels extending up and down the bole; and a V-shaped gallery with two branches extending in the same direction, either up or down. Larval galleries extend outward from the egg galleries and meander but usually turn up or down the bole (figure 207F). Light infestations on living trees create patch kills that leave boles scarred. Heavy infestation can cause tree mortality (figure 207G), but this pest is of little economic importance.

Control. Only one hymenopterous parasite—*Spathius sequoiae* Ashmead—has been recorded (Krombein and others 1979). Direct controls have not been needed.

Trypophloeus populi Hopkins

[aspen bark beetle] (figure 208)

Hosts. Poplar. Quaking aspen favored, but black cottonwood, narrowleaf cottonwood, and lanceleaf cottonwood also recorded (Petty 1977, Wood 1982).

Range. Eastern Nevada and northern Arizona north to Saskatchewan and Manitoba; single collection recorded from New Brunswick (Petty 1977, Wood 1982).

Description. ***Adult.*** Small, black compact bark beetle, 1.7 to 2.1 mm long, about 2.3 times as long as wide (figure 208A) (Wood 1982). Head largely concealed from above; frons flattened and weakly convex; antennal club longer than scape, about 1.9 times as long as wide. Pronotum slightly wider than long; four rather large, subcontiguous teeth; asperate in front of summit; short, fine, semierect pubescence. Elytra shiny; striae not impressed and punctures shallow; declivity rather steep and convex; vestiture short; interstrial scalelike setae. ***Egg.*** Oblong, white, translucent, sticky surface, 0.33 by 0.65 mm (figure 208C) (Petty 1977). ***Larva.*** White, except darker when intestines filled with brown bark; legless; grublike.

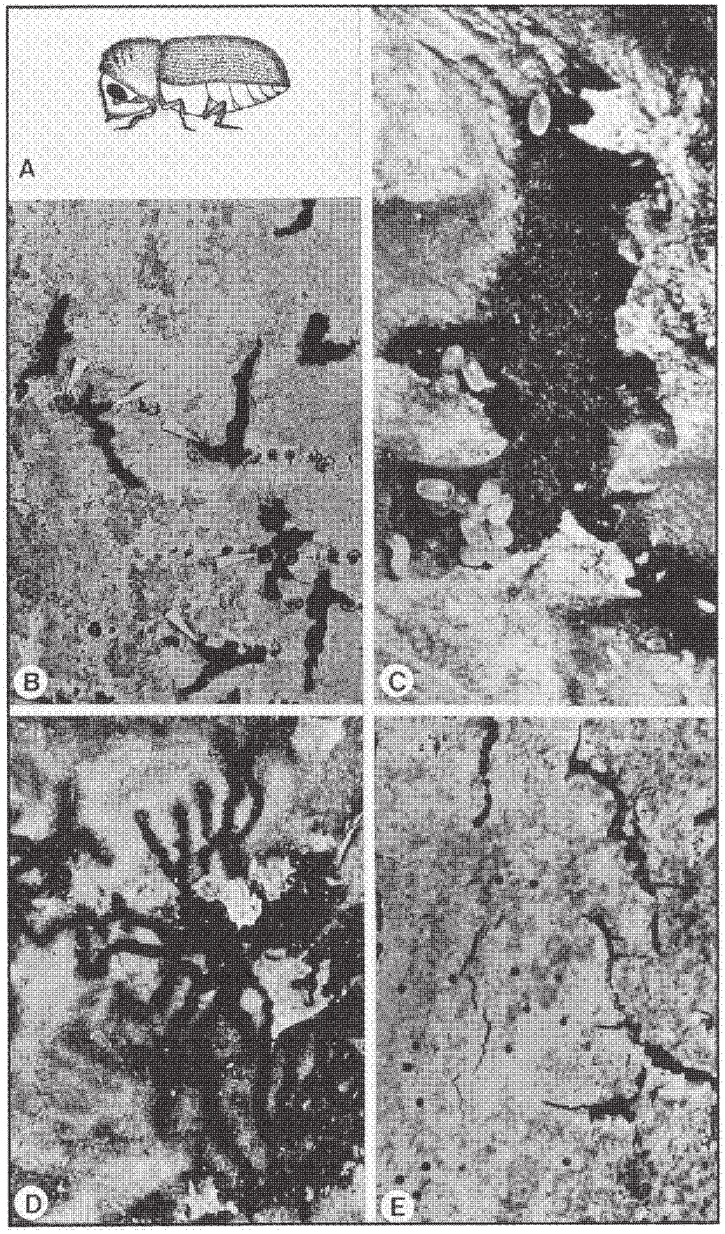

Figure 208—Trypophloeus populi, *[aspen bark beetle]: A, adult; B, epidermis removed to expose primary galleries in bark; C, closeup of primary gallery with egg chamber containing cluster of eggs; D, larval galleries meandering outward from egg chamber; E, adult exit holes in bark (courtesy J. Petty).*

Biology. Adults emerge in June and July and have been found through the summer and fall as late as October 10 (Petty 1977, Wood 1982). Beetles fly in search of weakened trees. After alighting on a susceptible tree, females explore the bark surface and generally select rough darkened areas to initiate attacks. Females initiate the galleries by making entrance tunnels about 2.5 mm long and are soon joined by males. Normally, galleries are shared by one parental male and female. After mating, females excavate a primary egg chamber and deposit an average of 15 eggs (range 10 to 24) in clusters (Petty 1977, Stewart and others 1979). Females also excavate food tunnels and sometimes secondary egg chambers and deposit a few additional eggs. Some females exit the bark and initiate another primary gallery. After hatching, the young larvae bore into the wall of the primary gallery and make individual galleries extending in all directions. Larvae pass through three feeding instars. Larvae overwinter within galleries in all three instars, but survival of those in second and third instars is best. Larvae feed for a while in spring and then excavate frass-free pupal cells at the ends of the galleries. Pupation begins in late June. By early July, adults are emerging and attacking new trees, and by mid-July, they are ovipositing in the new primary galleries. This bark beetle has one to one and a half generations a year.

Injury and damage. Trees stressed and weakened by drought, poor site, disease, or other causes—especially those bordering washes, trails, roadways, and seepage areas—are particularly vulnerable to attack (Petty 1977, Wood 1982). Attack sites may occur on boles, branches, and twigs as small as 10 mm in diameter. Small entrance holes are difficult to detect because of their occurrence in dark roughened bark. Small amounts of frass may be observed on the bark. The gallery system can be exposed by carefully cutting away the outer bark (figure 208B). Typically, the gallery system consists of (1) a 2.5-mm-long entrance tunnel to (2) an irregular cavelike primary egg chamber about 1.5 to 3.5 mm by 10 to 13 mm (figure 208C); (3) a food tunnel about 10 mm long (usually directed upward from the primary egg chamber and partially filled with frass); (4) a secondary egg chamber (sometimes excavated at the end of the food chamber); and (5) narrow larval galleries (about 20 mm long, packed with frass and stained dark brown) that extend outward from the primary egg chamber. These larval galleries follow either a straight course, meander, or reverse directions abruptly (figure 208D). Emerging adults leave small, round holes about 1 mm in diameter in the bark (figure 208E). Susceptible trees are often attacked en masse; thus, infested trees may be covered with galleries from the lower bole to the branches. Foliage of infested trees turns yellow and then brown; the trunk usually is faint orange. Heavily infested trees usually die within 3 to 10 weeks.

Control. Predaceous mites have been found in the galleries, and the species competes with other bark and wood borers (Petty 1977, Stewart and others 1979). On average, about 55% of the larvae survive to

produce adults. Direct controls have not yet been needed.

Dryocoetes betulae Hopkins

birch bark beetle (figure 209)

Hosts. Birch, sweetgum, wild cherry, beech, pear. Yellow birch, paper birch, and sweetgum are favored (Beal and Massey 1945, Blatchley and Leng 1916, Chamberlin 1939).

Range. Across Canada from Newfoundland to British Columbia south throughout the eastern United States to Florida and west to Louisiana, then northwest to Montana and Washington (Bright 1963).

Description. ***Adult.*** Oblong, dark reddish brown, elliptical bark beetle, 2.8 to 4.5 mm long (Blackman 1922, Blatchley and Leng 1916, Bright 1963). Front of head clothed with dense brush of long yellowish hairs with smooth, shiny median space. Antennae elbowed and have club-shaped segments at tips. Pronotum as long as wide, broadly rounded in front, and sides strongly arcuate and aspirate. Elytra nearly twice as long as wide, parallel sides, broadly rounded behind. Declivity of elytra flat to slightly convex.

Biology. Adults have been noted in July, September, and November (Blackman 1922, Blatchley and Leng 1916, Bright 1963). Males enter the inner bark and prepare nuptial chambers and are soon joined by one to four females. After mating, females construct egg tunnels that radiate from the nuptial chambers. Eggs are deposited singly in niches along the gallery walls and covered with tiny frass plugs. The male helps keep the galleries free of frass by pushing it out the entrance hole. Later in the year, males construct special galleries used for hibernation at the nuptial chamber. Larval galleries meander away from egg galleries. Broods produced the first summer overwinter in the same tree with the parent beetles. Overwintering females emerge in spring and attack new hosts. The pest appears to have a 2-year generation in its northern range and a 1-year generation in its southern range.

Injury and damage. Seriously weakened, injured, and recently dead trees, fresh-cut logs, and stumps may be attacked (Beal and Massey 1945, Blackman 1922, Bright 1963). The lower bole and exposed roots are most likely to be infested. Entrance holes and some frass may be found on the bark of trees under attack. Removing the bark reveals the gallery system mostly in the inner phloem. Burrows irregularly radiate, and a variable number of egg galleries may extend longitudinally, diagonally, or transversely to the stem (figure 209A). Numerous tiny niches can be observed along both sides of the egg gallery. Most egg galleries are slightly to moderately curved. The larval galleries, tiny at first but becoming larger, radiate outward and make abrupt turns to avoid adjacent larval galleries and other large egg galleries (figure 209B). Emerging adults leave round holes in the bark. Because of the condition of the hosts attacked, the insect is of little economic importance.

Control. No natural enemies have been reported, and direct controls have not been needed.

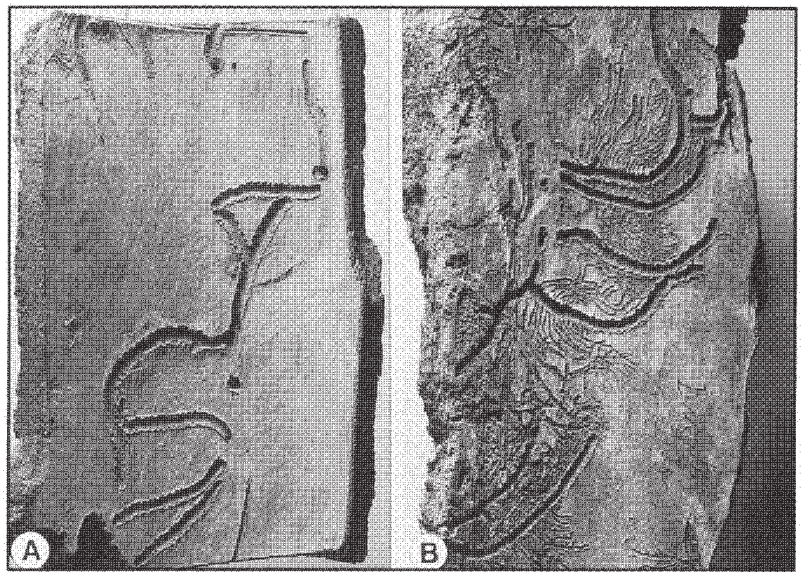

Figure 209—Dryocoetes betulae, *birch bark beetle: A, egg tunnels with tiny egg niches along gallery walls; B, egg tunnels with tiny larval galleries radiating outward (specimens courtesy J. Simeone).*

Pseudopityophthorus minutissimus (Zimmermann)

[oak bark beetle] (figure 210)

Hosts. Oak, chestnut, birch, beech, hickory, dogwood, hornbeam, hophornbeam, serviceberry, witch-hazel, black cherry. Oaks are major hosts; red oaks preferred with scarlet and black oaks particularly susceptible (Beal and Massey 1945, Chamberlin 1939, McMullen and others 1955).

Range. The Atlantic Coast west to the Great Plains and from Quebec south to the Gulf Coast (Chamberlin 1939, McMullen and others 1955).

Description. ***Adult.*** Minute, slender, dark reddish brown bark beetle, 1.5 to 1.8 mm long (figure 210A) (Chamberlin 1939, McMullen and others 1955). Head hidden in dorsal view by enlarged, shield-like pronotum. Front of head with long yellow hairs in males; hairs much shorter in females. Pronotum slightly longer than wide, asperate in front. Elytra 1.7 times longer than wide, sides nearly straight and parallel, broadly rounded behind, surface shiny, fine shallow punctures, sparsely covered with short pubescence. Elytral declivity steep and convex. ***Egg.*** White, soft, spherical, and about 0.2 mm in diameter. ***Larva.*** Tiny, legless, 3 to 4 mm long, body pale white when digestive tract empty; brownish gray when filled with dark phloem.

Biology. Adults that develop from overwintering broods in or near the latitude of Missouri to West Virginia emerge in April (Rexrode and Jones 1970); in Wisconsin, adults appear in early May (McMullen and others 1955). Emerging adults fly to healthy trees and make deep feeding cavities in twig crotches and in bud, leaf, and immature acorn axils on small twigs (Rexrode and Jones 1970). Males make entrance holes usually in roughened or concealed areas of bark (Rexrode 1969). Females usually join the males while they build entrances or turn niches and soon construct horizontal egg galleries. Females deposit eggs singly in niches (then packed firmly with frass) along both sides of the gallery at about two a day while egg gallery is being extended. The number of egg niches per egg gallery ranges from 14 to 85. Eggs hatch in 4 to 6 days. Larvae feed at right angles to the egg galleries and pass through three to five developmental stages. In Wisconsin, larvae mature during summer in 7 to 8 weeks. Pupation occurs in small cells between the bark and wood at the end of the larval galleries; the pupal stage last 6 to 16 days. Newly formed beetles bore directly out through the bark from their pupal cells. Up to 50% of the parent beetles reemerge and attack the same or different trees; such re-emergence and attack may occur up to three times. Beetles overwinter in every stage except the pupal. In Wisconsin, there is one and a partial second generation, and in southern Ohio, two generations plus a partial third generation occur. In the Deep South, where beetles oviposit through winter and probably breed continuously throughout the year, three to five generations are possible annually (Chamberlin 1939).

Injury and damage. Branches and small boles of unthrifty or severely weak-

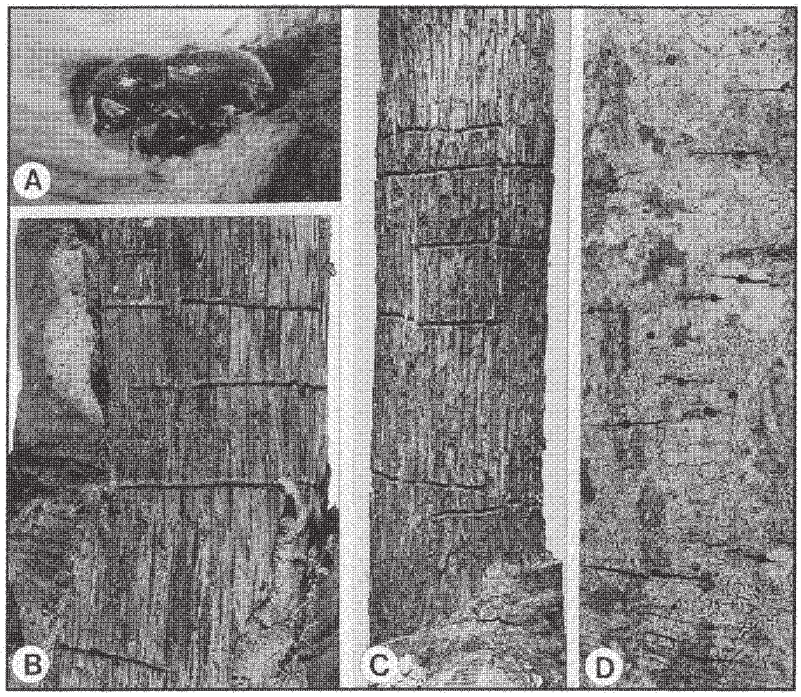

Figure 210—Pseudopityophthorus minutissimus, *[oak bark beetle]: A, adult in gallery; B, lateral egg tunnels engraved on sapwood of oak; C, egg galleries encircling small branch; D, tiny adult exit holes in bark.*

ened trees are commonly attacked, but recently cut trees, limbs, and logs, as well as stumps and cord wood are most attractive to these beetles (Blackman 1922, Chamberlin 1939, McMullen and others 1955, Rexrode 1969). Branches 1.3 to 10.0 cm in diameter are attacked far more frequently than trunks; stems larger than 20 cm in diameter are seldom attacked. Removing the bark reveals the characteristic gallery system (figure 210B and C). Entrance holes extend through the bark to the sapwood, at which point galleries extend 2 to 5 mm vertically. The vertical entrance gallery is bisected transversely by two nearly straight egg galleries that extend horizontally up to 2 cm in either direction, resulting in a distinctive, cross-shaped gallery that grooves both the bark and sapwood. Egg niches are along the upper and lower sides of the egg galleries. Larval galleries are quite straight and run perpendicular to the egg galleries, longitudinally with the wood grain. Larval galleries are almost entirely in the phloem, although they usually show on the inner surface of peeled bark. They are much less noticeable than the egg and entrance tunnel and may be difficult to see. The bark may be speckled with tiny holes made by emerging beetles (figure 210D). Although not a direct cause of tree mortality, large beetle populations can hasten the death of weak trees. Evidence is accumulating that the oak bark beetle is an important vector of oak wilt disease. Beetles developing in trees with oak wilt become contaminated with the fungus, then fly to healthy oaks and feed on live twig tissue, thus transmitting the fungus to uninfected trees (Rexrode and Jones 1970).

Control. Three species of hymenopterous parasites—*Ecphylus leptosulcus* Marsh, *Elachertodomyia phloeotribi* (Ashmead), and *Eurytoma phloeotribi* Ashmead—have been listed (Krombein and others 1979). Also, predatory mites, fungi, cannibalism, and severe winters take a heavy toll during some years (McMullen and others 1955). Cutting and destroying infested trees, branches, and slash while the broods are still present have been suggested for control (Beal and Massey 1945).

Pseudopityophthorus pruinosus (Eichhoff)

[larger oak bark beetle] (figure 211)

Hosts. Oak, American beech, black cherry, Chickasaw plum, chestnut, maple, hickory, hornbeam, and hophornbeam. Oaks preferred, especially red oaks (Beal and Massey 1945, Rexrode and others 1965).

Range. Widely distributed from Quebec and New York south to Florida and west to Michigan and Texas (Beal and Massey 1945) and southward into Mexico, Guatemala, and Honduras (Wood 1982).

Description. ***Adult.*** Small, dark brown bark beetle, 1.8 to 2.0 mm long, 2.8 times longer than wide (figure 211A) (Beal and Massey 1945, Blackman 1922, Wood 1982). Head largely hidden in dorsal view by large shieldlike pronotum. Front of head in male densely covered with long, incurved, yellowish hairs; these hairs shorter in female. Pronotum longer than wide, front portion densely asperate, posterior region

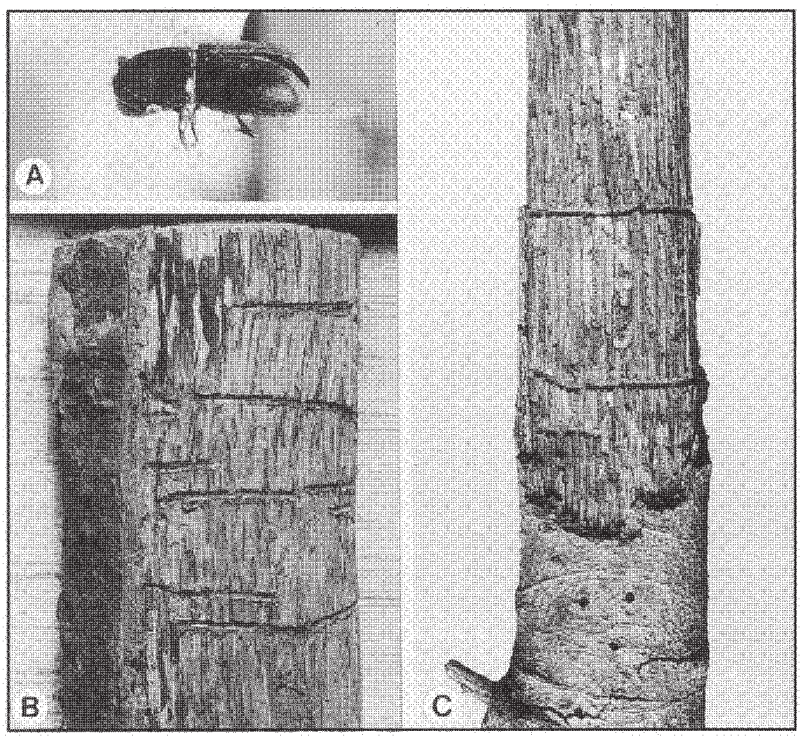

Figure 211—Pseudopityophthorus pruinosus, *[larger oak bark beetle]: A, adult; B, egg and larval galleries in bark and surface of sapwood; C, lateral egg galleries encircling stem and adult exit holes in bark (A, courtesy M. Roling).*

shiny and finely punctured. Elytra as wide as pronotum, without striae, with fine shallow punctures; densely covered with short, coarse, gray, scalelike hairs next to elytral suture. Adults distinguished from those of *P. minutissimus* (Zimmermann) by larger size and elytral punctures, and stouter, almost scalelike elytral setae. ***Egg.*** White, round, about 0.2 mm in diameter. ***Larva.*** White (except brownish gray when gut is full), legless, 3 to 4 mm long.

Biology. Adults emerge in April and May in the beetle's northern and middle ranges and may be active throughout the year along the Gulf Coast and its southern range (Blackman 1922, Rexrode and Jones 1970, Rexrode and others 1965). After emerging, beetles fly to healthy trees and feed mainly at nodes between the previous and current year's growth, but they also feed in leaf axils, female flower axils, and bud axils on current growth, making small, round, deep punctures. After feeding, they fly to weakened trees for reproduction. Males initiate brood galleries and are soon joined by females. Females make turning niches in the phloem, mate, and excavate transverse egg galleries. Oviposition commences as females begin to construct egg galleries. On average, each female deposits 41 eggs in tiny niches along the walls of each egg gallery. Eggs hatch in 4 to 5 days. Larvae tunnel between the bark and wood perpendicular to the egg gallery, closely following the wood grain. The original attacking beetles usually emerge, attack the same or different trees, and oviposit up to three times. Larvae pupate between the bark and wood in small cells at the ends of their almost straight galleries. In southern Ohio, first-generation larvae develop in 25 to 28 days but require longer periods during cooler times of the year. The pupal stage lasts about 15 days. There are two and a half generations a year in West Virginia but up to five generations a year along the Gulf Coast. This species overwinters under the bark in all except the pupal stage (Rexrode 1969).

Injury and damage. Beetles attack weakened and dying hosts, healthy branches and trunks of small trees, and freshly felled trees and slash (Beal and Massey 1945, Blackman 1922, Rexrode and others 1965). Smooth bark of branches and small upper trunks are preferred attack sites. The gallery pattern can be examined by removing the bark from infested trees (figure 211B). Characteristic gallery systems consist of an entrance hole with a very short turning niche extending up and down from the entrance about 5 mm. Two egg galleries with distinctly visible niches along the sides extend 25 to 50 mm transversely across the grain from the junction of the short vertical gallery. Very small threadlike larval galleries extend vertically, perpendicular to the egg galleries. Larval galleries are mostly within the phloem and difficult to see. Brood galleries may be indistinguishable from those of *P. minutissimus* and are sometimes found in the same tree. Bark may be speckled with tiny emergence holes (figure 211C). Because of the condition of hosts attacked, this insect is of minor concern. However, since it can transmit the oak wilt

fungus to healthy trees, it is economically damaging in oak-wilt-infected areas (Rexrode and Jones 1970).

Control. Two hymenopterous parasites—*Ecphylus leptosulcus* Marsh and *Eurytoma phloeotribi* Ashmead—have been reported, but nothing is known of rates of parasitism (Krombein and others 1979). Populations can be reduced in small woodlots by cutting and destroying affected trees and slash while the beetle broods are present (Beal and Massey 1945).

Pseudopityophthorus pubipennis (LeConte)

[western oak bark beetle] (figure 212)

Hosts. Oak. Coast live oak, California black oak, Oregon white oak (Wood 1982), and probably most other western oaks are hosts (Chamberlin 1939).

Range. British Columbia southward along the Pacific Coast through Washington and Oregon to southern California (Chamberlin 1939, Furniss and Carolin 1977).

Description. ***Adult.*** Small, cylindrical, dark reddish brown to black bark beetle, 1.7 to 2.5 mm long, 2.7 times as long as wide (Brown and Eads 1965a, Chamberlin 1939, Wood 1982). Front of head in male densely punctate but masked by long, coarse, yellow hairs; front of head in female clothed with short, fine, more evenly distributed hairs; head hidden from dorsal view. Pronotum slightly longer than wide, anterior margin rounded and bearing numerous serrations. Elytra 1.6 times as long as wide, sides straight and parallel except rounded behind, finely punctured, and densely clothed with recumbent hairs. Elytral declivity steep, rather broadly convex, but slightly depressed along each side.

Biology. This beetle overwinters under the bark in adult and larval stages. Adults emerge during spring and summer and fly to host trees to feed and reproduce in the bark (Brown and Eads 1965a, Doane and others 1936, Wood 1982). Beetles prefer boles, branches, and twigs of unhealthy, weakened, and dying trees. They bore through the bark and construct two transverse egg galleries. Eggs are deposited along both sides of galleries. After hatching, the larvae burrow in fine threadlike galleries perpendicular to the egg galleries. As pupation nears, they tunnel mostly in the inner phloem and hollow out small chambers to pupate. Newly formed adults make their own exit holes through the bark. This beetle has two or more generations a year.

Injury and damage. Beetles attack living trees, but weakened, dying, and recently dead trees are most commonly attacked (Brown and Eads 1965a, Doane and others 1936, Wood 1982). Bleeding sap is sometimes associated with entrance holes on the bark, often followed by stained bark surface and discoloration at the junction of the inner bark and the sapwood (figure 212A). The gallery system consists of an entrance hole in the bark, two lateral egg tunnels, and many short, narrow larval tunnels running with the grain of the wood (figure 212B). When populations are heavy, it is as though a thickly woven cloth had been impressed on the bark's inner surface and on the sapwood. The bark of heavily

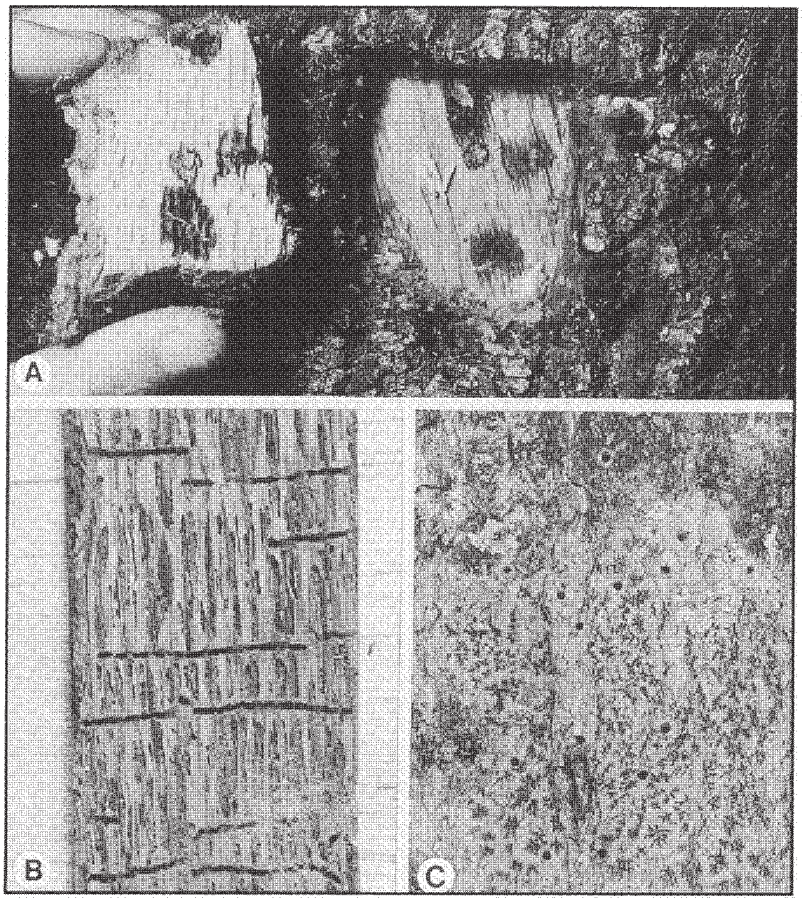

Figure 212—Pseudopityophthorus pubipennis, *[western oak bark beetle]: A, bark removed from living oak to expose new attack sites surrounded by dark stain; B, lateral egg tunnels and vertical larval galleries; C, adult exit holes in bark (A, courtesy L. Brown; B & C, specimens courtesy D. Whitehead).*

infested trees may be peppered with many small, round exit holes (figure 212C). The insect generally does not attack healthy trees but can hasten the death of weakened trees. It is of only minor economic importance.

Control. Natural enemies have not been reported. Judicious pruning, watering, and fertilization of valuable trees can minimize attack (Brown and Eads 1965a).

Corthylus columbianus Hopkins

Columbian timber beetle (figure 213)

Hosts. Maple, oak, yellow-poplar, beech, boxelder, sycamore, birch, basswood, chestnut, elm. Very common in silver maple and red maple from southern Indiana southward and in chestnut oak and post oak over extensive areas. Infestation of white oak is high in areas of West Virginia; infestation of yellow-poplar is high in areas of North Carolina and Virginia. Less commonly found in southern red oak, northern red oak, chinkapin oak, black oak, overcup oak, American beech, boxelder, sycamore, yellow birch, American basswood, American chestnut, and elm (Hay 1974b, Nord and McManus 1972).

Range. Eastern species occurring from Massachusetts south to north Florida and west to Arkansas, Kansas, and Michigan (Nord and McManus 1972, USDA FS 1985).

Description. ***Adult.*** Very dark, reddish brown to black, cylindrical ambrosia beetle, about 3.6 to 4.0 mm long and 1.4 to 1.6 mm in diameter (figure 213D) (Nord and McManus 1972, USDA FS 1985). Front of head in females broadly concave and covered with short, stiff, yellowish hairs; convex and almost hairless in males. Pronotum broadly rounded and asperate in front. Elytra shiny, striate, and coarsely and shallowly punctured. Elytral declivity armed with small tubercles. ***Egg.*** White, translucent, shiny, smooth shell, oval, 1.0 mm long and 0.5 mm in diameter (figure 213A). ***Larva.*** White, legless, C-shaped, with at least two stages (figure 213B). About 1 mm long at hatching, and 4 mm long at maturity. ***Pupa.*** White, darkening with age, mummylike, 3.4 to 4.0 mm long (figure 213C).

Biology. Adults (figure 213D) overwinter under bark and vines, usually around the base of host trees (Nord 1972, Nord and McManus 1972). In spring, adults become active on the same tree or move to new, healthy host trees and begin excavating galleries (figure 213E). Males initiate the entrance but are soon joined by females, and later one or two additional females may enter the gallery. Completed galleries consist of a primary channel, 1 to 4 secondary channels, occasionally tertiary branches, and 1 to 20 or more short brood cells (cradles) extending at right angles above and below the channels. Soon after the gallery is started, two fungi—*Ambrosiella xylebori* Brader and *Pichia* sp.—that are carried by the beetles begin growing on the gallery walls (Nord 1972, Wilson 1959). These fungi (known as ambrosia), rather than the host plant tissue, serve as food for larvae and adults. Eggs are deposited singly in each brood cell, and the entrances are plugged with tightly packed bits of the ambrosia fungi and minute wood particles. During incubation, the ambrosia fungi grow

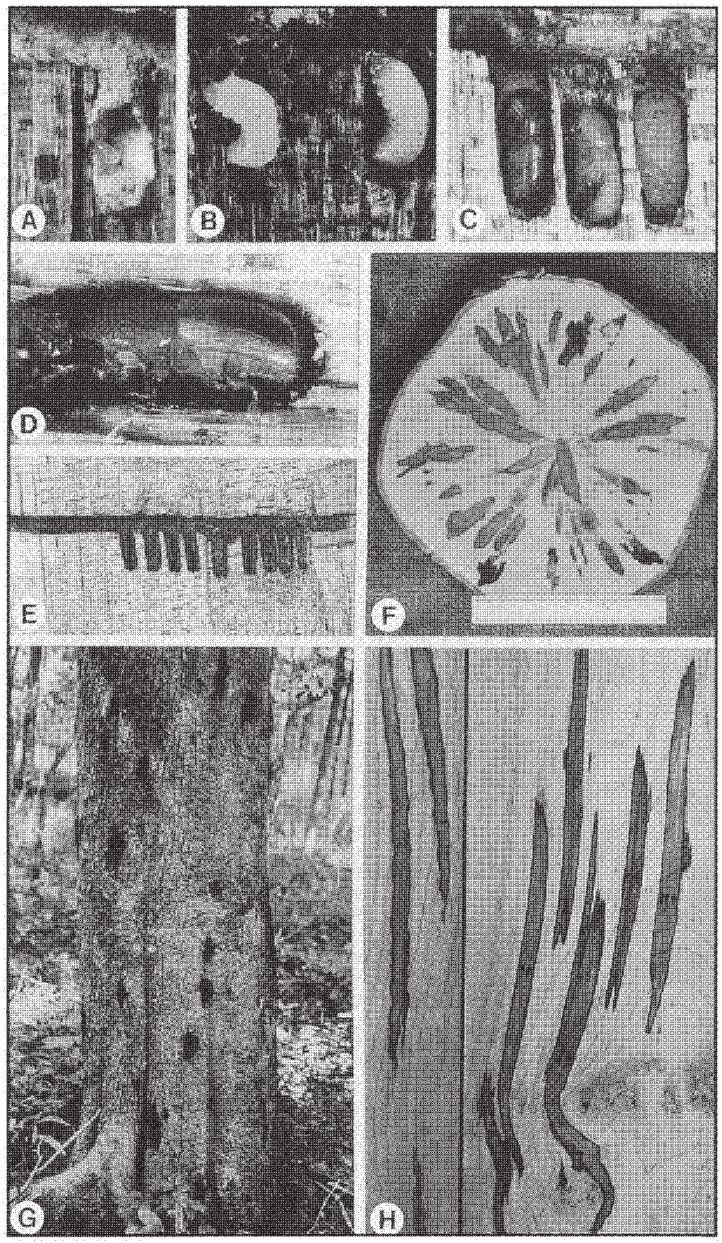

Figure 213—Corthylus columbianus, *Columbian timber beetle: A, egg in cradle containing ambrosia fungus; B, larvae in cradles; C, pupae in cradles; D, adult in gallery; E, gallery with nine cradles; F, stains in log end; G, wet spots at bark entrances; H, bluish gray stains surrounding galleries in maple lumber (courtesy J. Nord).*

on the brood-cell walls. By the time the eggs hatch, the fungi have grown into thick, white, cottony mats that envelop the attached end of eggs. Larvae feed on the fungal growth, almost completely consuming it before they pupate. Pupation and transformation to the adult stage occur inside the plugged brood cell. Brood emergence is 6 to 7 weeks after initiation of the brood gallery. This beetle typically has three generations per year, but this may vary. In Georgia, the first brood emerges in late June to late July, the second from mid-August to mid-September, and the third from late September to late October. After emergence, the third generation moves to overwintering sites.

Injury and damage. Light-colored, dry, granular frass on the bark around the entrance holes is evidence of fresh infestation (Nord 1972, Nord and McManus 1972) that may appear from mid-May through September on healthy trees, from small saplings to the largest mature trees. Several days after boring starts, sap oozes out of the entrance holes, wetting the frass and the bark (figure 213G). Wet spots remain until the galleries callus over, perhaps as late as the following spring if the attack begins in late summer. In some species, such as red maple, a characteristic bark formation indicates old infestations. This formation, associated with annual growth, results in an elongated scar 5 to 15 cm long that tapers to a point at both ends. In sycamore, these bark scars are shorter, often swollen, and sometimes bulge noticeably outward. Dissection reveals the characteristic galleries. Damage in logs can be detected by the radiating stains in the log ends (figure 213F). Lumber and veneer stains vary in pigmentation, shape, and size depending on the species of tree involved, the sawing method, and the number of channels in the gallery. In sawn lumber, defects consist of one to five black round holes (1.8 mm in diameter) surrounded by vertical, elongate, blue or gray stains 5 to 60 cm long and 1.0 to 2.5 cm wide (figure 213H). The lumber industry knows these defects as "flagworm," "spotworm," or "steamboats" (Nord 1971). In soft maple, the concentration of beetle attack sites is greatest in the lower bole and decreases with increasing height above ground. This, together with repeated attacks during a tree's life, means that there is little clear wood in butt logs. Soft maple and white oak lumber with flagworm defect sells at about 25% below the price of undamaged lumber. Conversely, a few sawmills are making character-marked paneling and other decorative products out of maple, sycamore, and boxelder lumber having flagworm defects.

Control. Mites, nematodes, and dipterous larvae have been associated with the beetles in galleries, but none have been confirmed as parasites or predators (Nord 1972, Nord and McManus 1972). Despite the economic importance of this insect, direct controls probably could not be economically justified and have not been developed.

Corthylus punctatissimus (Zimmermann)

[pitted ambrosia beetle] (figure 214)

Hosts. Maple, dogwood, sassafras, hornbeam, elm, hophornbeam, hazel, azalea, rhododendron, blueberry, mountain mahog-

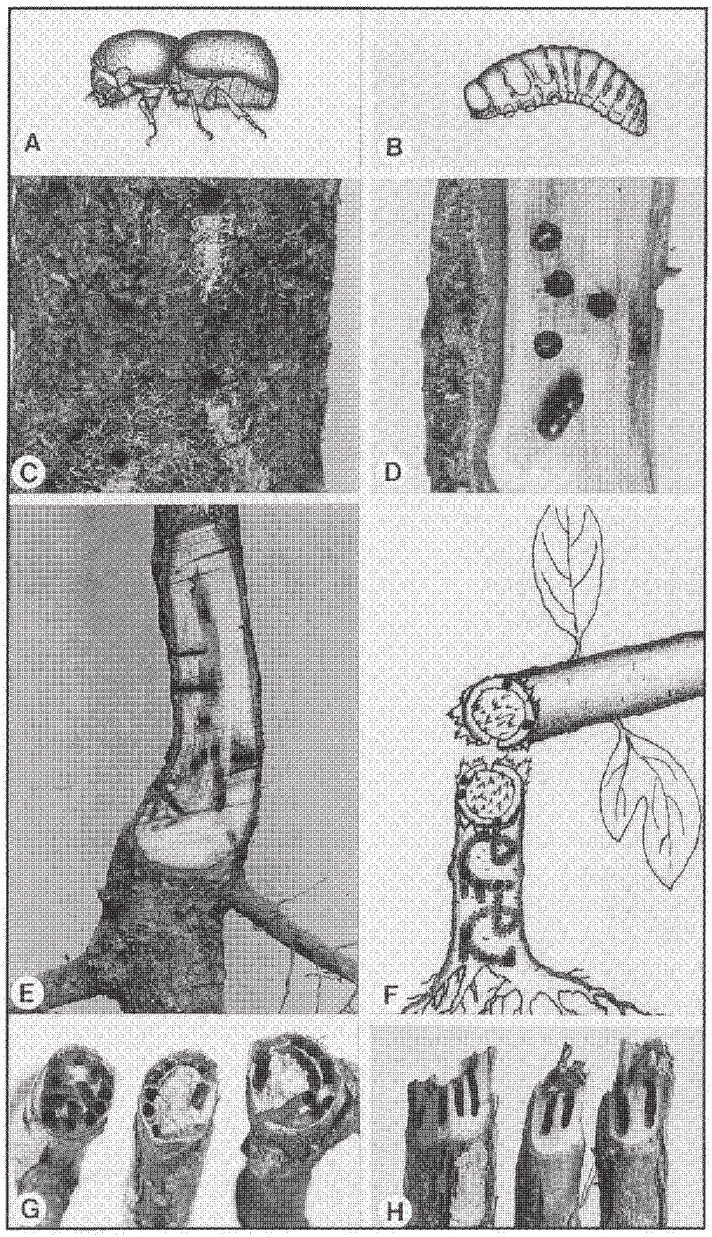

Figure 214—Corthylus punctatissimus, *[pitted ambrosia beetle]: A, adult; B, larva; C, adult entrance holes with frass; D, bark removed exposing holes in xylem; E, galleries in root collar of sassafras seedling; F, spiral gallery with cradles; G, end view of cradles; H, side view of cradles.*

any, mountain-laurel, beech, white ash, and wild and cultivated currants. Prefers sugar maple and rhododendron in the North; red maple in the South (Finnegan 1967, Weiss 1915).

Range. Indigenous to eastern North America, known from Quebec and Ontario through New York south to Georgia and Alabama and west to Colorado (Finnegan 1967, USDA FS 1985).

Description. ***Adult.*** Cylindrical, robust, dark reddish brown to black, shiny ambrosia beetle, 3 to 4 mm long (figure 214A) (Finnegan 1967, USDA FS 1985). Legs and antennae rusty reddish brown. Pronotum longer than wide, tuberculate in front, finely and sparsely punctured, and extends hoodlike over head. Elytra strongly punctured, rounded behind, and without furrows of teeth. ***Egg.*** Shiny, nearly transparent, light creamy color, slightly pointed at one end, 0.71 mm long and 0.44 mm in diameter. ***Larva.*** White, nearly transparent, except for black mandibles (figure 214B). Second instar has well-developed prolegs and wing buds.

Biology. Adults overwinter in galleries made the previous summer or in duff on the forest floor and remain more or less inactive until early summer (Finnegan 1967, Merriam 1883, Roeper and others 1987). Flights begin in mid-June and last until early August. Males initiate attack, usually at the base of young plants and are soon joined by females. Although males do most of the tunneling, the females help push frass from the galleries. Spiral galleries with 3 to 12 egg chambers ("cradles") are constructed in the small stem. Males inoculate the galleries and egg cradles with ambrosia fungi (from their mycetangia) that grow into white fungal mats ("ambrosia") on the gallery walls. Females deposit eggs singly in the rich fungal growth within the cradles. They plug cradle entrances with mixtures of ambrosia mycelia and frass. After hatching, the larvae feed exclusively on the ambrosia fungi and complete development in about 2 weeks. Pupation occurs within the cradles with the head pointing toward the main gallery and lasts about 1 week. Most parents leave the galleries after oviposition and apparently fly to new hosts and start more broods. Although newly developed adults appear in the cradles as early as late August, only a few leave the gallery. Most progeny adults overwinter in their cradles. There is one generation a year.

Injury and damage. Seedlings and young saplings 3 to 12 years old are vulnerable to attack (Finnegan 1967, Roeper and others 1987, Schwarz 1892). Plants with a basal diameter of 4 to 14 mm and 28 to 136 cm in height may be attacked. Infested plants can be easily detected by wilting, yellowing, and browning of the foliage. Foliar symptoms are especially noticeable in late August and early September when dead foliage contrasts with healthy plants nearby. Affected plants have one to four small entrance holes, sometimes with frass, on the basal stem just above or below the groundline (figure 214C and D). Generally, only one of the entrance holes leads to a fully developed gallery system with egg niches. Dissection reveals the gallery system (figure 214E

and F). In small stems, tunnels usually extend directly through the center to the opposite side, then spiral immediately inside the cambium in the xylem; in large stems, tunnels spiral as soon as the entrance holes pierce the cambium. The spiral tunnel makes one or two complete revolutions encircling the stem and averages about 26 mm long but can be up to 51 mm long. At intervals along the spiral tunnel, short cradles 5 to 6 mm long oriented vertically either upward or downward are constructed (figure 214G and H). Girdling and/or breaking of the stem near the groundline kill many plants. Serious damage to sugar maple regeneration has been reported in New York, Ontario, and Quebec (Finnegan and others 1959, Merriam 1883), and to azalea, mountain laurel, and rhododendron in New Jersey (Weiss 1915). Mortality in localized maple stands has been as high as 80% of the seedlings.

Control. In stands with a history of serious injury, infested plants should be pruned below the girdle or lifted and burned to destroy the beetles and brood (Weiss 1915). Because damage is greatest in heavily shaded understory regeneration, practices that promote an open plant canopy help to minimize beetle survival and brood development (Finnegan 1967). Insecticides applied during early summer can provide protection when the overwintering beetles are emerging, dispersing, and attacking new plants.

Monarthrum mali (Fitch)

[apple wood stainer] (figure 215)

Hosts. Maple, oak, birch, buckeye, honeylocust, sugarberry, sweetgum, elm, beech, basswood, yellow-poplar, blackgum, apple, plum, cherry, orange, pine, hemlock, cedar. Favors broadleaf trees, especially apple, honeylocust, and sugarberry; but also occasionally attacks conifers (Brooks 1916, Chamberlin 1939, Gossard 1913).

Range. New Brunswick to Ontario and throughout the eastern United States west to the Great Plains and reported from California (Bright 1976, Wood 1982).

Description. ***Adult.*** Elongate, cylindrical ambrosia beetle, 1.8 to 2.4 mm long (figure 215A) (Blackman 1922, Chamberlin 1939, Wood 1982). Body yellowish to light reddish brown; bases of pronotum and elytra paler. Pronotum considerably longer than wide with parallel sides, broadly rounded in front, weakly roughened, minutely punctured. Elytra narrows slightly toward rear, surface smooth, shiny, containing fine inconspicuous punctures. Elytral declivity steep, narrowly sulcate, flattened below, with two pairs of blunt denticles. ***Larva.*** White with light brown head, curved to C-shaped, 2.0 to 2.4 mm long (figure 215B).

Biology. Adults overwinter in galleries, emerge in early spring, and begin new galleries in the same or different hosts. Males carry ambrosia fungi (*Monilla* spp.) and inoculate the new galleries. The galleries are extended directly into the wood and then branch. Females deposit eggs singly in circular pits or niches along the gallery and loosely pack them with wood chips and ambrosia mycelium. New larvae lie curled in pits made by the parent beetles. As larvae

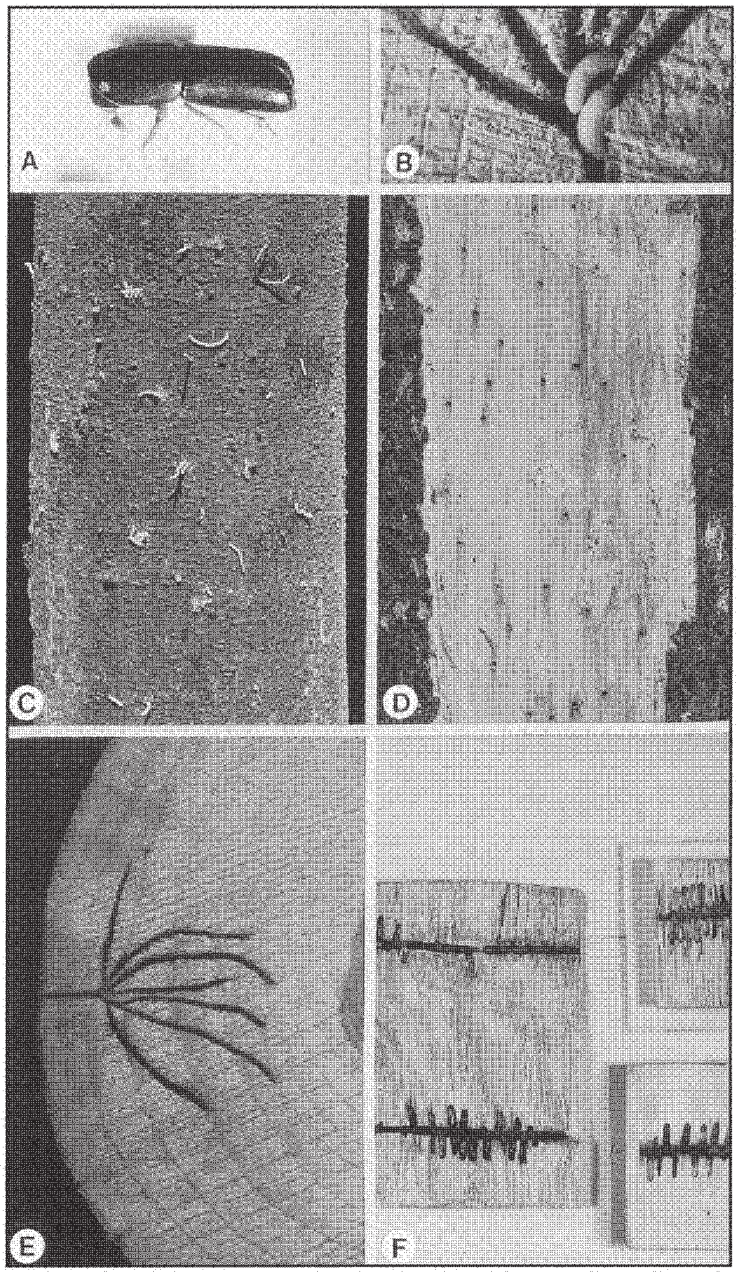

Figure 215—Monarthrum mali, *[apple wood stainer]: A, adult; B, larvae; C, strings of compacted frass on bark; D, bark removed to expose entrance holes; E, cross section of gallery system; F, sections of gallery with cradles (A, courtesy M. Roling).*

grow, they enlarge and deepen the cradles so that they slightly exceed the length of the larvae. Both the larvae and adults feed on a mixture of fungus ambrosia and wood. Females maintain the fungus cultures and attend developing larvae. Pupae form in the larval cradles, and the newly formed adults emerge through entrance holes made by the parent beetles (Blackman 1922, Brooks 1916, Chamberlin 1939, Gossard 1913, Lugger 1899).

Injury and damage. Weakened, diseased, injured, and dying trees, and fresh-cut logs larger than 10 cm in diameter are favored; healthy trees are rarely attacked (Blackman 1922, Brooks 1916, Gossard 1913, Wood 1982). Small round entrance holes 0.8 to 0.9 mm in diameter are found in the bark. Bark may be stained around the holes. Frass is fine and usually scattered in bark crevices or ejected in long strings (figure 215C). Black-stained entrance holes can be easily observed by removing the bark (figure 215D). In cross section, the black galleries extend horizontally straight through the bark into the wood for 5 to 12 mm and open into a slightly enlarged chamber (figure 215E). From here, 1 to 8 egg galleries, 2 to 5 cm long, branch off or fan out. The first egg galleries begin nearly at right angles on each side of the entrance gallery and often follow the curvature of the tree growth rings. Other egg galleries extend across the growth rings toward the center of the tree. Exposed egg galleries reveal numerous short egg cradles above and below the galleries (figure 215F). Although apple and other orchard trees are sometimes injured, the greatest economic damage occurs in timber trees and unseasoned logs. Lumber sawn from infested logs may be peppered with small black holes. Wine, cider, and vinegar casks filled and in storage are sometimes badly damaged.

Control. Injury to orchard trees can be minimized by keeping the trees healthy (Blackman 1922, Brooks 1916). Weakened and dying timber in heavily infested stands should be harvested and milled promptly. Unseasoned logs should be promptly sawn into lumber. When rapid utilization of green logs is not possible, beetle infestation can be minimized by immersing logs in water or by storage in piles under continuous water spray.

Monarthrum fasciatum (Say)

[yellow-banded timber beetle] (figure 216)

Hosts. Oak, maple, birch, chestnut, sweetgum, blackgum, poplar, hickory, mimosa, apple, peach, pine. Favors deciduous hardwoods; hosts probably include many species not recorded (Chamberlin 1939, Wood 1982). Pine occasionally a host.

Range. Throughout eastern North America from Quebec, Ontario, and Massachusetts south to Florida and west to Texas and Wisconsin (Wood 1982). Most common in southern range (USDA FS 1985).

Description. ***Adult.*** Brown and yellow, elongate, cylindrical ambrosia beetle, 2.3 to 3.1 mm long, 3.2 times as long as wide (figure 216A) (Beal and Massey 1945, Chamberlin 1939, Roling and Kearby 1974, Wood 1982). Body generally reddish brown with wide pale yellow band across middle

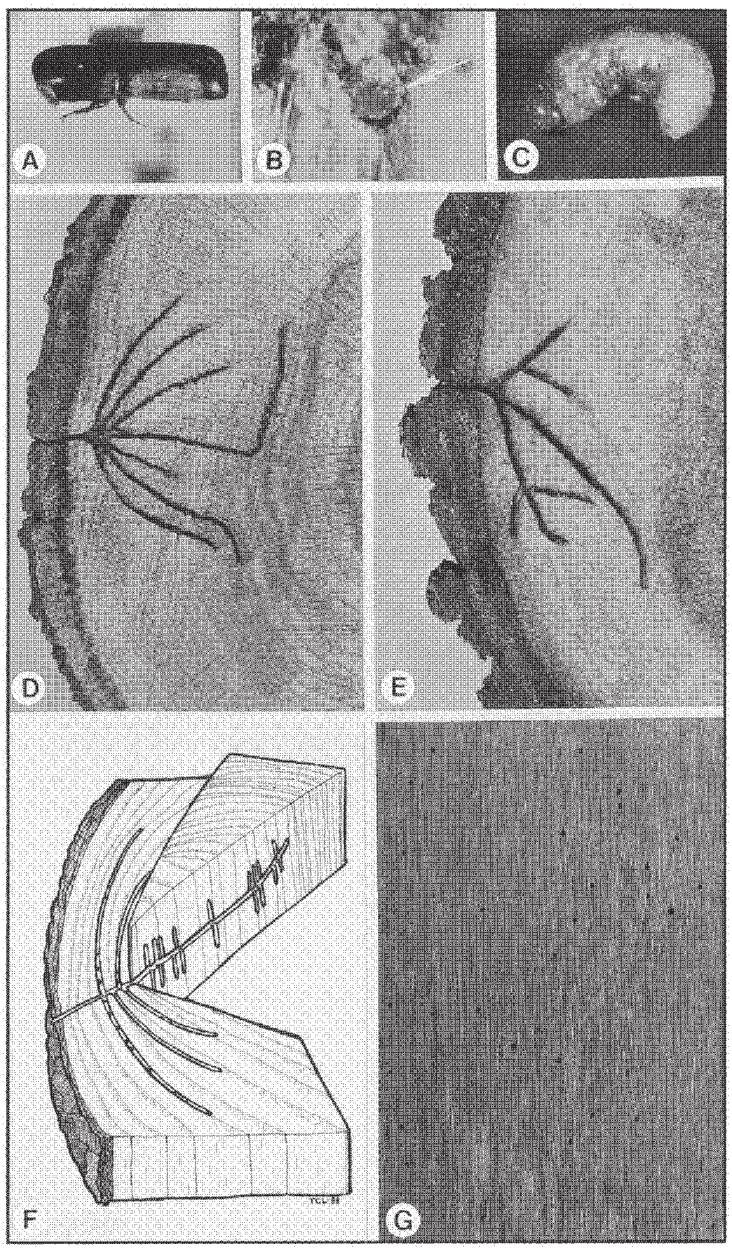

Figure 216—Monarthrum fasciatum, *[yellow-banded timber beetle]: A, adult; B, egg in niche; C, larva; D, typical gallery system in red oak; E, variation of gallery system in cottonwood; F, complete gallery system with cradles; G, tiny holes in air-drying lumber (A-C, courtesy M. Roling).*

part of elytra. Pronotum roughened in front and smooth behind. Elytral declivity abrupt and covered with long, yellow hairs; small blunt tooth on each side of median ridge. ***Egg.*** Oval, smooth, and translucent, 0.45 by 0.75 mm (figure 216B). ***Larva.*** White with amber head and jaws, curved to C-shaped, 0.8 to 2.9 mm long (figure 216C). Very similar to *M. mali* (Fitch); adults larger with yellow band across elytra.

Biology. Flights commence in March in Mississippi and Missouri (Blackman 1922, Roling and Kearby 1974). Males initiate attack, construct entrance tunnels, and are soon joined by one or more females. A nuptial chamber and up to eight egg galleries are constructed. Egg galleries are typically occupied by single females and the entrance holes by single males. Beetles inoculate the gallery walls with special fungi (*Monilia* spp.) that produce ambrosial mycelium used for food by adults and larvae. Females deposit eggs singly in a series of niches on the upper and lower gallery wall surfaces, parallel to the wood grain. Larvae develop and enlarge egg niches into short, fingerlike cradles slightly larger than the larvae. In the egg galleries, females maintain cultures of ambrosial fungi that supply the larvae with food throughout their development. Larvae pupate in the cradles, always with their heads facing the egg gallery. New brood beetles emerge through the same entrance holes made by parent beetles. There are three generations per year in Missouri. First emergence and flight occur from early March to mid-May; the second extends from early June to late July. Second-generation beetles emerge by late August or early September and produce a third generation, but second-generation adults that do not emerge by early autumn overwinter in partially formed new galleries. Some adults of the second generation hibernate in their parents' galleries until the following spring. All adults of the third generation overwinter in the parents' galleries.

Injury and damage. Unthrifty, injured, and dying trees and recently cut logs are most frequently attacked (Beal and Massey 1945, Blackman 1922, Chamberlin 1939, Gossard 1913, Roling and Kearby 1974). On standing trees, attack sites may occur from ground level to 13 m and on larger branches. Newly attacked trees usually have fine white frass in bark crevices or strings of frass that extrude from the entrance holes. Dissection reveals the typical gallery system. When a log is viewed in cross section (figure 216D and E), an entrance hole 0.9 to 1.1 mm in diameter extends horizontally through the bark into the sapwood to depths of 22 mm. The entrance hole opens into a widened nuptial chamber about 3 by 3 mm. From 1 to 8 egg galleries branch or fan out from the widest part of the nuptial chamber; some follow the curvature of the annual rings, whereas others cut across the rings (figure 216F). Egg galleries are up to 77 mm long, but most are less than 40 mm. Vertically oriented egg cradles range from 0.5 to 3.6 mm long and 0.84 to 1.16 mm in diameter; 0 to 14 per egg gallery. They may seriously damage dying timber, fresh-cut logs, and green-sawn lumber. Lumber sawn

from infested trees or logs contains pinhole defects (with or without associated stain) that reduce its value (figure 216G). Wine casks (filled and in use) have been heavily bored in some parts of the South.

Control. Dying timber should be harvested promptly, and fresh-cut logs should be quickly removed to avoid infestations. Logs that cannot be milled promptly should be stored submerged in ponds of water or in piles under continuous water spray (Beal and Massey 1945). At some mill sites, green-sawn lumber intended for air drying must be given a 10-second insecticide dip for protection.

Xyloterinus politus (Say)

[beech timber beetle] (figure 217)

Hosts. Beech, maple, birch, oak, chestnut, hickory, ash, elm, poplar, black cherry, magnolia, alder, pine, spruce, hemlock. Beech favored, but maple and birch commonly attacked (Blackman 1922, Dodge 1938, USDA FS 1985, Wood 1957). Conifers rarely attacked.

Range. New Brunswick, Quebec, and Ontario and throughout the eastern United States from Maine south to northern Florida and westward to Mississippi and Minnesota (Wood 1957).

Description. ***Adult.*** Dark-brown to black, cylindrical ambrosia beetle, 2.8 to 3.7 mm long, 2.7 times as long as wide (figure 217A) (Beal and Massey 1945, Wood 1957). Front of head convex, granulate, with median ridge; eyes completely divided; antennal club without sutures. Pronotum very slightly wider than long, slightly wider than elytra, broadly rounded in front and sides, anterior margin armed with asperites and four median teeth; female with noticeable mycetangium. Elytra 1.7 times as long as wide; striae finely punctured, covered by sparse, fine, hairlike setae. Elytral declivity rather steep and convex. ***Egg.*** Whitish, ovoid, translucent, 0.89 mm by 0.66 mm (figure 217B) (MacLean and Giese 1967). ***Larva.*** Whitish, legless, slightly curved, about 2.8 mm long (figure 217C). ***Pupa.*** Soft bodied, whitish but gradually darkening; head concealed from above by prothorax.

Biology. The insect overwinters in adult stage in old larval cradles and adult galleries (MacLean and Giese 1967). Adults emerge in March and April and have been taken in flight from March through August in West Virginia. Males mate with females before emergence from brood galleries or on the bark surface of new hosts before attack. After beetles locate susceptible trees, females initiate the attack and carry out gallery construction. Each female extends a gallery into the sapwood where it may fork into one or more secondary tunnels (MacLean and Giese 1967). Females inoculate the gallery walls with ambrosia fungi and deposit eggs singly in cuplike depressions or niches 1.4 mm wide by 0.7 mm deep along the ceiling and floor of the gallery and then cover each egg with a plug of frass. Most eggs are deposited along the secondary tunnels. Egg niches are gradually lengthened by developing larvae to slightly larger than their bodies. During development of the three larval stages, the opening between

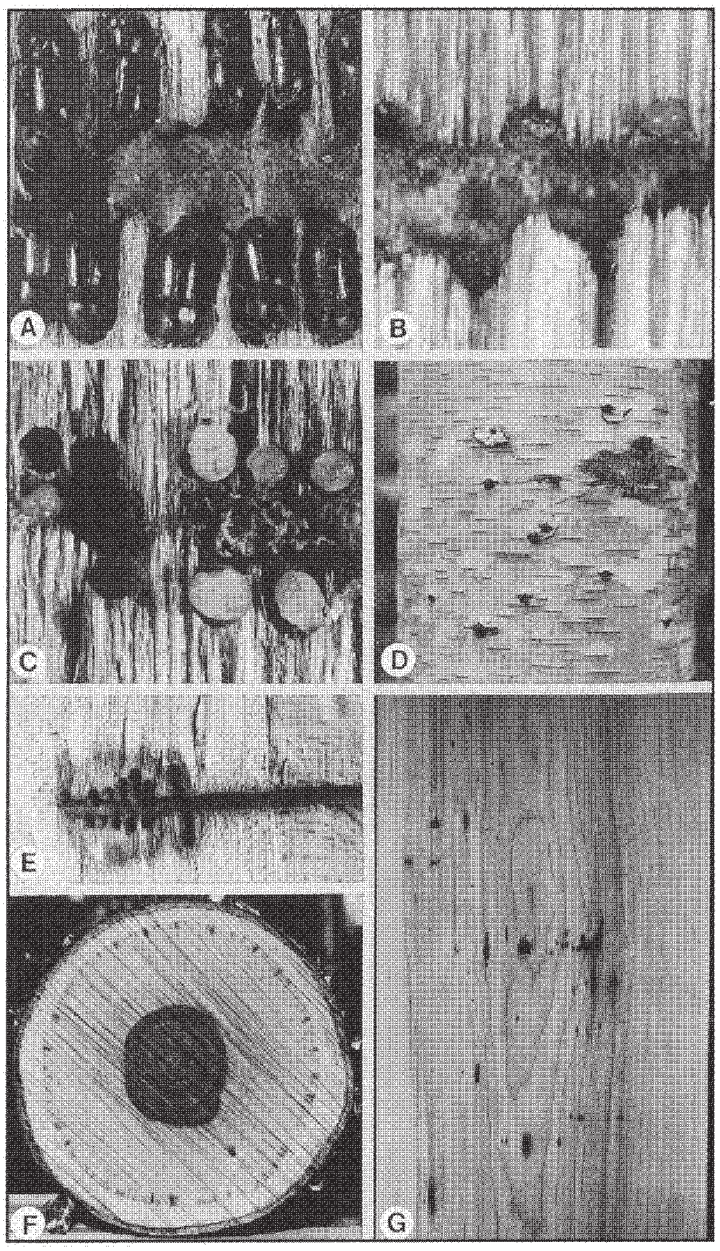

Figure 217—Xyloterinus politus, *[beech timber beetle]: A, teneral adults in cradles; B, eggs in niches along gallery walls; C, young larvae in niches; D, adult entrance holes; E, cradles above and below gallery; F, beetle stains in log end; G, blackened pinholes in lumber (A-C, courtesy R. Giese; D-F, courtesy A. Shigo).*

the larval cradle and the egg gallery remains plugged with frass. Larvae are xylomycetophagus, that is, they feed on both wood and the ambrosia fungi that grow on the cradle walls and frass plug. Mature larvae pupate in the larval cradles. Newly formed adults remove the frass plug from the mouth of the larval cradles and emerge through the parent galleries and entrance holes. In Indiana, eggs and larvae are found from July 3 to 15 and again from August 7 to 28, indicating two generations a year.

Injury and damage. Beetles attack low-vigor trees and are most injurious to the green wood of diseased, injured, and dying trees (Blackman 1922, USDA FS 1985). They also infest recently cut logs and green stumps. Most attacks on standing trees occur within the basal 2.1 m of the bole; none are found above 6.1 m. Trees under attack can be recognized by accumulations of light-colored frass in bark crevices and often by columns or cylinders of frass protruding from entrance holes (MacLean and Giese 1967). Later, only small round holes can be seen in the bark (figure 217D). A gallery consists of an entrance tunnel about 1.6 mm in diameter that extends into the sapwood for 2 to 45 mm before branching into one or two, 14-mm long secondary tunnels at right angles to the main gallery. Occasionally, a secondary gallery rebranches and extends further into the sapwood. The main gallery usually continues past the secondary tunnel for 1.5 to 10.0 mm, where it either ends or branches into a second pair of perpendicular tunnels. Larval cradles are often in double compound rows with two projecting above and two below the secondary tunnels and occasionally along the main tunnel (figure 217E). The double compound rows of cradles are distinct from the single compound row characteristic of other ambrosia beetles (Beal and Massey 1945, Dodge 1938, Drake 1921). Windthrown beech and hard maple in the Adirondack Mountains of New York have been particularly susceptible (Drake 1921). Logs, especially paper and yellow birch logs, containing beetle injuries can often be detected by stains or islands of discoloration on their ends (figure 217F) (Shigo 1966). Lumber or veneer sawn from infested logs contains blackened pinhole defects that render it worthless for many uses, including furniture (figure 217G).

Control. A small parasitic wasp—*Ipideurytoma* sp.—has been reared from larval cradles of this species (MacLean and Giese 1967). Prompt harvesting and utilization of timber and logs are recommended (Beal and Massey 1945). Sometimes, damage can be minimized by removing logs from shade and storing them off the ground in direct sunlight (Blackman 1922).

Trypodendron retusum (LeConte)

[poplar timber beetle] (figure 218)

Hosts. Poplar. Eastern cottonwood, quaking aspen, and bigtooth aspen recorded (Chamberlin 1939, Swaine 1918, Wood 1982). Also attacks paper birch but does not reproduce in this species.

Range. Alaska; south across Canada and into the northern United States; recorded as far south as West Virginia, New Mexico, and

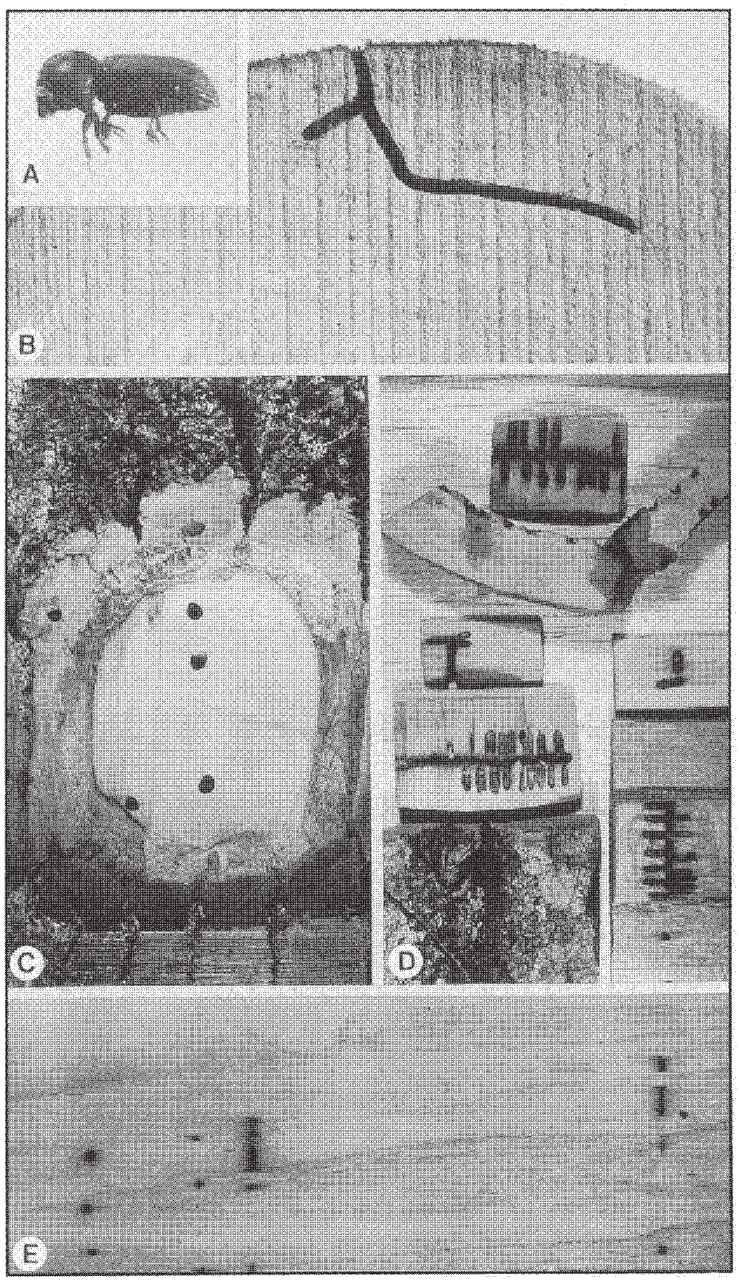

Figure 218—Trypodendron retusum, *[poplar timber beetle]: A, adult; B, entrance and two lateral galleries; C, bark removed to expose entrance holes; D, galleries and cradles; E, dark-stained pinholes in aspen lumber (D, specimen courtesy D. Whitehead).*

California (Wood 1982).

Description. ***Adult.*** Stout, cylindrical, shiny, brownish black ambrosia beetle, 3.6 to 4.6 mm long, 2.5 times as long as wide (figure 218A). Young adults with pale yellowish brown at base of pronotum and along elytral suture. Front of head in female convex; in male, concave and sparsely clothed with fine erect hairs. Pronotum broader than long, anterior half rounded with front margin armed with four teeth; female with conspicuous mycetangium. Elytra nearly twice as long as wide, sides straight, slightly punctured. Elytral declivity convex, moderately steep. ***Larva.*** White, with brown head, legless, curved body, 3.6 to 5.0 mm long. Head widths of mature larvae 0.66 to 0.79 mm (Brewer and others 1988).

Biology. This species overwinters in adult stage in forest litter (Brewer and others 1988). Spring flights from hibernation begin in early April and continue until early May. After flying to susceptible trees, females initiate attack. Within a day or so, a male joins each female. The beetles are monogamous; mating occurs at the entrance tunnel or on the bark surface. One pair usually occupies an entire gallery system. Rarely, several pairs may dwell within the same gallery system, but when they do, pairs occupy different lateral tunnels (Bright 1976). Females are found deep in the galleries and do most or all of the tunneling; the males are found near the entrance and push the frass out of the entrance holes. Ambrosia fungi are carried in the mycetangia of the female and are inoculated onto the gallery walls. The female completes the primary tunnel in 5 to 10 days. One to three lateral tunnels may be constructed; shallow cradles are excavated vertically either up or down along the lateral tunnels. Eggs covered with a mixture of boring material and fungal cells are deposited singly in each shallow cradle. As many as seven cradles, spaced 2 to 8 mm apart, are made along each lateral tunnel, mostly toward the end; none are found along the entrance tunnel. Eggs hatch in about 1 week, and larvae enlarge the cradles as they grow, feeding on the ambrosia fungus and wood. There are two larval instars; development requires 3 to 4 weeks. The pupal stage lasts slightly over 1 week. Fully developed adults leave their galleries during late summer and fall to hibernate.

Injury and damage. Injured and declining trees, as well as windthrown and recently cut trees larger than 10 cm in diameter, are commonly attacked (Brewer and others 1988, Chamberlin 1939, Hinds and Davidson 1972, Wood 1982). Round entrance holes in the bark lead into the sapwood (figure 218B and C). Early in the attack, white frass may be present at entrance sites. Dissection of an infested stem reveals the gallery system, which consists of an entrance tunnel penetrating directly into the sapwood 5 to 55 mm, and two to five lateral tunnels usually following a growth ring and totalling 25 to 109 mm long (figure 218B). Four to seven larval cradles are oriented vertically above or below each lateral tunnel (figure 218D). Large pinholes along with dark-stained wood on the gallery walls are defects that sometimes seriously degrade lumber sawn from infest-

ed timber (figure 218E) (Bright 1976).

Control. Natural enemies have not been recorded, and direct controls have not been investigated.

Trypodendron betulae Swaine

[birch timber beetle] (figure 219)

Hosts. Birch, alder. Birch, particularly paper birch and yellow birch, are preferred, found rarely in alder (Chamberlin 1939; Dodge 1938; Furniss and Carolin 1977; Wood 1957, 1982).

Range. Southern Canada from Quebec west to Manitoba and northern United States from Maine west to northern Idaho; probably throughout the range of white birch (Furniss and Carolin 1977; Wood 1957, 1982).

Description. ***Adult.*** Small dark brown to black ambrosia beetle with broad dorsal pale yellowish brown area of varying size extending from base to margin of declivity, 2.7 to 3.5 mm long, 2.6 times as long as wide (figure 219A) (Bright 1976; Chamberlin 1939; USDA FS 1985; Wood 1957, 1982). Front of head convex and coarsely but sparsely granulate in females; front of head deeply concave with median tubercle between upper halves of eyes in males. Pronotum wider than long, broadly rounded from midlateral sides to front, with anterior margin bearing two large and two small median teeth in female but straight and unarmed in male. Elytral declivity convex and moderately steep. ***Larva.*** White (except for light brown head), footless, curved 3 to 5 mm long (MacAloney and Ewan 1964).

Biology. Adults emerge from hibernation in spring and early summer and fly to susceptible host trees. Both sexes work together in constructing galleries. Females construct the entrance tunnels that branch; the males remove the frass (Doane and others 1936, MacAloney and Ewan 1964). Eggs are deposited in shallow niches cut by the female along the sides of the branched tunnels. Larvae enlarge their niches into short cradles where they spend their immature lives. They feed on ambrosia fungus and wood, pupate, and transform to adults (figure 219B). In late summer and fall, they leave the galleries for hibernation sites in debris on the forest floor.

Injury and damage. Weakened, injured, dying, and felled trees are most apt to be attacked (Doane and others 1936, MacAloney and Ewan 1964). Entrance holes and white frass may be initial injury symptoms. The gallery consists of an entrance that extends directly into the wood and then branches right and left, often following the growth rings (figure 219B and C). Larval cradles extend vertically up and down from the branched gallery (figure 219B). Galleries are similar to those of *T. retusum* but are smaller and extend deeper into the wood (Dodge 1938). Black-stained holes degrade birch lumber and veneer sawn from infested trees.

Control. Nothing is known of natural controls. Direct controls have not been reported.

Xyleborus celsus Eichhoff

[hickory timber beetle] (figure 220)

Hosts. Hickory. Reported in black,

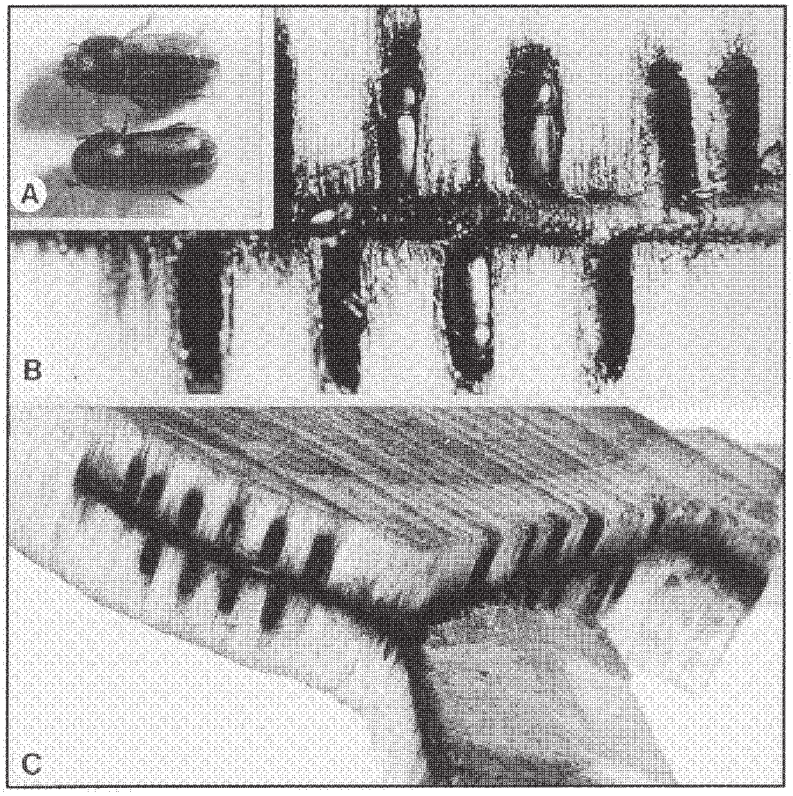

Figure 219—Trypodendron betulae, *[birch timber beetle]: A, adult; B, part of gallery with cradles containing teneral adults; C, gallery system showing entrance tunnel, branched galleries with numerous cradles (courtesy L. Abrahamson).*

water, and pignut hickories, but undoubtedly attacks other hickory species (Gagne and Kearby 1979, Wood 1982).

Range. Vermont south to Florida and west to Texas and Kansas (Bright 1968, Wood 1982); probably occurs throughout the natural range of hickories (Beal and Massey 1945, Blackman 1922).

Description. ***Adult.*** Reddish brown, cylindrical ambrosia beetle with head directed downward and hidden from above by pronotum (figure 220A) (Beal and Massey 1945, Bright 1968, Wood 1982). One of the largest species of *Xyleborus* in North America; females 3.9 to 4.5 mm long, males 2.3 to 2.6 mm long and somewhat lighter colored. Pronotum slightly longer than wide, broadly rounded in front, roughened on anterior, and shiny and sparsely punctured on posterior. Elytra slightly wider than pronotum with sides parallel. Elytral declivity drops off abruptly and steeply and bears four large acute teeth and several acute granules. ***Egg.*** Oval, smooth, white, 0.9 mm long by 0.4 mm wide (Gagne and Kearby 1979). ***Larva.*** White with amber head and mandibles, legless, C-shaped body, 2.5 to 4.7 mm long. ***Pupa.*** Exarate, white.

Biology. This beetle overwinters in adult stage in galleries of host trees. Hibernating adults emerge and are attracted to new susceptible host trees by their odors during March and April (Beal and Massey 1945, Chamberlin 1939, Gagne and Kearby 1979). Most attacks are in the lower trunk. Male beetles are rare in most populations. Females bore through the bark and straight into the wood. They often make cavelike excavations at the end of the straight entrance tunnel from which unbranched galleries radiate outward. This species does not deposit eggs in niches or cradles as do many scolytids, but lays them in groups of 1 to 16, mostly toward the ends of open galleries about 1.5 cm long. Eggs hatch in about 7 days. Larvae move freely in the gallery system and feed on the ambrosial fungi that grow on gallery walls; the fungus is transmitted from host to host by adult females. Larvae have three instars and develop from eggs to adults in about 35 days. New adults either emerge and seek new hosts or remain and extend the existing gallery system. The second generation of adults commences in early July, but most attacks are in late July and early August. There are two generations per year; second generation adults do not emerge and seek new hosts but overwinter in the galleries.

Injury and damage. Weakened and dying trees are most susceptible, but this pest occasionally attacks fresh-cut logs and stumps (Beal and Massey 1945, Blackman 1922, Gagne and Kearby 1979). Trees under attack by *Scolytus quadrispinosus* are particularly susceptible to infestation. Attacks are common on the basal portion of the trunk within 1.5 m of the ground and in buttress roots. Large trees generally sustain a higher rate of infestation per unit area than small trees. White frass in bark crevices usually is the first sign of beetle attack (figure 220B). Dissection reveals palmate or simple, branched gallery system (figure 220C and D). Entrance tunnels extend straight into the bole 1 to 3 cm then branch up to

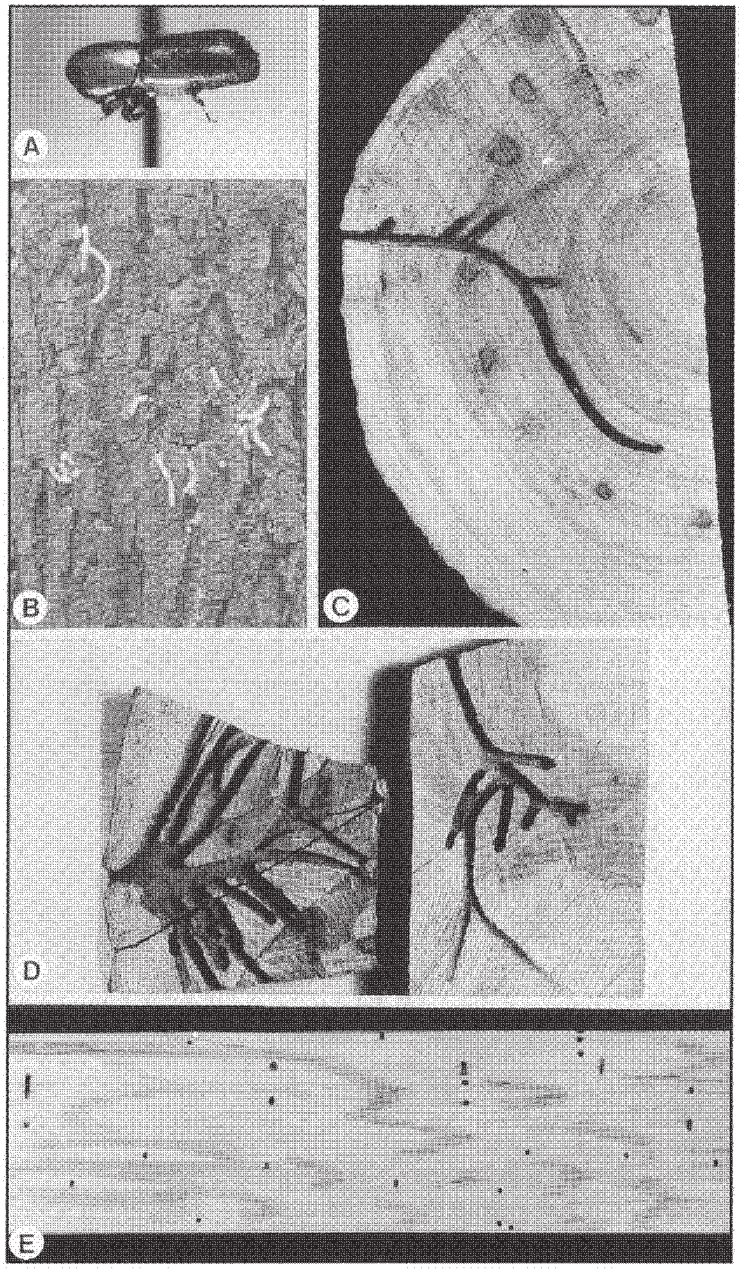

Figure 220—Xyleborus celsus, *[hickory timber beetle]: A, adult; B, white frass on bark; C, simple branched gallery; D, entrance tunnels, cavelike chamber, and palmate branching; E, stained holes in lumber (A, specimen courtesy M. Roling).*

six times. At the end of the entrance tunnel, beetles often make a cavelike excavation from which unbranched galleries radiate in a fanlike pattern in a single plane. Branch galleries are usually simple, but some have secondary branches and a few even anastomose or rejoin. Galleries may extend to depths of 6 cm or more. Those extended by second-generation beetles are longer and more complex. This insect causes rapid deterioration of dying hickories. The black-stained galleries degrade wood products sawn from infested logs (figure 220E).

Control. Practices that keep trees healthy and prevent *S. quadrispinosus* attacks will largely eliminate problems with *X. celsus*. Prompt harvesting and milling of weakened trees and those infested by *S. quadrispinosus* will minimize losses from degrade by *X. celsus* (Beal and Massey 1945).

Xyleborus affinis Eichhoff

[oak-hickory ambrosia beetle]

Hosts. Oak, hickory, pecan, chestnut, sweetgum, persimmon, locust, hackberry, birch, mimosa, black cherry, cedar, baldcypress. More than 250 species of trees, including hardwoods, palms, and a few conifers. Oak, hickory, pecan, and sweetgum favored in the United States (Beal and Massey 1945, Bright 1968, Wood 1982).

Range. Worldwide. Throughout the eastern United States from Massachusetts south to Florida and west to Michigan and Texas (Bright 1968, Wood 1982). Also in all of Mexico and Central and South America; also found in Hawaii, Malaysia, India, and tropical Africa.

Description. ***Adult.*** Yellowish to reddish brown, 2.6 to 2.9 times longer than wide, cylindrical ambrosia beetle with its head directed downward under pronotum (Beal and Massey 1945, Bright 1968, Wood 1982). Females, 2.3 to 2.8 mm long, larger and darker than males, 1.7 to 2.0 mm long. Front of head shiny with large punctures; antennal club as long as wide. Pronotum of female broadly rounded in front and roughened, smooth, shiny, and finely punctured. Pronotum of male with anterior area shallowly concave and anterior margin with blunt tubercle. Elytra as broad as pronotum and rounded behind. Elytral declivity broadly convex, sloping, surface dull, opaque. ***Egg.*** Off white, shiny, oblong, 0.62 to 1.05 mm long (Roeper and others 1980). ***Larva.*** White, slightly curved to C-shaped, legless. ***Pupa.*** White initially, then pigmented to light brown, 1.9 to 2.2 mm long.

Biology. In the eastern United States, females emerge from hibernation in spring and fly to susceptible hosts. One female initiates the gallery; in time, 15 to 20 progeny females and only 1 or 2 males may be present (Hubbard 1897, Roeper and others 1980, Wood 1982). Eggs are deposited in groups of two to six in the galleries; larvae feed and develop on the ambrosial fungus that grows on the gallery walls and eventually pupate freely in the same galleries. New progeny females either emerge and seek new hosts or attack the same hosts in which they developed; some even extend old parent galleries. However, new adults emerge and usually seek new hosts with a high wood-mois-

ture content more suitable for the ambrosia fungus culture and brood development. Life cycle requires approximately 1 month. Beetles reared on a synthetic diet produce broods with a sex ratio of 8.5 females to 1.0 male; fertilized females deposit only one unfertilized male egg per brood. The male beetle always matures and emerges before its sibling females and is ready to inseminate each as she emerges. Because males are flightless, mating must occur before the females leave the tree in which they developed. An unmated female produces two to three haploid males with whom she mates to produce female progeny. There are two or more generations a year.

Injury and damage. This beetle occasionally attacks weakened and dying trees but prefers cut, souring (fermenting) logs, green-sawn lumber, and stumps (Beal and Massey 1945, Roeper and others 1980, Wood 1982). Numerous pin-sized holes in bark indicate attack. Sawdust-like frass pushed from holes indicate that the beetles are constructing galleries in the wood. The gallery system is more complex than that of most other ambrosia beetles. Removal of the bark and dissection of the wood can expose the gallery system. The main entrance penetrates the bark and often turns longitudinally (less commonly horizontally), etching the surface of the sapwood. Surface galleries may branch and rebranch but eventually turn radially into the sapwood and frequently extend into the heartwood. The transverse galleries in the wood often branch and rebranch in more than one horizontal plane or level. Galleries are often more extensive and usually more heavily stained than those made by many other scolytid species. Thus, damage can be extensive in logs intended for lumber and other wood products. This beetle is one of the most destructive sawmill species in the tropical lumber industry. It sometimes bores wine and beer casks, causing leakage.

Control. Nothing is known of the natural enemies. In areas with a history of damage, fresh-cut logs can be safely stored under continuous water spray. Green lumber can be protected by an insecticidal dip.

Xyleborus ferrugineus (Fabricius)

[cosmopolitan ambrosia beetle]

Hosts. Oak, hickory, birch, ash, maple, beech, walnut, water tupelo, sweetgum, chestnut, baldcypress, pine. More than 180 host species recorded worldwide (Bright 1968, USDA FS 1985, Wood 1982). Sweetgum, oak, and hickory favored in the southern United States.

Range. One of the most widely distributed and economically important ambrosia beetles in the world, especially in the Tropics (Bright 1968, Wood 1982). Occurs from Massachusetts south to Florida and west to Michigan and southern California. Found in Mexico, Central and South America, tropical Africa, Hawaii to Micronesia, Australia, and southern Asia.

Description. ***Adult.*** Reddish brown, elongate, cylindrical ambrosia beetle; female 2.0 to 3.3 mm long and male about 1.8 mm long, 2.8 times longer than wide (Blackman 1922, Blatchley and Leng 1916, Wood 1982). Head tucked under pronotum

and not visible from above. Pronotum of female slightly longer than wide, broadly rounded in front, roughened with rasplike ridges in front; posterior portion shining with sparse, moderately coarse punctures. Pronotum of male drastically different—front margin drawn into an acute point, anterior slope distinctly concave and much smoother. Elytral declivity rather steep, flat to slightly convex, sloping, two large teeth near middle and several small granules.
Larva. White except for brown head, curved, legless.

Biology. Habits are similar to those of other members of the genus *Xyleborus* (Beal and Massey 1945, Blackman 1922, Doane and others 1936, Wood 1982). Adults overwinter in brood chambers. In spring, some females remain in the host, extend the galleries, and continue to produce offspring; other females emerge and fly, usually at night, to new host trees. Females mate before leaving the brood tree because males do not fly. Single females begin the new entrance galleries and are often joined by additional females. In some cases, apparently depending on the moisture content of the host, they make galleries on the surface of the sapwood, then penetrate all the sapwood, whether it is 2 or 30 cm deep. Heartwood is less commonly tunneled. Eggs are deposited near the ends of galleries but not in niches. Eggs hatch in 6 to 10 days, and the larvae feed freely within the galleries on ambrosia fungi cultured on the gallery walls by the adults. Galleries are constantly being extended to accommodate the enlarging family. Females leave the brood colony from time to time to start new colonies, but the original colony continues to work in the same tree as long as the moisture content of the wood is favorable for ambrosia fungus growth. Adults have been taken in flight monthly from April through September in Georgia (Turnbow and Franklin 1980b).

Injury and damage. Beetles favor unthrifty, cut, and broken trees, especially logs and stumps over 10 cm in diameter in a fermenting condition (Beal and Massey 1945, Blackman 1922, Wood 1982). Occasionally attacks slightly weakened trees, hastening or causing mortality. Lower tree trunks and sour logs on the ground are especially attractive. White frass may be seen on the bark. Dissection reveals the complex gallery system. Entrance galleries penetrate the bark, then extend longitudinally over the surface of the sapwood, etching both the inner bark and wood. Transverse or diagonal galleries branch off the longitudinal galleries and then rebranch. At different heights, tunnels lead radially from the surface galleries into the sapwood; these, in turn, branch and rebranch. The same gallery system is often extended by new brood females, sometimes into heartwood, in time producing an elaborate system of galleries. Most economically damaging losses occur in the Tropics to cut logs in the forest, in temporary storage, or on loading docks, where tunnels may render the sapwood worthless within a few weeks. This borer is the principal vector of wilt disease of cacao.

Control. Nothing is known of natural

enemies. Prompt salvage and use of infested trees and logs, along with destruction of infested debris and slabs, can help to minimize losses.

Xyleborus xylographus (Say)

[oak timber beetle]

Hosts. Oak, hickory, walnut, chestnut, maple, beech, birch, apple, pine, spruce, hemlock, larch. Prefers oaks, but attacks many other hardwoods (Beal and Massey 1945, Blatchley and Leng 1916, Doane and others 1936, Hopkins 1898, Wood 1982).

Range. Quebec, Ontario, and New Hampshire south to Florida and west to Texas, Kansas, and Minnesota (Bright 1968, Wood 1982). Also recorded from Cuba.

Description. ***Adult.*** Reddish brown to yellowish, or red, elongate, cylindrical ambrosia beetle; female 2.5 to 2.8 mm long, and male 2.2 to 2.4 mm long, 2.8 times as long as wide (Blatchley and Leng 1916, Bright 1968, Hopkins 1898, Wood 1982). Head directed downward under pronotum, not visible from above; ends of antennae club shaped. Pronotum has parallel sides; anterior margin broadly rounded with asperities; posterior portion smooth, shiny, and finely punctured. Elytra shiny with parallel sides. Elytral declivity steep, flattened, somewhat convex; interiors of large, strial punctures reticulate. ***Egg.*** Ovate, yellow to pearly white, 0.52 to 0.55 mm long and 0.24 to 0.26 mm wide. ***Larva.*** Yellowish white to yellow, with pale brown head; prothorax with conical hump larger than head and abdomen and sparsely clothed with fine hairs, 2.8 to 3.0 mm long.

Biology. Because of identification errors, much of the older literature refers to *X. saxeseni* (Ratzeburg). Females emerge in April and May from galleries in brood trees where they overwinter as adults (Beal and Massey 1945, Doane and others 1936, Hopkins 1898). Males have no flight wings, so they must mate before females emerge to find new hosts; females outnumber males about 20 to 1. Females construct entrance galleries that penetrate the bark and enter the sapwood, then branch. Females deposit as many as 10 eggs loosely against gallery walls. Periodically, females enlarge or extend the walls of the brood chamber and deposit additional eggs; consequently, all development stages are present in brood chambers during summer and early fall. More than one brood may be produced in a gallery system, but new progeny females often emerge and attack new hosts.

Injury and damage. Beetles favor lower portions of declining and dying trees, logs, stumps, exposed roots, and green slash (Beal and Massey 1945, Doane and others 1936, Hopkins 1898). Attack sites are common around the edges of wounds, in deep bark crevices, and in roughened areas of bark. Favorite entrance sites are in and adjacent to bark openings made by sapsuckers and large insect borers. White frass occurs at entrance holes. In cross sections, there is an entrance gallery that penetrates the bark and enters straight or obliquely into the sapwood for 25 mm or more, then branches and rebranches more or less following the annual growth rings. Fungus-blackened galleries in the sapwood

and heartwood are defects that degrade wood products sawn from infested logs.

Control. Unidentified predaceous insects and disease cause some mortality (Hopkins 1898). Maintenance of tree health and prevention of bark injuries will help lessen the likelihood of attack. Prompt use of infested material can help to minimize losses from wood degrade.

Xyleborus dispar (Fabricius)

[pear blight beetle]

Hosts. Alder, ash, beech, birch, chestnut, elm, maple, oak, poplar, sycamore, yellow-poplar, willow, apple, apricot, cherry, grape, hawthorn, peach, pear, plum, pomegranate, quince, walnut, nectarine, hazel, acacia, pine, hemlock, cedar. Fruit trees, particularly pear, preferred. Attacks many broadleaf species and a few conifers (Essig 1958, Mathers 1940, Wilson 1913, Wood 1982).

Range. Apparently introduced from Europe, this beetle was first reported from Massachusetts in 1816 (Essig 1958, Wilson 1913, Wood 1982). Eastern North America, from Nova Scotia and Maine south to North Carolina and west to Ontario and Michigan; in the West from British Columbia south through Washington, Idaho, Oregon, Utah, and California.

Description. ***Adult.*** Dark brown to black ambrosia beetle, elongate, cylindrical, elytra strongly punctured with fine yellowish hairs arising from punctures (Wilson 1913, Wood 1982). Females 2.8 to 3.5 mm long, 2.2 times as long as wide; males lighter colored and much more compressed, about 1.7 mm long. Head almost globular; frons broadly convex. Pronotum armed with six to eight serrations on anterior margin. Elytra with sides parallel anteriorly and narrowly rounded behind. Elytral declivity moderately steep, not serrate or armed with denticles. ***Egg.*** Pearly white, oblong, 0.1 mm long and 0.6 mm wide. ***Larva.*** Pure white except for dark alimentary canal visible through cuticle and brownish mandibles; legless, curved shape, nearly cylindrical except slight tapering toward posterior end; about 5 mm long. ***Pupa.*** White, sparsely hairy and roughened with large thick tubercles.

Biology. Beetles overwinter in galleries in host trees. Adults emerge in late March and April (Mathers 1940, Slingerland and Crosby 1919, Wilson 1913, Wood 1982). Females fly to susceptible host trees to produce new broods. Males do not fly but they mate before females move to new hosts. Females bore through the bark and into the sapwood, then construct vertical galleries from the main galleries. When the first vertical branch gallery is completed, a female deposits a cluster of one to seven eggs, then plugs the branch gallery with frass. Females can produce one or more vertical galleries and lay additional eggs. From 6 to 45 eggs have been observed in a gallery system. Oviposition is complete by mid-June. Eggs hatch in 2 to 3 weeks. Larvae apparently consume little or no wood but feed almost entirely on ambrosial fungus that grows on the gallery walls. Pupation occurs freely in the galleries and lasts about 4 weeks. Beetles, if cultured on artificial diets, develop from eggs to adults

in 42 days, but require 80 to 84 days in the field. New adults complete development by late summer or autumn, but they remain in their galleries during winter; adults often line up in overwintering galleries. There is one generation a year.

Injury and damage. Unthrifty, injured, and dying trees, including limbs and boles 5 to 20 cm in diameter, are most often attacked (Essig 1958, Gossard 1913, Slingerland and Crosby 1919, Wilson 1913, Wood 1982). Fruit trees, particularly pear, seem especially susceptible. They sometimes girdle and kill young trees growing in nurseries. Dying and flagging branch tips of pear and apple are often mistaken for blight disease. Frass can be seen around the entrance holes, which are most often located just below bud scars on the bark. In small main stems and branches, the main gallery penetrates the sapwood, then turns and spirals or circles the small stems, girdling and killing them. In larger stems and branches, the entrance gallery penetrates straight into the sapwood for 1 to 5 cm, then branches into two transverse galleries. Vertical galleries, both above and below the transverse galleries, may be present. This beetle is troublesome in commercial pear, apple, nectarine, and apricot orchards. It may be a vector of fire blight disease.

Control. Cultural practices that keep trees healthy and vigorous and prompt disposal of prunings and broken branches prevent most attacks (Essig 1958, Gossard 1913, Slingerland and Crosby 1919).

Xyleborus sayi (Hopkins)

[eastern twig ambrosia beetle]

Hosts. Maple, birch, hickory, walnut, ash, basswood, sassafras, northern red oak, American hornbeam, chestnut, dogwood, tupelo, mountain-laurel, spicebush. Favors maples, especially red and sugar maples, in northern range; sassafras favored in southern range (Beal and Massey 1945, Bright 1968, Hazen and Roeper 1980, Wood 1982).

Range. Eastern species recorded from Ontario, Quebec, and Maine southward to northern Georgia and west to Missouri, Illinois, and Michigan (Bright 1968, Wood 1982).

Description. ***Adult.*** Dark brown to black, stout, elliptical ambrosia beetle, 2.2 times as long as wide (Beal and Massey 1945, Bright 1968, Wood 1982). Females 2.3 to 2.7 mm long; males 1.2 to 1.6 mm long with nonfunctional wings. Head hidden from above by prothorax; antennal club obliquely truncate. Pronotum broadly rounded and feebly punctured with two small teeth at apex. Elytra shiny, pubescent, punctures shallow. Elytral declivity convex, nearly smooth except striae coarsely punctured, without marginal teeth. ***Egg.*** Whitish, translucent, oblong, 0.70 mm long by 0.36 mm wide (Hazen and Roeper 1980). ***Larva.*** White with brownish mandibles, legless, slightly curved.

Biology. Adults overwinter within galleries. In Michigan, adults emerge and attack in late April and cease in early July (Hazen and Roeper 1980). In northeast Georgia, emergence and flight begin in March, peak in April, and continue until early September

(Turnbow and Franklin 1980b). Females fly to susceptible trees, bore through the bark and into the xylem, and inoculate the galleries with ambrosia fungus that is carried in an intersegmental pouchlike mycetangium on the thorax. Eggs are laid in small groups near the ends of lateral galleries from mid-May to late July in Michigan. Larvae feed freely throughout the gallery system on whitish ambrosia fungus growing from the gallery walls, pass through two larval instars, and are present from early June to mid-August. Pupae are found free in the galleries from mid-July to early September. Progeny adults per gallery system range from 14 to 25; females outnumber males 3.6 to 1.0 and are first observed in late July. Females mate with flightless, sibling males in the parent galleries. New progeny adults remain in brood galleries to overwinter. This beetle has one generation a year in Michigan and possibly more in its southern range.

Injury and damage. This ambrosia beetle attacks weakened and windthrown trees and fresh-cut logs but prefers twigs, small-diameter stems, and branches, especially small subcanopy maples of low vitality (Hazen and Roeper 1980, Wood 1982). Wilted and yellowed foliage on branches and young trees is evidence of infestation. Entrance holes are usually found at lenticels on smooth bark of young maples and are generally spaced regularly over the bark surface, averaging one hole per square decimeter. Fine frass is ejected from the entrances, but only small amounts accumulate on the bark. Entrance galleries are perpendicular to the bark surface and penetrate the wood 7 to 10 mm. This pest constructs a lateral tunnel 13 to 22 mm long perpendicular to the entrance gallery on the same plane; usually, the tunnel follows the annual growth rings. Often, another branch tunnel originates at the deepest point of the entrance tunnel and runs opposite the first branch tunnel. Tertiary galleries occasionally extend from the secondary branches. Damage to sugar maple regeneration is generally minor; no more than 2% of understory maple saplings have been infested in a given year.

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

Xyleborinus saxeseni (Ratzeburg)

[lesser shothole borer] (figure 221)

Hosts. Hickory, pecan, oak, walnut, sweetgum, yellow-poplar, dogwood, persimmon, holly, maple, honeylocust, beech, yellow birch, hackberry, mimosa, madrone, hemlock, baldcypress, cedar. Wide host range of forest, ornamental, and fruit trees including both broadleaf and coniferous species. Prefers hickory, pecan, peach, oak, beech, and maple (Beal and Massey 1945, Blatchley and Leng 1916, Kovach and Gorsuch 1985).

Range. Introduced from Europe. Southern Canada from Ontario to British Columbia; in the United States from Maine south to Florida and west to California; and in Baja California and Hidalgo, Mexico (Wood 1982). Common in southeastern United States (Kovach and Gorsuch 1985, Turnbow

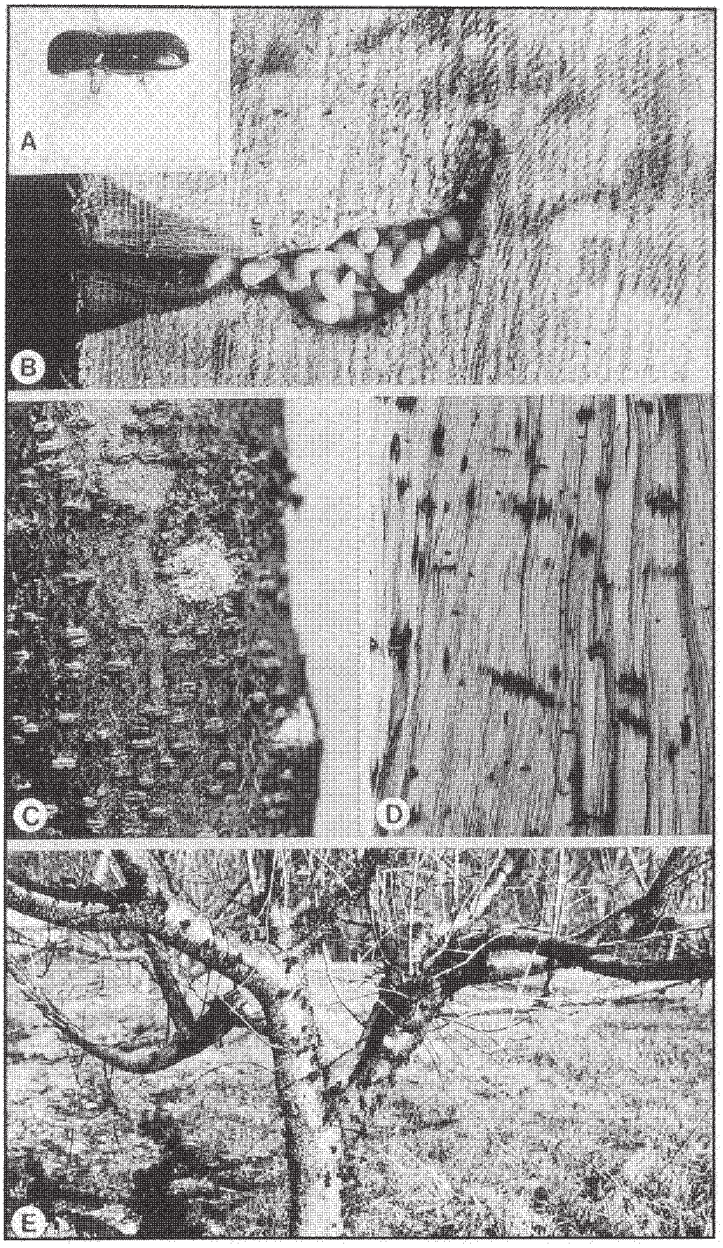

Figure 221—Xyleborinus saxeseni, *[lesser shothole borer]: A, adult; B, mass of nearly mature larvae in cavelike brood chambers; C, white frass on bark; D, black-stained galleries in wood; E, globular masses of gum at entrance holes (A, courtesy M. Roling; C & E, courtesy C. Gorsuch).*

and Franklin 1980b). Occurs in Europe, Asia, Australia, and South America.

Description. ***Adult.*** Dark brown, elongate, cylindrical ambrosia beetle, female 1.9 to 2.4 mm long, male slightly smaller, three times as long as wide (figure 221A) (Blackman 1922, Blatchley and Leng 1916, Wood 1982). Front of head convex with coarse shallow punctures. Anterior part of pronotum broadly rounded and roughened; posterior portion smooth, minutely punctured. Distinguished from the *Xyleborus* species by its conical scutellum. Elytra shiny with coarse shallow punctures. Elytral declivity convex with steep slope and armed with rows of acute granules. ***Egg.*** Whitish, translucent, and oblong. ***Larva.*** White with light brown head, curved to C-shaped, 1.9 to 2.8 mm long (figure 221B).

Biology. In northeast Georgia, adults emerge from hibernation in mid-February when temperatures reach 18°C; flights increase sharply during March, peak in April, then decline until November (Turnbow and Franklin 1980b). Females fly to susceptible trees, bore into the sapwood, and make enlarged chambers in the galleries that they inoculate with an ambrosia fungus (Blackman 1922, Kovach and Gorsuch 1985, Wood 1982). Eggs are deposited in the chambers. Larvae and adults work to extend and enlarge the brood chambers. The larvae feed on a combination of ambrosial fungus growing on the chamber walls and on wood produced by enlarging the burrows. At times, the chambers are filled with a mass of larvae. There are no individual cradles, and pupation occurs freely in the large chambers. All stages are sometimes found together in the same chamber. An average of 21 beetles develop and emerge from each brood chamber. Females outnumber males by ratios of 7:1 to 37:1; mating occurs either before the females leave the parent trees or unmated females produce two to three males with whom they mate before they can produce female progeny. A generation is completed in less than 2 months; four to five generations a year may be produced in the southern United States.

Injury and damage. Weakened, injured, and dying trees and fresh-cut logs are prone to infestation (Beal and Massey 1945, Blackman 1922, Wood 1982). Trunks 5 to 50 cm in diameter are most apt to be attacked, but branches down to about 2.5 cm in diameter are also susceptible. White frass can be seen on the bark below the tiny round entrance holes (figure 221C). Dissection of infested stems reveals a radial entrance tunnel about 1 mm in diameter extending through the bark and 1 to 7 cm into the wood. The innermost portion of the gallery (about half the gallery length) is widened and enlarged mostly in a vertical direction parallel with the wood grain (figure 221B). The enlarged portion of the gallery is sometimes referred to as a "tabular cave" or a leaf-type chamber. The walls of the galleries, and sometimes the wood immediately surrounding the galleries, is stained black (figure 221D). Logs and lumber with stained pinhole defect are downgraded for use in fine furniture and other select uses. This pest also attacks wine

casks. In *Prunus* species, especially peach, globular masses of gum exude and accumulate on the bark of living trees that have been attacked (figure 221E). This beetle is the most common scolytid, representing 95% of about a dozen species found in South Carolina peach orchards.

Control. Two species of predaceous beetles—*Colydium lineola* Say and *Enoclerus sphegeus* (Fabricius)—have been found in galleries (Essig 1958). Infested timber should be harvested and milled promptly. Along the Gulf Coast, logs cut during the warm seasons should be removed and used within 1 to 2 weeks (Blackman 1922).

Xylosandrus compactus (Eichhoff)

black twig borer (figure 222)

Hosts. Avocado, magnolia, common fig, dogwood, golden-shower, Jerusalem-thorn, live oak, laurel oak, red maple, Florida maple, pecan, hickory, redbud, sweetgum, French mulberry, sugarberry, camphor-tree, mango, eastern hophornbeam, redbay, sycamore, southern elder, sweetleaf, eucalyptus. Host range along the southern parts of the United States undoubtedly will grow, because the species is known to have at least 200 host species belonging to 62 families worldwide (Chellman 1978, Nelson and Davis 1972, Ngoan and others 1976, Oliver 1978).

Range. Native of Southeast Asia, widely distributed in tropical and subtropical regions from West Africa to Hawaii, southern Japan, and Brazil (Ngoan and others 1976, Wood 1982). First collected in Florida in 1941 but reported several years later. Has since spread northward into Georgia and westward into Alabama, Mississippi, Louisiana, and eastern Texas.

Description. ***Adult.*** Tiny, dark brown to black, shiny, stout, cylindrical ambrosia beetle (figure 222A) (Bright 1968, Ngoan and others 1976, Wood 1982). Females 1.4 to 1.8 mm long, 2.1 times as long as wide; males 0.8 to 1.1 mm long, reddish brown. Head concealed from above. Pronotum subcircular, anterior margin with six to eight serrations. Elytra have parallel sides and are broadly rounded behind. Elytral declivity evenly arched, finely granulate. ***Egg.*** White, translucent, ovoid, without sculpture, 0.55 by 0.33 mm (figure 222B). ***Larva.*** White except for pale brown head, legless, curved to C-shaped, abdomen pointed posteriorly in young larva but rounded in mature larva (figure 222C). ***Pupa.*** White, yellow, finally black, soft bodied, exarate (figure 222D).

Biology. In north Florida, female beetles emerge from hibernation and attack new twigs from late February to mid-March about the time dogwood trees bloom (Ngoan and others 1976, Wood 1982). Females bore into twigs and branches of host trees and produce brood chambers in the stem pith. They deposit eggs in loose clusters in the brood chambers and not in individual cradles as do some ambrosia beetles. The eggs hatch in 4 to 6 days, and the larvae feed on ambrosia fungus growing from the walls of the brood chambers. The fungus *Fusarium solani* (Mart.) Sacc. is carried by the females into the brood chambers for

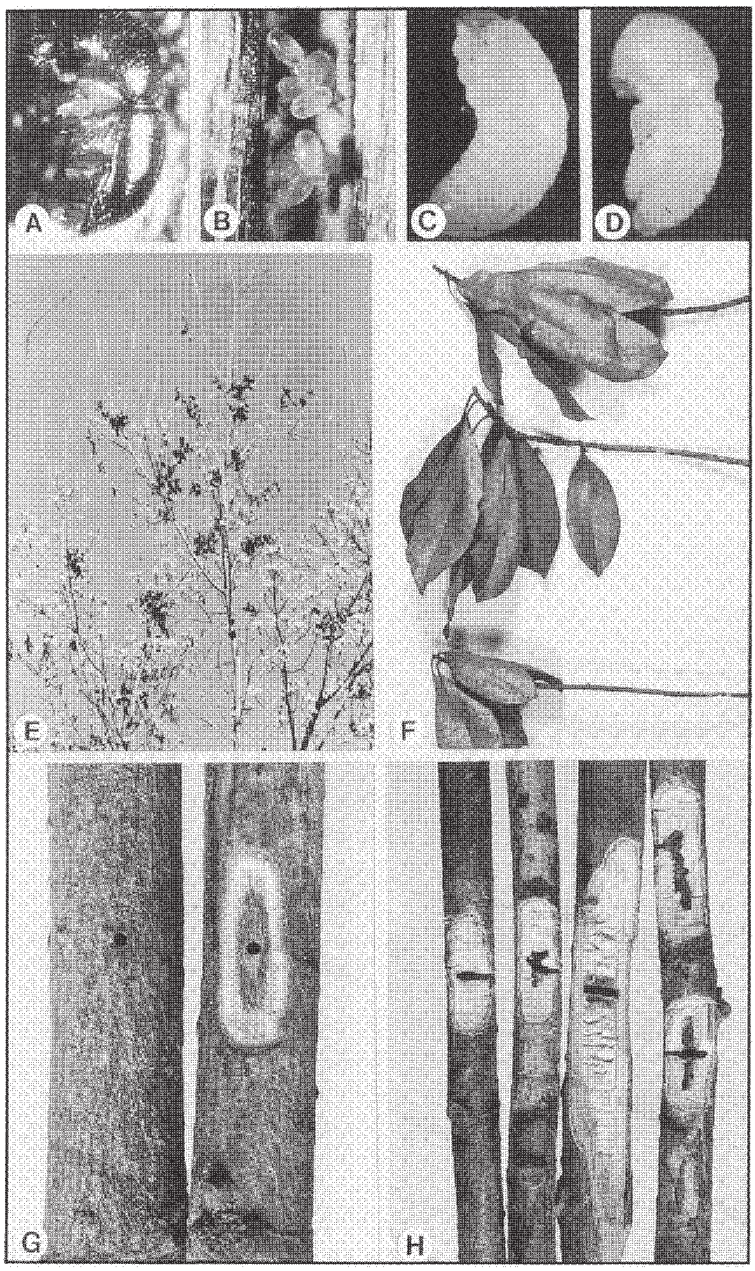

Figure 222—Xylosandrus compactus, *[black twig borer]: A, adult; B, eggs; C, larva; D, pupa; E, twigs dying from beetle attack; F, twigs killed by beetles; G, entrance hole in bark and wood; H, brood chambers in pith of twigs (A-E, courtesy R. Wilkinson).*

inoculation. Larvae mature in 7 to 8 days and pupate freely in the brood chambers. Pupae develop in 8 to 9 days. From 1 to 40 beetles develop in a brood chamber. Adults mature in 8 to 9 days. New beetles emerge during the afternoon and attack the same or different host usually within 30 minutes. Populations are highest from June to September, when all stages may be present. Females outnumber males by about 10 to 1. Beetles have been captured in sticky traps from February through September, making it difficult to evaluate numbers of generations a year. Average life cycle is 28 days. Thus, it is possible to complete five to six generations a year. Adults remain in the brood chambers to overwinter.

Injury and damage. This beetle attacks healthy, vigorous twigs of living dicotyledonous trees and shrubs. The first signs of infestation are terminals, twigs, and small branches with fading, wilting, yellowing, and browning foliage scattered through the tree crown (figure 222E and F) (Chellman 1978, Nelson and Davis 1972, Ngoan and others 1976, Oliver 1978, Wood 1982). As many as 50 affected branchlets have been observed on 1 large infested magnolia in Louisiana. Inspection of a flagging branchlet reveals a small pin-sized hole, usually on the underside of the stem (figure 222G). Small quantities of frass may be present at the entrance. The entrance hole is slightly oval, ranging from 0.76 to 0.89 mm by 0.71 to 0.81 mm. The entrance hole extends directly through the bark and xylem at a right angle to the stem axis. The hole extends to the stem pith, where small cavities or brood chambers 2 to 57 mm long are excavated along the stem axis, usually in both directions from the entrance (figure 222H). Dissecting affected twigs may reveal all stages of the insect in the brood chambers and dark stain in the xylem adjacent to the chambers. Small, infested twigs 1 to 8 mm in diameter typically contain one entrance, and they usually succumb. Larger twigs 8 to 22 mm in diameter usually have several entrance holes (up to 20 per twig). These twigs also die, or cankerlike swellings form along them. Cankers range from 10 to 210 mm long, with up to 13 entrance holes. Injuries result in dieback, canker formation, unsightly dead leaves on attacked twigs, and, less commonly, tree mortality (Mangold and others 1977). Economic losses have been sustained by avocado growers in Florida, and the beetle has become increasingly destructive to ornamental trees and shrubs (Ngoan and others 1976). It causes extensive mortality among large forest trees and understory shrubs in Hawaii (Nelson and Davis 1972).

Control. Flagging twigs and branches should be pruned out and destroyed while the brood is present (Oliver 1978). Fertilization and irrigation that keep trees healthy and vigorous can help to lessen dieback and injury (Chellman 1978). Insecticides applied with a hydraulic sprayer have controlled infestations in flowering dogwood in Florida (Mangold and others 1977).

***Xylosandrus germanus* (Blandford)**
[black stem borer] (figure 223)

Hosts. Elm, oak, red maple, beech, hickory, pecan, sumac, willow, birch, sweetgum, tupelo, dogwood, ash, black cherry, redbud, buckeye, linden, sassafras, black walnut, butternut, bayberry, yellow-poplar, hornbeam, pear, apple, rhododendron, grape, poison ivy, pine, cedar, hemlock. Worldwide, over 200 species in 52 families recorded as hosts; favors broadleaf trees and shrubs but also attacks some conifers (Hoffman 1941, Weber and McPherson 1983a).

Range. The Far East, Central Europe. In the eastern United States, it has been found in 17 states, from Connecticut and New York south to Georgia and west to eastern Texas, Missouri, and Michigan (Weber and McPherson 1982). Introduced apparently from Japan; first reported in 1932 on greenhouse-grown grape vines in Long Island, New York (Hoffman 1941).

Description. ***Adult.*** Dark brown to black, shiny, stout, almost cylindrical ambrosia beetle, rounded in front and rear (figure 223A) (Hoffman 1941, Wood 1982). Females 2.2 to 2.4 mm long, 2.3 times as long as wide; males 1.5 to 1.7 mm long, lighter in color. Head finely and scantily punctured, hidden under prominent pronotum; eyes deeply emarginate. Pronotum about as long as wide, anterior margin in female with 8 to 10 low, blunt asperites, and posterior smooth and faintly punctured; anterior margin of male pronotum smooth and anterior slope with numerous low asperites. Elytral declivity begins slightly behind middle; steep, broadly convex, more oblique than abrupt, suture slightly raised. ***Egg.*** Elliptical, soft, white, translucent, shiny, 0.67 by 0.38 mm (figure 223B). ***Larva.*** White, with light brown head, elongate and rather flat when newly hatched, but becoming robust, slightly curved (figure 223C). ***Pupa.*** White, exarate, 1.8 to 2.5 mm long.

Biology. Beetles emerge from hibernation in late March in North Carolina and in mid-May in Illinois and New Jersey (Hoffman 1941, Schneider and Farrier 1969, Weber and McPherson 1983b). Adult flights to suitable hosts peak from late April to early June. Females bore through the bark into the sapwood, construct a brood chamber and one or more branch galleries, and inoculate the gallery walls with an ambrosia fungus—*Ambrosiella hartigii* Batra. Egg laying does not begin until the brood chambers have been formed and the white ambrosia fungus begins to grow—about 5 days after the galleries were excavated. Females deposit from 2 to 50 eggs loosely in small clusters in the brood chamber. Oviposition period averages about 26 days, and females deposit an average of 1 egg per day, but a few females deposit up to 140 eggs. After oviposition in the brood chambers, the females construct the branch galleries. Eggs hatch in 4 to 6 days, and the young larvae feed on the ambrosia fungus mats in both the brood chamber and branch galleries. The larvae pass through three larval instars and pupate freely in the galleries in about 12 days. Pupation lasts 7 to 8 days. New adults assume normal color 5 to 6 days

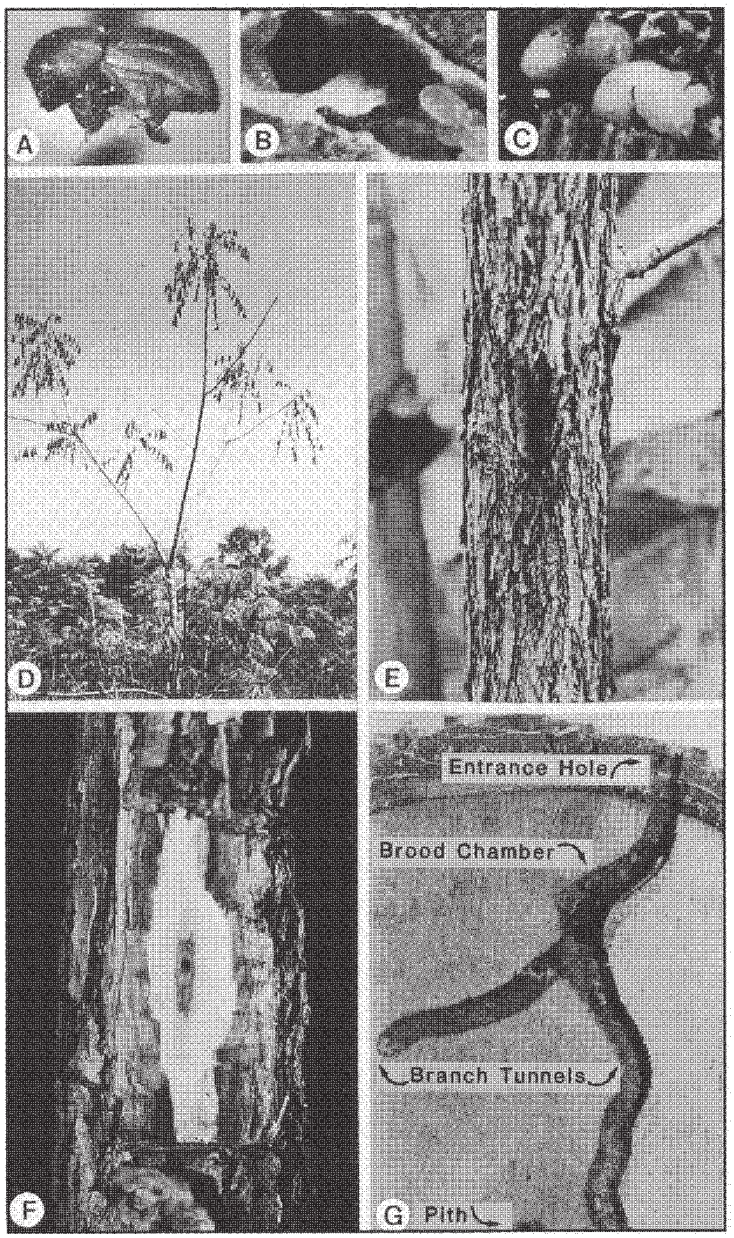

Figure 223—Xylosandrus germanus, *[black stem borer]: A, adult; B, cluster of eggs in gallery with white ambrosia fungus; C, larvae; D, black walnut sapling dying from beetle attack; E, sap-stained bark at beetle entrance; F, entrance hole in sapwood; G, gallery entrance, brood chamber, and branch tunnels (courtesy B. Weber and J. Van Sambeek).*

after emergence. Development from egg to adult averages about 26 days. Diploid females are produced from fertilized eggs, whereas haploid males arise from unfertilized eggs; females outnumber males by about 10 to 1. Males cannot fly, so females must either mate before leaving the brood trees or first produce two to three males parthenogenetically with whom they mate. The beetles overwinter in the brood chambers where they develop; sometimes, as many as 200 beetles may be found hibernating in 1 gallery system. The beetle has two generations a year, and possibly three, in the southern parts of its range.

Injury and damage. Unlike most ambrosia beetles, this insect attacks vigorous trees as well as diseased, dying, and recently dead ones and fresh-cut trees and stumps (Anderson and Hoffard 1978, Schneider and Farrier 1969, Weber 1981, Weber and McPherson 1983b, Wood 1982). On black walnut in young plantations and elm and maple growing as understory plants, attack sites are most common on the lower trunks of saplings 0.9 to 6.4 cm (occasionally up to 10 cm) in diameter and less common in the lower branches within 2 m of the ground. Cut oak and beech stumps up to 50 cm in diameter are sometimes attacked. Wilting, yellowing, and dying foliage on the aboveground portion of the tree are initial symptoms of attack and are found most frequently during May and June (figure 223D). Sometimes the only symptoms of attack are pinholes, but they are small (about 1 mm diameter) and difficult to detect. Sap may ooze from the pinholes and stain the bark (figure 223E and F). Fine dustlike frass is often present in bark crevices around the pinholes. Under moist conditions, cylindrical rods or coiled strands of compacted frass up to 5 cm long are extruded from the entrance holes. *Fusarium* cankers of varying sizes are often associated with pinholes and dieback. These cankers appear as sunken necrotic areas under the bark; later, the bark cracks and callus tissue may be visible around the canker. Although the tops of attacked trees may die, the roots are usually still alive and send out sprouts. About 75% of infested trees suffer top dieback, but most of these produce basal sprouts, which are good indicators of injury. Dissection reveals a gallery entrance about 1 mm in diameter and a horizontal entrance tunnel 2 to 3 mm long extending into the sapwood. This tunnel is then enlarged into an elongate (7 to 12 mm), irregular, vertically oriented, cavelike gallery (figure 223G). One to three branch tunnels 1 to 25 mm long may extend more or less radially from the cavelike brood chamber. In some young black walnut plantations, 30 to 40% of the trees have suffered dieback from beetle/*Fusarium* canker attacks. Also, high rates of dieback, resprouting, and deformity from the beetle/*Fusarium* attacks have occurred in yellow-poplar plantations in Ohio. The beetle has also been implicated in the transmission of Dutch elm disease.

Control. Some predation by an unidentified immature hemipteran has been observed; no parasites have been reported (Weber and McPherson 1983b). Good

management and silvicultural practices including establishing plantations on good sites, planting trees to permit thinning of injured ones, and providing adequate weed control are best for minimizing losses (Weber 1981). Fresh hardwood stumps within a radius of 500 m of young plantations in problem areas should be chemically treated to prevent population buildup. Also, cankered, dying, and dead treetops and branches should be removed and burned promptly to destroy developing beetles. Differences among geographic seed sources in susceptibility to beetle attack in research trials offer future control alternatives.

Xylosandrus crassiusculus (Motschulsky)

[granulate ambrosia beetle] (figure 224)

Hosts. Sweetgum, peach, cherry, plum, pecan, willow oak, water hickory, honeylocust, cottonwood, black willow, American elm, sugarberry, persimmon, magnolia, grape. Attacks over 200 broadleaf trees, shrubs, and vines worldwide in 41 plant families (Anderson 1974, Wood 1982). In the 20 years since this beetle's introduction into North America, it has been found in 13 broadleaf species but shows some preference for sweetgum.

Range. Widely distributed in Africa, southern Asia, Indonesia, Australia, and the islands of the Pacific, including the Hawaiian Islands (Wood 1960). Apparently migrated from Indonesia or southern Asia by way of Hawaii to the mainland United States. It was first reported in 1974 in North America from Summerville (Dorchester County), South Carolina (Anderson 1974). The insect has spread rapidly. Besides South Carolina, published records now include Florida, North Carolina, Louisiana, and east Texas (Atkinson and others 1988, Chapin and Oliver 1986). Additional unpublished records in the United States National Museum collection reveal specimens collected in Georgia and Mississippi.

Description. ***Adult.*** Reddish brown, stout, cylindrical ambrosia beetle, rounded in front and rear, with head largely hidden under prominent pronotum (figure 224A) (Atkinson and others 1988, Kovach and Gorsuch 1985, Wood 1982). Front of head strongly and uniformly reticulate. Pronotum as long as wide, anterior margin in female with several blunt asperites; pronotal asperites absent in male. Females 2.1 to 2.9 mm long, 2.1 times as long as wide; males remotely resemble females but are very small, with radically reduced thorax and hunchbacked appearance. Elytra are slightly longer than wide, and somewhat larger than pronotum, with small punctures. Elytral declivity steep, convex, dull, densely covered with small granules. ***Larva.*** White with well-developed, light brown head and legless, curved body (figure 224B).

Biology. Adult beetles are found from May through August (Atkinson and others 1988, Wood 1982). Overwintering probably occurs in the adult stage as in other *Xylosandrus* spp. Males are rare, small, flightless, and presumably haploid. Females mate with sibling males before emerging to attack new hosts. Females fly to suitable hosts in spring to initiate new attacks. They bore

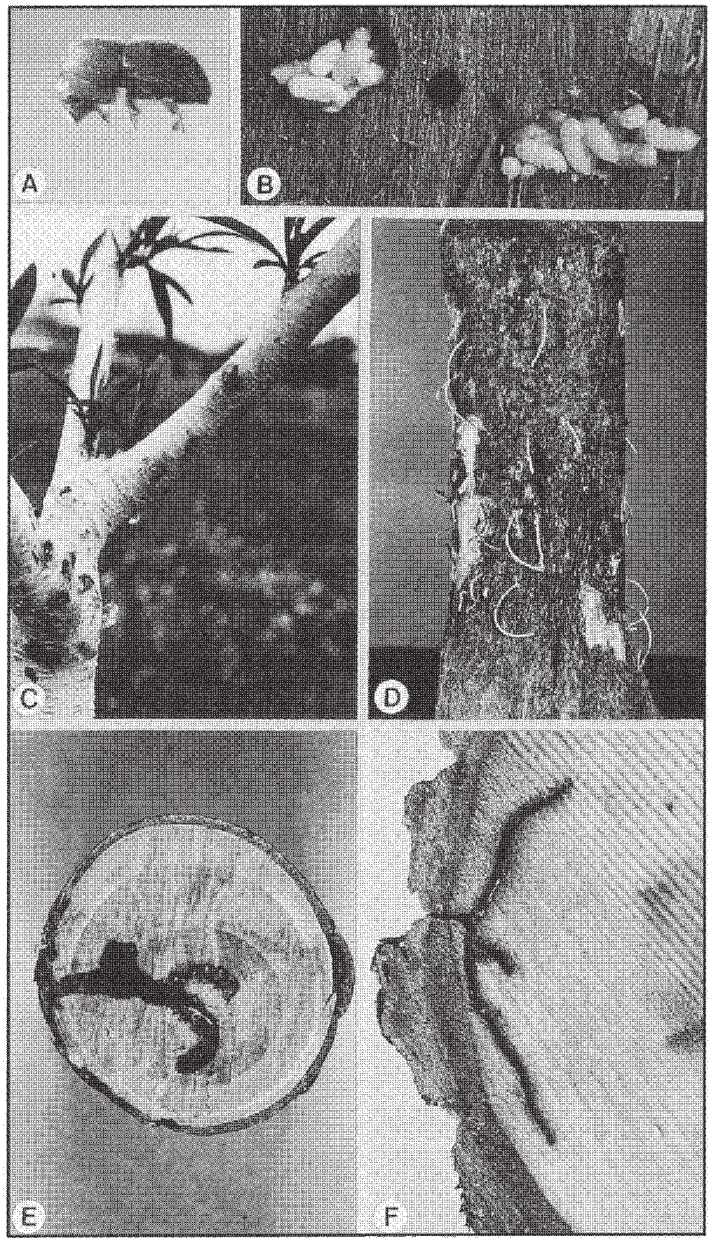

Figure 224—Xylosandrus crassiusculus, *[granulate ambrosia beetle]: A, adult; B, larvae and pupae; C, gummy exudate at entrances on peach bark; D, strands of compacted frass; E, gallery with entrance, brood chamber, and branch galleries; F, gallery system in large cottonwood (C & E, courtesy C. Gorsuch).*

tunnels that usually contain a brood chamber and branch one or more times in the sapwood. Females deposit eggs in the brood chamber, and the larvae feed on the ambrosia fungus cultured on the gallery walls. Masses of larvae and pupae can sometimes be found together in the brood chamber. No individual egg niches, larval tunnels, or pupal chambers are made. In Malaysia, the life cycle reportedly is 5 to 7 weeks. The number of progeny varies from 23 to more than 100 per gallery. Several generations occur per year.

Injury and damage. Healthy and stressed trees as well as freshly cut material from 1.5 cm in diameter to large logs are attacked (Wood 1982). This beetle prefers stems smaller than 7.5 cm in diameter but sometimes infests material larger than 20 cm in diameter. It commonly attacks newly transplanted seedlings near the root collar. Round 2-mm diameter entrance holes usually at lenticels may be found in the bark (Kovach and Gorsuch 1985). Masses of gummy exudate usually accumulate at entrance sites on *Prunus* spp. such as peach trees (figure 224C). Long strands of compacted frass sometimes curl out of the galleries (figure 224D). Dissection reveals a gallery system that reportedly resembles that of *Xyleborus dispar* (Wood 1982), but actually the galleries seem to vary with host species, stem diameter, and possibly wood moisture content. In small-diameter stems, galleries penetrate the bark and sapwood for 4 to 8 mm, then open into an enlarged cavelike brood chamber that contains one or two short branch galleries (figure 224E). In large diameter stems, the brood chambers are usually smaller and more elongate, and the branch galleries are usually longer and more numerous (figure 224F). Apparently healthy peach trees have been attacked in South Carolina; growers are concerned because of the beetles' aggressive behavior toward both healthy and stressed trees (Kovach and Gorsuch 1985). Nursery-grown oaks and elms have suffered from attacks in Florida (Atkinson and others 1988). In south Mississippi, young 8- to 9-year-old pecan plantations have been heavily infested and some trees have died.

Control. Cultural practices that eliminate breeding sites help minimize populations and losses (Atkinson and others 1988, Kovach and Gorsuch 1985). Prunings should be burned or destroyed with a flail mower. Dying trees, brush piles, and other debris should be burned by late winter before the adults emerge and reinfest crop trees. Growers should emphasize practices that promote tree vigor. Chemical controls may be needed to protect valuable trees.

Family Platypodidae — Ambrosia Beetles

The platypodids are almost all tropical and subtropical beetles; only two species are covered in this manual. They are distinguished from other ambrosia beetles by their large size; longer, more slender body; wide, prominent head flattened in front, not covered by the pronotum; and long, slender tarsus, with the basal joint longer than the others combined (Arnett 1968, USDA FS 1985). Larvae are elongate, fleshy, straight to only slightly curved, and subcylindrical, with only scattered short setae. They bore into the wood and cultivate an ambrosial fungus upon which both adults and larvae feed. When abundant, they are more destructive than other ambrosia beetles because their burrows are more extensive and penetrate deeper into the sapwood and heartwood. Weakened, dying, and recently felled trees are preferred; however, vigorous, healthy trees are also attacked, especially when wounds and dead areas are present. Their burrows and associated wood stains often ruin the value of hardwood timber.

Genus and Species

Platypus
- *compositus* (Say) *578*
- *quadridentatus* (Olivier) *581*

Platypus compositus (Say)

[hardwood platypus] (figure 225)

Hosts. Oak, hickory, pecan, chestnut, poplar, birch, beech, elm, basswood, sweetgum, magnolia, persimmon, willow, maple, cherry, tupelo, baldcypress. Prefers oak, hickory, maple, and beech, but other hosts are also commonly attacked (Beal and Massey 1945, Chamberlin 1939).

Range. Primarily a tropical and subtropical species, extending through Central and South America and Mexico into Texas east to Florida and northward from southern Missouri to southern New York (Atkinson 1989, Beal and Massey 1945, Blackman 1922, Hubbard 1897). Most common and widely distributed *Platypus* sp. in the United States; most common in the South, particularly along the Gulf Coast.

Description. ***Adult.*** Large, very elongate, cylindrical, reddish brown ambrosia beetle, 4.3 to 5.0 mm long, about four times as long as wide (figure 225A) (Arnett 1968, Atkinson 1989, Beal and Massey 1945, Blackman 1922, Hubbard 1897). Head visible from above, as wide as pronotum, noticeably broad and flattened in front. Pronotum finely, shallowly, and sparsely punctured, longer than wide, with two tiny margined pits just behind the middle of both sexes. Elytra elongate with punctate striae. Elytral declivity in males prolonged into heavy process that bears three teeth on their tips; truncate and unarmed (toothless) in females. ***Egg.*** Elongate to oval, pearly white, clear to opaque, 0.72 to 0.89 mm long, 0.41 to 0.48 mm wide (figure 225B). ***Larva.*** Elongate, fleshy, subcylindrical, nearly straight to slightly curved, white to creamy white, with prominent chitinous ridges dorsally on prothorax, 4.8 to 6.4 mm long (figure 225C).

Biology. Adults are active throughout the growing season from spring to October

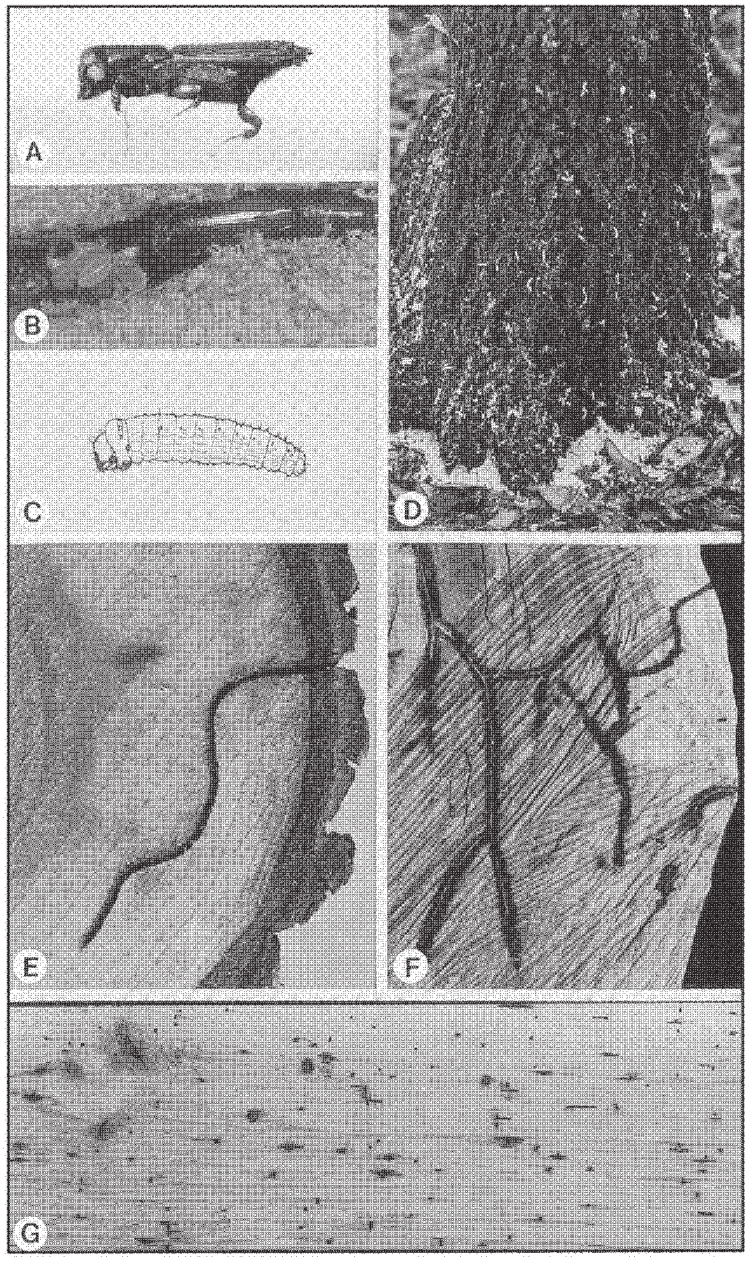

Figure 225—Platypus compositus, *[hardwood platypus]: A, adult; B, egg cluster; C, larva; D, white frass on bark and piled around base of tree; E, unbranched gallery in cottonwood; F, multibranched gallery in pecan; G, black-stained holes in oak lumber.*

or November (Blackman 1922, Chamberlin 1939, Doane and others 1936, Hubbard 1897). Adults are attracted to declining host trees, particularly those with fermenting sap. Males initiate the galleries; each male is soon joined by one female. The males are aggressive fighters and frequently battle over females. The beetles produce deep galleries in the sapwood and heartwood. Females deposit 100 to 200 eggs in loose clusters of 10 to 12 in the galleries. Larvae feed entirely on ambrosia fungus (brought to new sites by parent beetles) that grows prolifically on moist gallery walls. Larvae wander freely in the tunnels as they feed and grow. They can move rapidly within the tunnels, but they do not damage or destroy eggs and small larvae along the galleries. Larvae require 5 to 6 weeks to develop. When nearly mature, the larvae help to extend the galleries, but they do not consume the wood. To pupate, mature larvae construct deep cradles above and below the feeding galleries; pupation occurs in these cradles, and newly transformed adults emerge from the host through entrance holes made by the parent beetles. There are three to four generations per year in the Gulf Coast region.

Injury and damage. This pest seldom attacks healthy, vigorous trees but rather limits its attacks on living trees to those weakened from drought, disease, old age, insect defoliation, wounding, and other factors that produce serious stress (Chamberlin 1939, Craighead 1950, Hubbard 1897). It prefers severely weakened and dying trees, fresh-felled trees, and logs full of moisture. Larger trees in the pole- and sawtimber size classes are favored over smaller trees. Whitish, fibrous boring dust is often present in bark crevices around the entrance holes. During periods of plentiful moisture and high humidity, the borings may stick together as they are pushed out to form compacted, stringlike strands; the white borings sometimes accumulate in loose piles around the base of infested trees (figure 225D). Dissection reveals a simple but extensive gallery system that often penetrates deep into the sapwood and sometimes into the heartwood (figure 225E). In some trees and logs where the moisture level remains favorable, the galleries may branch and rebranch several times, and sometimes follow the growth rings (figure 225F). Numerous short, vertical pupation cells or cradles may be present above or below the galleries. Galleries and cradles are stained black by fungi growing on the gallery walls. Beetles do not kill trees but may hasten the death of severely weakened ones. The most serious damage caused by this insect is the extensive black, fungus-stained galleries that penetrate the sapwood and heartwood. This insect, one of the most destructive ambrosia beetle species in the logging and lumbering industry, can, in a few weeks, render wood worthless for lumber (figure 225G).

Control. Preventive measures, such as keeping trees vigorous and preventing wounds, are the best means of minimizing damage to living timber. In the Deep South, trees felled between April and October should be removed from the woods and processed within 2 to 3 weeks (Craighead 1950). If green logs cannot be milled

promptly, they should be either stored under water, sprayed continuously with water, or sprayed with a protective insecticide. Trap trees with girdling and destruction properly timed have been used with some success in high-risk areas (Blackman 1922).

Platypus quadridentatus (Olivier)

[oak platypus] (figure 226)

Hosts. Oak, chestnut, horse chestnut, magnolia, hemlock. Oaks, particularly red oaks, are favored (Beal and Massey 1945, Chamberlin 1939).

Range. Mexico and northward from east Texas and southern Missouri east to southern Pennsylvania and Florida (Atkinson 1989, Beal and Massey 1945, Blackman 1922, USDA FS 1985).

Description. ***Adult.*** Elongate, slender, cylindrical, dark brown to reddish brown ambrosia beetle, 4.2 to 4.6 mm long, 3.8 times as long as wide (figure 226A) (Arnett 1968, Atkinson 1989, Beal and Massey 1945, Blackman 1922, Hubbard 1897). Head visible from above, noticeably flattened in front, shallowly and densely punctured, sparsely clothed with moderately long hairs. Pronotum longer than broad, slightly constricted along sides at middle, bears two very large pores just behind middle in female; pits very small to absent in male. Elytra elongate, serrate, third and fifth interstriae elevated, forming blunt processes in female; male with large acuminate process arising from interstria 9 and a spinose process arising from interstria 3 of declivity. ***Egg.*** Elongate to oval (slightly shorter and thicker than that of *P. compositus*), pearly white to clear or opaque (figure 226B). ***Larva.*** Elongate, fleshy, subcylindrical, white with light brown head, 4.5 to 6 mm long (figure 226C).

Biology. Adults, present from spring to fall, are attracted to weakened trees (Beal and Massey 1945, Doane and others 1936, Hubbard 1897, USDA FS 1985). The male initiates the gallery. After mating, females bore deeply into both the sapwood and heartwood. Females attract several males but choose only one. Beetles inoculate the galleries with ambrosia fungus and deposit up to 200 eggs loosely in small clusters along the galleries. Larvae wander or roam freely throughout the extensive gallery system and feed on ambrosia fungus growing from the gallery walls; they mature in 5 to 6 weeks. Mature larvae bore short cradles at right angles to the main galleries and parallel to the wood grain to pupate. Pupation takes place in the cradles, which commonly occur in groups up to 10 or 12. One generation is produced in a given host. Three or more generation occur each year in the South.

Injury and damage. Weakened, windthrown, and dying trees, recently cut logs, and unseasoned green lumber may be attacked (Chamberlin 1939, Doane and others 1936, Hubbard 1897, USDA FS 1985). The lower boles of standing sawtimber-sized trees are particularly susceptible. Large amounts of white, fluffy, shredded, fibrous frass are often present on the bark and on the ground at the base of the tree or log (figure 226D). Entrance holes in the bark are 0.9 to 1.3 mm in diameter. The

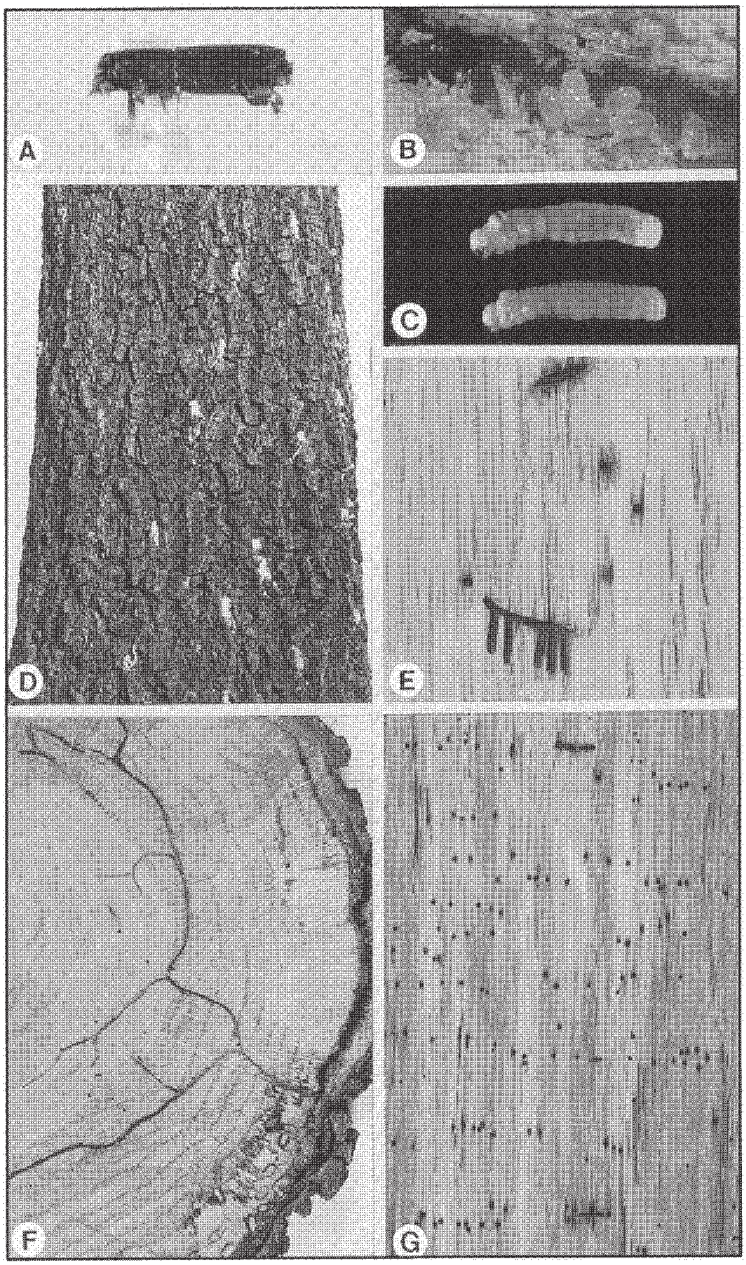

Figure 226—Platypus quadridentatus, *[oak platypus]: A, adult; B, egg cluster; C, larvae; D, white piles of frass on bark; E, closeup of galleries with cradles; F, complete gallery with branching in red oak; G, numerous black holes in oak lumber.*

gallery system is simple but very extensive, penetrating deeply into the sapwood and heartwood, sometimes to depths of 25 to 30 cm, and often branching and rebranching many times (figure 226E and F). Short pupal cells or cradles occur vertically either above or below the galleries (figure 226E). Although less common and less populous than *P. compositus*, it is still one of the most destructive ambrosia beetles. Its black-stained holes degrade the wood and lower the monetary value of affected logs and lumber (figure 226G). In the past, magnolia seedlings grown in nurseries have been seriously damaged by this beetle in Florida.

Control. Maintenance of tree health and vigor can prevent injury (USDA FS 1985). Individual trees and timber stands stressed from drought, unseasonal flooding from beaver dams, wildfire, or storm damage, should be surveyed frequently for infestation. Prompt salvage may be dictated when stressed timber becomes infested. During the warm season in the Deep South, logs should be milled within 2 to 3 weeks to avoid damage (Craighead 1950, Hubbard 1897). Green logs can be protected by submerging in water, storing under continuous water spray, or spraying with an insecticide. Insecticides may be needed occasionally to protect seedlings in nurseries.

Order Hymenoptera—Sawflies And Horntails

Hymenoptera, one of the largest orders of insects, is divided into two suborders. Members of Apocrita, the larger suborder, are largely beneficial, either as parasites or predators of pests or as pollinators of commercial crops. Members of the suborder Symphyta are mostly phytophagous and include the sawfly and horntail borers covered here (Borror and others 1981, USDA FS 1985). Adults are characterized as having four membranous wings; the fore pair is larger and more completely veined than the hind pair. Members of Symphyta are distinguished by having an abdomen that is broadly joined to the thorax (not threadlike as in Apocrita). Also, the adult females have a well-developed ovipositor, either sawlike or hornlike, fitted for making incisions and inserting eggs in plant tissue. Larvae are slightly curved to S-shaped, with three pairs of small thoracic legs and abdominal prolegs often reduced or absent. Members of this group feed in tender shoots, petioles, galls, or solid wood. They seldom cause widespread economically damaging losses, but sometimes are troublesome and cause moderate damage locally to nurseries, young plantations, ornamentals, and weakened timber stands.

Family

Tenthredinidae *585*
Siricidae *597*
Xiphydriidae *600*
Cephidae *603*

Family Tenthredinidae—Gall Sawflies

Members of this family are mostly leaf feeders, but some burrow internally in buds, petioles, twigs, or stems, usually producing galls (Smith 1968b, Smith 1979, USDA FS 1985). Twenty-nine species of *Euura* are listed as forming galls on petioles, twigs, and stems of willow (Smith 1979), but little is known about most species. Therefore, only four species of *Euura* are covered in this manual. Adults are small sawflies with clear wings and short sawlike ovipositors. Larvae vary from white to yellowish, greenish, and purplish, usually slightly curved, have three pairs of legs, and most have abdominal prolegs. Although troublesome on ornamentals, they are of minor importance.

Genus and Species

Caulocampus
acericaulis (MacGillivray) *585*
Euura
atra (Jurine) *588*
exiguae Smith *591*
lasiolepis Smith *593*
salicis-nodus Walsh *596*

Caulocampus acericaulis (MacGillivray)

maple petiole borer (figure 227)

Hosts. Maple. Sugar maple is preferred (Britton 1906). Norway maple and planetree maple have also been recorded; other species of maple probably serve as occasional hosts (Johnson and Lyon 1988, Solomon 1982).

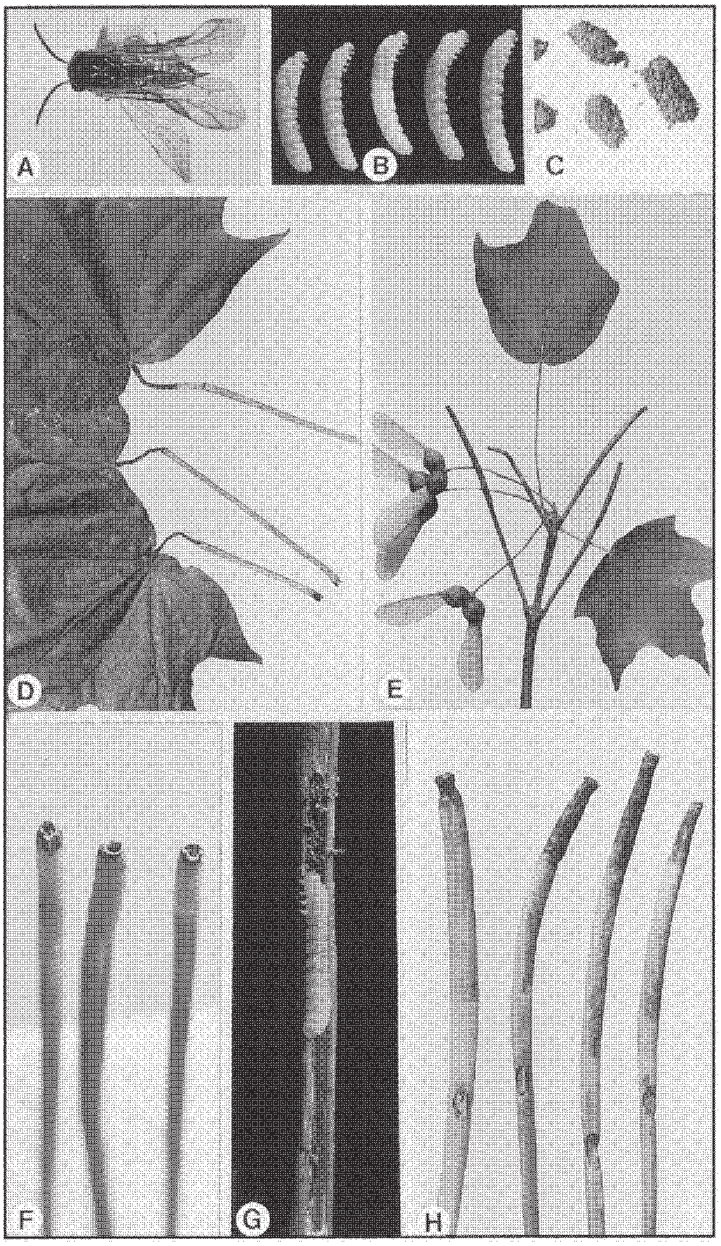

Figure 227—Caulocampus acericaulis, *maple petiole borer: A, adult; B, larvae; C, earthen pupal cells; D, infested petioles limp and darkened; E, petioles with leaf blades detached; F, swollen petioles severed; G, hollowed petiole with larva; H, oval exit holes in petioles (B-H, specimens courtesy C. Pless).*

Range. First reported in 1899 from Danbury, Connecticut (Britton 1906, Johnson and Lyon 1988). Now known from southeastern Canada, Vermont, and New York south through Tennessee and Alabama and west to Kansas, Indiana, and Wisconsin (Solomon 1982, USDA FS 1985).

Description. ***Adult.*** Very small, black and yellow, wasplike sawfly, about 4 mm long, with four transparent wings with wingspan of 10 mm (figure 227A) (Britton 1906, 1912a; Herrick 1935; Smith 1968a). Head and thorax shiny black, except yellowish on underside of thorax; antennae black with first two segments yellowish, and about 2 mm long. Abdomen and legs honey yellow, except tip of abdomen black. ***Egg.*** Colorless, very long, slender, noticeably curved or falcate, nearly uniform in thickness except slightly thicker at one end, 0.98 by 0.19 mm. ***Larva.*** Uniformly buff or straw yellow, head dark yellow to light brown with dark brown to black mandibles, three pair small thoracic prolegs (figure 227B). Full-grown larvae about 8.0 mm long and 1.5 mm in diameter, slightly curved resembling weevil larvae. ***Pupa.*** Pupal case round-to-oval earthen cell, about 5 mm in diameter (figure 227C).

Biology. Adults emerge from pupation cells in the soil in late April and May (Britton 1906, 1912a; Craighead 1950; Herrick 1935). The adults fly to host trees and oviposit mostly during early May. Females deposit eggs singly, primarily in the distal end of the petiole or in the base of the leaf blade where the major veins branch from the petiole. As many as 19 eggs have been found in the abdomen of a female. After a short incubation, the eggs hatch, and the larvae begin feeding and tunneling in the petiole. In about 3 weeks, the leaf blades are severed or break and fall to the ground. The larvae continue to feed inside the portion of petiole still attached to the tree. In 7 to 14 days, the bare petioles containing the larvae abscise and fall to the ground. The larvae vacate their petiole galleries and burrow into the soil 5 to 8 cm. Here, they form tiny earthen cells around themselves where they overwinter as prepupae. Pupation occurs in spring, and adults soon emerge to complete the life cycle. There is one generation a year.

Injury and damage. The first symptoms of wilting, yellowing, and browning leaves appear about mid-May. Injured leaves begin to fall to the ground in late May and early June (Britton 1906, 1912a; Craighead 1950; Johnson and Lyon 1988; USDA FS 1985). Close examination of the affected leaves will reveal that about 6 to 12 mm of the petiole extending from the leaf blade is limp, partially hollowed, and darkening (figure 227D). Inspection of the foliage will show the remainder of the infested petioles to be slightly swollen and still attached to the tree (figure 227E). The severed ends of the petioles appear neatly girdled (figure 227F). Slicing the petiole reveals the hollowed interior, the larva, and loose granular frass (figure 227G). The bare petioles drop to the ground from early to late June. Larvae leave a tiny, irregularly oval hole in each petiole as they enter the soil (figure 227H). The ground under heavily infested sugar

maples may be littered, almost covered with fallen leaves and bare petioles during June and early July. Leaf drop and defoliation of 5 to 20% is common in Ohio, and up to one-third of the leaves are lost on infested trees in Connecticut (Britton 1912a, Solomon 1982). However, leaf drop is seldom serious enough to substantially weaken or threaten the tree. Conversely, early season leaf drop is unsightly and disturbs owners of shade and ornamental maples and sometimes creates unseasonal cleanup problems.

Control. Two hymenopterous parasites—*Bracon montowesi* (Viereck) and an unidentified chalcid—have been reported (Britton 1906, Marsh 1979). Picking and destroying the infested petioles on small trees as soon as they are noticed may help to reduce sawfly populations (Craighead 1950). Raking and burning the infested fallen petioles promptly and daily before the larvae vacate their galleries is recommended (Britton 1906, Herrick 1935). Chemical treatment has been suggested and may provide some protection in problem areas (Britton 1906, Craighead 1950).

Euura atra (Jurine)

[smaller willow shoot sawfly] (figure 228)

Hosts. Willow. Acute leaf, golden leaf, laurel leaf, weeping, crack, and European yellow willows have been recorded as hosts (Ives and Wong 1988, Wong and others 1976). Introduced European willows, especially acute leaf willow, are preferred in Alberta. European aspen and several other willow species have been recorded as hosts in Europe.

Range. An introduced palearctic species first recorded in North America in 1888 in Quebec. It has since been reported from the Maritime Provinces and New Brunswick westward to Alberta (Ives and Wong 1988, MacCall and others 1972, Smith 1979, Wong and others 1976). It seems to be most troublesome across the Canadian prairies.

Description. ***Adult.*** Small, slender, dark black sawfly, shiny, 5 to 8 mm long, with short sheath and saw on abdomen of female (figure 228A). Two pair of clear wings; forewings reach slightly beyond abdomen. Antennae threadlike and slightly less than half body length. ***Egg.*** Pale, whitish, elongate, markedly tapered at one end, about 0.26 by 0.83 mm (figure 228B) (Ives and Wong 1988, Wong and others 1976). ***Larva.*** Pale black head with dark gray shading, greenish white body, three pairs of well-developed thoracic prolegs with claws, caudal abdominal segments usually held in slightly curled position, about 8 mm long when mature (figure 228C) (Ives and Wong 1988, Rose and Lindquist 1982, Wong and others 1976).

Biology. Adults emerge during late May and early June (Ives and Wong 1988, MacCall and others 1972, Rose and Lindquist 1982, Wong and others 1976). After mating, females make a saw-puncture opening in tender succulent shoots, usually near the base of the shoot, and deposit eggs singly next to the shoot pith. Most oviposition occurs during mid-June, and eggs hatch from mid- to late June. Larvae tunnel in or near the pith and undergo five to seven instars. Young larvae produce reddish frass,

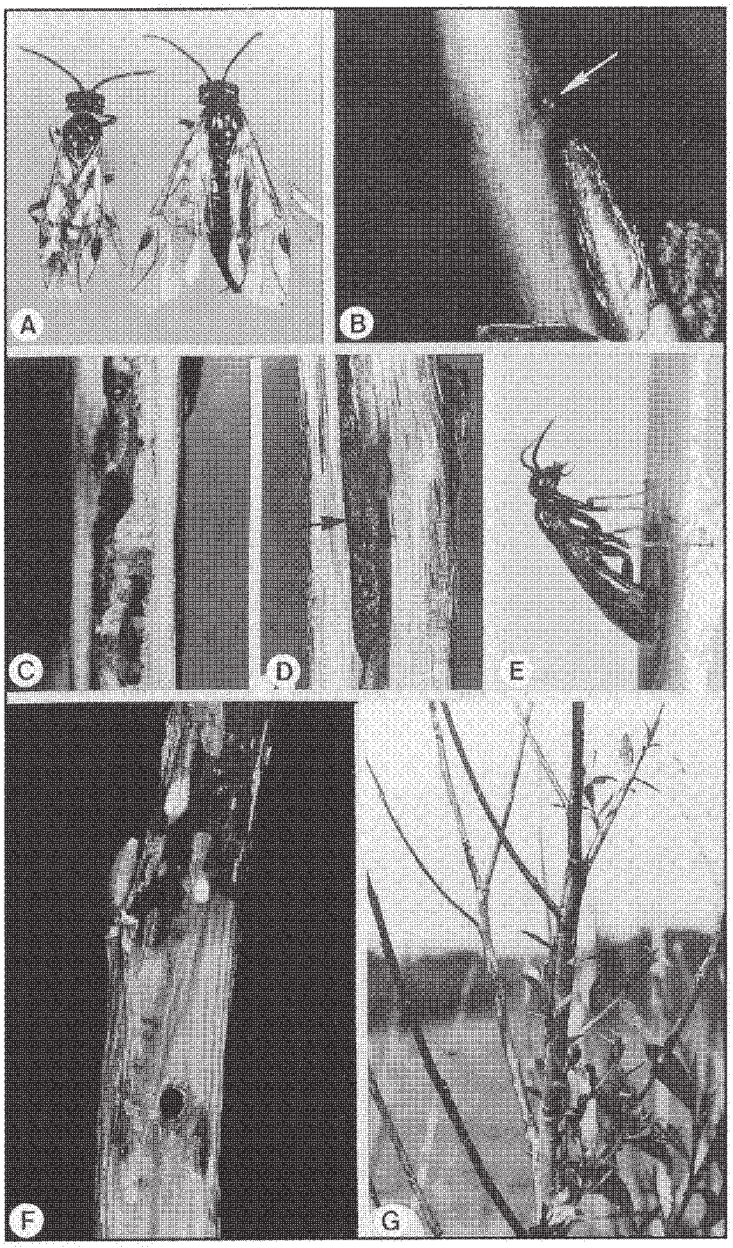

Figure 228—Euura atra, *[smaller willow shoot sawfly]: A, adults; B, egg niche site just above bud; C, larval burrow with frass and larva; D, cocoon within gallery; E, adult emerging from hole in shoot; F, exit hole; G, infested willow shoots failing to leaf out in spring (courtesy H. Wong).*

and older larvae produce whitish frass, which is generally pushed to one end of the tunnel. Stems may contain more than one larva, but each larva has a separate gallery; if not, cannibalism occurs. Larvae may tunnel toward the shoot tip or toward the base of the shoot. When feeding is complete by late September or early October, the larvae gnaw exit holes through the bark at one end of the gallery, then plug them with frass, bits of pith, and silk. The larvae then retreat to the other end of their galleries in late October and early November and spin brownish transparent cocoons in which they overwinter in the larval stage or as prepupae. A few larvae overwinter in the galleries without constructing cocoons. This sawfly has one generation a year.

Injury and damage. New tender shoots 3 to 18 mm in diameter are most susceptible to attack (Ives and Wong 1988, MacCall and others 1972, Rose and Lindquist 1982, Wong and others 1976). Few symptoms are noticeable during the early stages of attack. The trained eye may see the tiny egg scars that occur in succulent shoots near their base (figure 228B). In some cases, infested stems may swell slightly. Tunneling usually kills the infested shoots, but dieback does not occur until late in the growing season or more likely the following spring. The leaves on infested shoots turn yellow and brown, and the stem becomes brown. Dying shoots are commonly infected by a *Cytospora* fungus. Dissection of infested shoots in summer reveals the larvae along with one to three galleries about 12 mm long (ranging from 8 to 21 mm) in the pith. The frass typically is pushed to one end of the gallery (figure 228C). Dissection during winter and spring reveals a brown cocoon containing a prepupa or a pupa in the gallery (figure 228D). Adults emerge from tiny round exit holes usually indicated externally by a slightly depressed, round, discolored area on the shoot (figure 228E and F). This sawfly attacks terminals and branch ends; as many as 30 larvae have been observed in a 2-m-long whip of acute leaf willow. When the trees leaf out in spring, dead shoots are most noticeable (figure 228G). This insect sometimes causes severe damage to willow in nursery stooling beds and occasionally in shelterbelts. Cuttings have to be checked carefully before distribution to avoid dissemination of infested stock. Thus, infestations have the double effect of reducing the number of cuttings produced and increasing production costs because of the extra checking required.

Control. Several insect parasites have been reared from infested shoots including two *Eurytoma* spp., two *Tetrasticus* spp., and an unidentified species in the family Trichogrammatidae (MacCall and others 1972). The downy woodpecker has been observed digging the larvae from their tunnels (Wong and others 1976). In problem areas, growers should select the least susceptible species of willow, such as peach leaf willow, for planting. Pruning and destroying wilted blackened shoots as they appear in fall and spring before adults emerge may help to reduce infestations (Rose and Lindquist 1982). Soil-applied

systemic insecticides have given up to 93% control in nurseries (Wong and others 1976).

Euura exiguae Smith

[sandbar willow gall sawfly] (figure 229)

Host. Willow. Sandbar willow, commonly known as coyote willow, and its subspecies are only known hosts (Smith 1968b).

Range. A western species occurring from the Rocky Mountains to the Pacific Coast and the Columbia River in Oregon to southern California (Price 1989, Smith 1968b). It is the most common willow sawfly below about 2,000 m elevation.

Description. ***Adult.*** Black sawfly with orange to dull yellow markings on legs, ventral edges of tergites, distal edges of sternites of abdomen, and frontal crest and orbits of head (figure 229A) (Smith 1968b, 1970). Abdomen of female equipped with an ovipositor consisting of saw, sheath, and guide; saw averages 1.29 mm long and 0.11 mm wide; sheath from above tapers evenly to a point, not inflated. Front of head glossy or finely striate-punctate. Cerci subcylindrical or slightly clubbed apically. Females 3.6 to 7.0 mm long; males 3.0 to 5.5 mm long. ***Larva.*** Earliest instars pale green from ingested plant material; mid-instars become waxy, cream color; last instar dull, purplish gray, 8 to 10 mm long (figure 229B). Head light brown with pigmented spots on interocular area; antennae plate type and unsegmented; mandibles robust and toothed. Three pairs of thoracic prolegs and six pairs of prominent functional abdominal prolegs. ***Pupa.*** Creamy white, becoming yellowish and finally dark brown to black (figure 229C).

Biology. Adults begin emerging in early March, about the time the first sandbar willow blooms, peaking by late March and ceasing in late April (Smith 1968b, 1970). Adults drink water eagerly upon emerging from the gall and in cages consume small amounts of honey and sugar water. In nature, they are commonly observed on both male and female aments of their hosts eating pollen and drinking nectar; sometimes, they consume whole stamens and parts of capsules. Soon after emerging, mating, and feeding, the females begin ovipositing. Adults are relatively fragile and live only 1 to 2 weeks. Oviposition is accomplished as much through rapid vibration of the abdominal saw as by the more obvious sawing motion. When the oviposition punctures reach the proper depth, the egg and colleterial fluid from the accessory gland are injected through the ovipositor into the meristematic tissue of the tender shoot. Although the eggs are deposited singly, one to four eggs may be deposited in a shoot. The colleterial fluid immediately causes a gall—the expanding gall may become obvious within 48 hours. The galls expand rapidly and generally attain their maximum size before larval eclosion or by the end of the first larval stage. Larvae each make a separate burrow to feed on tissue within the gall. Mature larvae typically cut exit holes in the side of the gall, then plug them with frass, silk, and sawdust before retreating down the mine and entering the prepupal stage. They feed until reaching the prepupal

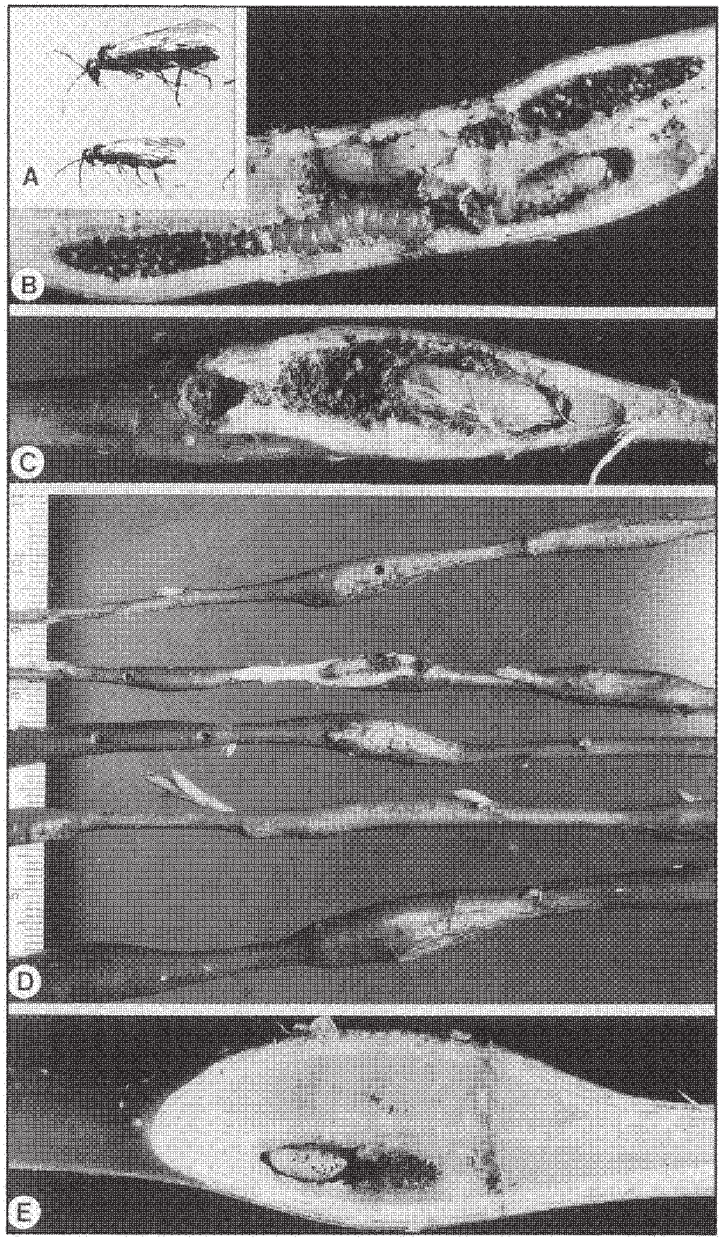

Figure 229—Euura exiguae, *[sandbar willow gall sawfly]: A, adults; B, larvae in gall galleries; C, pupa within gall; D, galls and exit holes on willow shoots; E,* Eurytoma *inquiline kills many sawfly larvae within gall (courtesy E. Smith).*

stage by late September. They overwinter in the prepupal stage within the gall (figure 229C). Pupation occurs during early spring, and the new adults emerge through precut exit holes. There is one generation a year.

Injury and damage. This pest favors sandbar willows growing in sheltered areas overhanging water or humid swales or thickets, with most galls often confined to the lee side of the plants (Price 1989; Smith 1968b, 1970). It is the most common gall sawfly of willow in lowland California and Oregon. Females prefer the most vigorous shoots such as sucker growth or sprouts. Oviposition scars are tiny puncture marks and difficult to detect; however, the galls form quickly and are very noticeable. The galls are thin walled, tapering at both ends, sinuate or linear in outline, and 20 to 70 mm long by 5 to 15 mm wide, with smooth, pubescent, or glabrous surfaces, but never glaucous (figure 229D). Young galls are green when first formed but become uniform brown to russet when mature. Exit holes 1.5 to 2.0 mm are left in the side of the galls. The largest and healthiest galls are characteristically those where the egg never hatched or the larva died early. Galls rarely adversely affect the host other than by distorting the stem. However, they can weaken the branches, causing some breakage. Heavily infested plants may exhibit multiple branching.

Control. Birds prey upon all stages of the insect (Smith 1970). Twelve species of braconid, ichneumonid, and pteromalid parasites kill large numbers of larvae. Also, several inquilines occupy, feed, and develop in the galls and destroy numerous sawfly larvae—a curculionid, *Anthonomus hematopus* (Boheman); three eurytomids, *Eurytoma fossae* Bugbee plus two *Eurytoma* spp.; and a cosmopterygid, *Batrachedra salicipomonella* (Clemens) (figure 229E). Although it is uncommon, some galls are flooded internally by sap, and the larvae drown. Also, excessive heat, caused when galls are exposed for extended periods to direct sunlight, kills some immature larvae.

Euura lasiolepis Smith

[arroyo willow gall sawfly] (figure 230)

Host. Willow. The insect is host species specific, attacking only arroyo willow and its varieties (Price and Clancy 1986, Smith 1968b); considerable variation exists in susceptibility among clones of arroyo willow.

Range. West of the Rocky Mountains to Pacific Coast and from northern California south to Arizona (Price and Craig 1984, Smith 1968b). A different color phase of the insect occurs in the Central Valley of California and in northern Arizona.

Description. ***Adult.*** Small wasplike sawfly, 3 to 8 mm long, with sheath and saw averaging 1.68 mm long and 0.10 mm wide (figure 230A) (Smith 1968b, 1970). Two geographic color phases—a dark, coastal phase that is black with small amber markings and an orange and black Central Valley phase that is slightly larger, translucent, and waxy orange except for brownish black markings. All intergrades occur in interior California. Front of head not polished as in

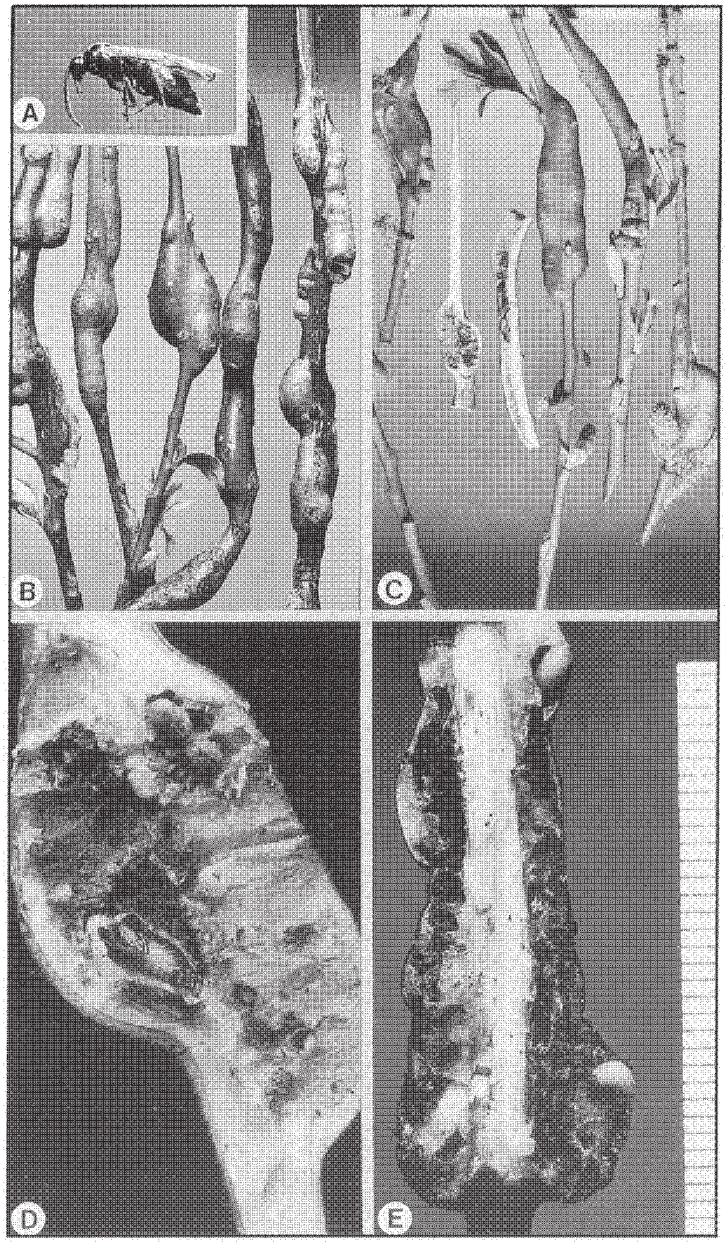

Figure 230—Euura lasiolepis, *[arroyo willow gall sawfly]: A, adult; B, typical galls on willow shoots; C, parasite exit holes and bird excavations in galls; D,* Ichneutes *parasite pupa in gall cell; E,* Dorytomus *inquiline larvae displaced sawfly larvae in gall (courtesy E. Smith).*

E. exiguae. Cerci tapering, distally acuminate, and keeled. ***Egg.*** Newly laid egg is sausage shaped, clear to transparent; anterior end slightly larger than posterior end, 0.55 to 0.60 mm long and 0.20 to 0.25 mm in diameter (Price and Craig 1984). Eggs swell rapidly during embryonic development, becoming more globose and measuring 0.50 to 0.55 mm long and 0.29 to 0.33 mm in diameter. ***Larva.*** Young larva pale green, becoming cream colored and shiny, and finally dull, bluish gray; 8 to 10 mm long (Smith 1970). There are three pairs of thoracic legs and six pairs of prominent abdominal prolegs.

Biology. In California, adult sawflies emerge from late February to early June, with peak emergence during early March (Smith 1968b). In Nevada and at higher elevations in Arizona, adults emerge mostly in May and June (Price and Craig 1984). Emergence generally occurs in the morning, and adults feed on host flowers (Smith 1970). Females lay trails of sex pheromone across the foliage to attract males. After mating, females begin ovipositing within a few minutes, usually on the same plant from which they emerged and then mated on. Females make many short flights between shoots. To oviposit, females search the terminal four or five nodes of shoots, then face down the short petiole toward the shoot and insert their long sawlike ovipositors down the petioles and into the young, succulent stems, laying individual eggs just below the axial bud primordium of each young stem. Two (or rarely 3) eggs, deposited by the same or different females, are in a stem or gall; up to 10 oviposition scars have been found on a shoot. At the time of oviposition, females inject colleterial fluid into the growing tissues, thus immediately inciting gall formation. Larvae feed on the parenchyma cells of galls, tunneling downward toward its base; males pass through five instars, and females pass through six instars. Final instars in October and November do not seem to feed but rasp away at the gall tissue to prevent being crushed by it. Full-grown larvae spin cocoons by matting frass and rasped gall tissues together with silk. Mature larvae overwinter within cocoons inside the galls. Pupation occurs from February through June; the pupal period lasts about 15 days. There is one generation a year.

Injury and damage. This sawfly favors vigorous clonal growths of arroyo willows with many tender shoots that grow in marshy areas along foothill streams, drainage ditches, borrow pits, and around springs and cattle tanks (Price and Clancy 1986; Price and Craig 1984; Smith 1968b, 1970). Oviposition leaves a small scar near the base of the petiole where the ovipositor was inserted; these scars become more noticeable with age as the margins separate and the damaged tissue browns slightly. Growth of galls is rapid through June, then decelerates during July and August; galls reach their greatest diameter by the end of August. The galls are thick walled and tortuous, with smooth, shiny, or corrugated surfaces; yellowish green except purple to red in bright sun; 20 to 70 mm long by 3 to 21 mm in diameter (figure 230B). The

larvae do not make exit holes in the galls for adults as occurs with *E. atra* and *E. exiguae*; instead, the new adults chew their own round exit holes in spring. Galled stems sometimes break, but overall damage to plants is slight.

Control. Natural controls often kill a high proportion of sawfly broods (Price and Craig 1984; Smith 1968b, 1970). Egg mortality caused by galls that fail to develop, or by rapid growth of gall tissue that crushes the eggs, accounts for about 39% of the brood and is the most important mortality factor in Arizona populations. In Arizona, 10% of the brood is killed by the ichneumonid parasite *Lathrostizus euurae* (Ashmead) and another 2% is parasitized by a pteromalid, *Pteromalus* sp. The inquiline *Batrachedra striolata* Zeller sometimes bores into galls, feeds on the gall tissue, and kills the sawfly larvae, but it kills only about 1% of the larvae. Birds, particularly mountain chickadees, peck into the galls and capture about 4% of the larvae from cocoons (figure 230B and C). Ants and grasshoppers destroy a few sawflies. In California, several species of parasites, especially *Ichneutes* sp. (figure 230D) and inquilines, particularly the weevil *Dorytomus luridus* (Mannerheim) (figure 230E), are important natural controls, but losses have not been assessed.

Euura salicis-nodus Walsh

[willow spindle gall sawfly]

Host. Willow. Sandbar willow is only recorded host; both very hairy and less hairy varieties attacked (Judd 1954, Rohwer 1909).

Range. Best known in northeastern North America but widely distributed west to the Rocky Mountains and from Ontario south to Mexico (Rohwer 1909, Smith 1979).

Description. ***Adult.*** Small, wasplike sawfly, black except for reddish brown spot enclosing ocelli on head, 4.1 to 4.6 mm long (Rohwer 1909). Head narrowed toward top; front of head strongly rugose. Wings hyaline, highly iridescent, with pale brown venation. Sheath broad, in lateral view, straight on upper margin, roundly truncate at apex. Cerci not extending beyond sheath. ***Larva.*** Body cylindrical, without setae, white or cream colored to pale; head greenish white, yellowish with dark eye spots and mandibles; body 4 to 9 mm long (Peterson 1962, Rohwer 1909).

Biology. Adult sawflies emerge during April and May, usually peaking in mid-April (Judd 1954). After feeding and mating, females begin ovipositing in tender shoots. One to three eggs are usually deposited in a shoot by the same or different females. The females inject colleterial fluid into the growing shoots during oviposition; galls develop rapidly whether or not eggs were actually deposited. Larvae feed on the gall tissue and usually develop in separate chambers within the galls. Galls become partially filled with frass. Full-grown larvae typically chew a round exit opening in the side, usually near one end of the gall, but some larvae leave a thin membrane cover-

ing the exit burrow. Mature larvae spin a flimsy cocoon surrounded by brown frass within the gall during fall and overwinter with their heads toward the gall openings. They pupate in spring. There is one generation per year.

Injury and damage. Shrubby growths of willow growing along the edges of fields, roadsides, and streams are likely targets for infestation (Judd 1954, Peterson 1962, Rohwer 1909). Spindle-shaped galls on twigs and branches are the most noticeable signs of infestation. Galls begin as gradual enlargements that eventually become spindle shaped, 19 to 38 mm long, and two or three times the stem diameter. Each gall may be perforated by one to three circular openings about 1 mm or more in diameter at either end. Dissection reveals one or two elongated chambers in the gall. Most galls are separate from one another, forming individual swellings along the twig. One or a few galls per stem commonly occur, but up to eight may occur per 30 cm of branch. Damage is generally negligible despite possible breakage or pruning at galled sites.

Control. Three species of hymenopterous parasites—*Habrocytus thyridopterigis* Howard, *Hoptocryptus* sp., and *Ichneutes* sp.—have been recorded, but little is known of their effectiveness (Judd 1954). *Eurytoma* sp., apparently an inquiline in the galls, destroys some sawfly larvae.

Family Siricidae—Horntails

The siricids are commonly known as horntails because of their hornlike projection on the last abdominal segment in adults. Only one species important to hardwoods is covered in this manual. The adults are medium to large, thick-waisted, cylindrical insects with long threadlike antennae and well-developed wings (Furniss and Carolin 1977, USDA FS 1985). Larvae are yellowish white and cylindrical with vestigial thoracic legs and lacking prolegs. Horntails occasionally attack healthy trees, but prefer trees that have been damaged or killed by fire, wind, insects, or diseases. Economic damage to hardwood trees is minor.

Genus and Species

Tremex columba (Linnaeus) *597*

Tremex columba (Linnaeus)

pigeon tremex (figure 231)

Hosts. Beech, elm, hickory, maple, oak, poplar, apple, pear, sycamore, hackberry. Prefers maple and beech, but readily attacks hickory, elm, and oak (Blackman and Ellis 1916, Stillwell 1967). Attacks other species less frequently.

Range. Throughout the United States and southern Canada west to the Rocky Mountains with a few records from Utah, Arizona, and southern California (Doane and others 1936, Ives and Wong 1988, USDA FS 1985). Three geographic races, with race 1 common in southeastern Canada and the northeastern United States, race 2 common in the southeastern United States north to Pennsylvania and west to Utah, and

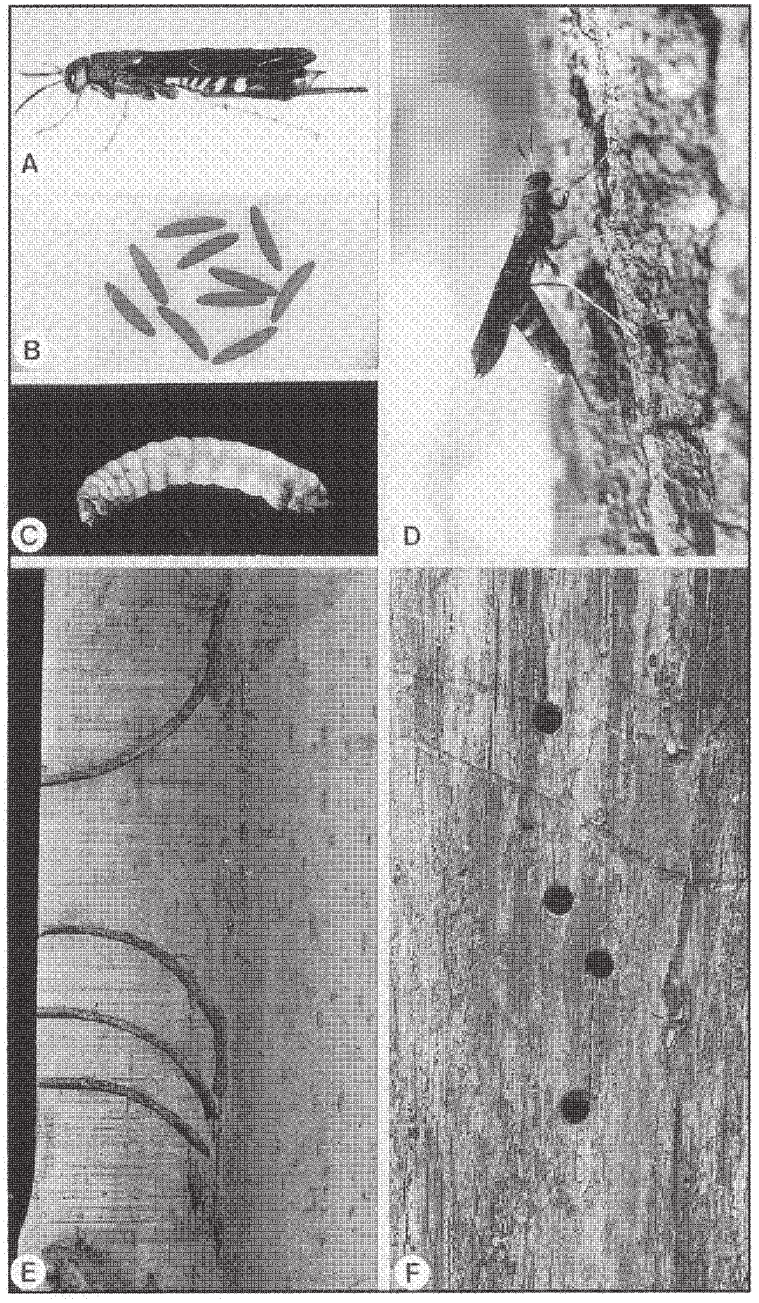

Figure 231—Tremex columba, *pigeon tremex: A, adult; B, eggs; C, larva; D, female ovipositing in tree; E, galleries with curving exits; F, round exit holes.*

race 3 in the Rocky Mountains. Some overlap in range among the three races.

Description. ***Adult.*** Large, cylindrical, heavily bodied, thick-waisted, wasplike horntail with abdomen ending in hornlike projection (figure 231A) (Beal and others 1952, Doane and others 1936, USDA FS 1985). Horny projection of abdomen long and spearlike; encasing ovipositor in females but short and triangular in males. Head large, widened behind eyes. Two pairs of wings transparent to smoky brown. Females 37 to 50 mm long; males 18 to 37 mm long. The three geographic races differ in color: race 1, abdomen black with brownish yellow bands and spots, head and thorax brown; race 2, abdomen yellow with sides of eighth and ninth segments black, head and thorax yellowish brown; race 3, brownish yellow throughout. ***Egg.*** Dark brown to blackish, elongate, slender, straight to slightly curved, narrow at ends, 1.0 to 1.5 mm long and about 0.2 mm in diameter (figure 231B) (Stillwell 1967). ***Larva.*** Cylindrical, straight to lightly curved or slightly S-shaped, white except for amber head, brownish mandibles; 14 to 50 mm long when mature (figure 231C) (Beal and others 1952, McDaniel 1936, Stillwell 1967). Head overhung by prothoracic segment, dome shaped, smooth, and shining. Three pairs small thoracic legs, nonsegmented, clawless. Abdomen ends in brown sclerotized prong.

Biology. In southern range, emergence of adults begins in early June, but in New Brunswick, emergence begins in mid-August, peaks in early September, and continues until early October (Blackman and Ellis 1916, McDaniel 1936, Stillwell 1967, USDA FS 1985). Over most of the range, adults are present from early summer to early fall. When ready to oviposit, females select suitable sites on the bark and drill holes with sawlike movements of the ovipositor (figure 231D). Oviposition channels are 2 to 20 mm deep in the wood and usually at right angles to the bark surface. From two to seven eggs are deposited at intervals, sometimes end to end in the oviposition channel as the ovipositor is withdrawn. Eggs usually hatch in 3 to 4 weeks, but in New Brunswick, some do not hatch until the following May or June. At oviposition, a wood-rotting fungus—*Daedalea unicolor* Buller ex Fries—carried in paired intersegmental sacs near the base of the ovipositor, is deposited in the wood. Larvae feed on the fungus-softened wood and construct long, round galleries that loop and meander through the sapwood and heartwood. Without the fungus, eggs hatch, but larvae cannot develop beyond the first instar. Larvae pack the frass tightly within the gallery and tunnel for 15 cm to 2 m, and occasionally up to 3 m. Female larvae also carry the wood-rotting fungus in a hypopleural fold between the first and second abdominal segments. Pupation occurs in the galleries in the sapwood and lasts 3 to 6 weeks. The new adults tunnel their way to the surface and emerge. In Michigan and New Brunswick, a generation requires 2 years, but in the southern range apparently only 1 year.

Injury and damage. This pest usually attacks trees weakened or dying from disease, other insects, fire, flooding, or other

causes; it occasionally attacks healthy trees, especially injured ones (Beal and others 1952, Blackman and Ellis 1916, Stillwell 1967). In the early stages, infestations present little or no evidence of entrance holes and ejected frass. However, it is common in the summer and fall to observe adult females ovipositing on susceptible tree trunks (figure 231A). Dead females with their ovipositors firmly wedged in the wood can sometimes be found, especially on living trees that have green or sappy wood. Dissecting infested stems can reveal frass-packed, meandering, larval galleries and the empty adult exit tunnels that curve in a sweep to the surface (figure 231E). From the exterior, the exit holes are circular and 7 to 8 mm in diameter (figure 231F). Exit holes are typically clustered in localized parts of stems. Because the insect prefers weakened trees, it is not an important pest. However, it can cause economically damaging losses in dying timber and salvage operations.

Control. Four species of hymenopterous parasites—*Ibalia maculipennis* Haldeman, *Megarhyssa atrata* (Fabricius), *M. greeni* Viereck, and *M. macrurus* (Linneaus)—destroy up to 40% of the larvae and pupae (Burks 1979, Carlson 1979, Stillwell 1967). Woodpeckers, especially the pileated woodpecker and hairy woodpecker, are effective predators, but unfortunately they destroy many of the parasites as well. Infestations can be avoided by keeping trees healthy and vigorous. Tree injuries should be promptly dressed and filled to discourage oviposition.

Family Xiphydriidae—Wood Wasps

Members of this family resemble the siricids in having threadlike antennae, well-developed wings, and a cylindrical body but are distinguished by smaller size and shorter ovipositor sheath (Borror and others 1981, USDA FS 1985). Larvae are smaller than but similar to the siricids. Only one species is covered here. It commonly attacks dying and dead branches of host trees; damage is usually minor.

Genus and Species

Xiphydria maculata Say *600*

Xiphydria maculata Say

[maple wood wasp] (figure 232)

Host. Maple. Silver maple and red maple recorded most frequently, but occasionally reported from sugar maple (Deyrup 1984, Knight 1968). Basswood and apple mentioned as hosts, but their status seems questionable (Smith 1976).

Range. Common in southeastern Canada from New Brunswick to Ontario and in the northeastern United States from Maine to Indiana; isolated records from as far west as Manitoba, Kansas, and eastern Texas; one dubious record from California (Deyrup 1984, Smith 1976, USDA FS 1985).

Description. ***Adult.*** Medium-sized, blackish wasp with yellow and white markings; female 11 to 20 mm long, male 7 to 11 mm long (figure 232A) (Harrington 1884, Rohwer 1918, Smith 1976). Head black with yellow stripes dorsally and laterally; antennae white with two basal segments

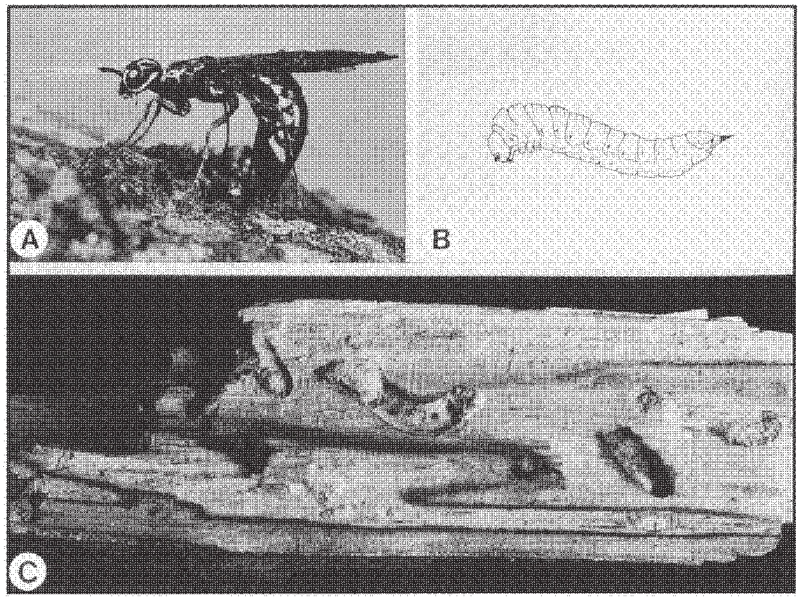

Figure 232—Xiphydria maculata, *[maple wood wasp]: A, adult ovipositing in maple branch; B, larva; C, larval galleries in wood (A, courtesy D. Funk; C, specimen courtesy D. Smith).*

black in female and brownish black throughout in male. Thorax black with broad, yellow band and two yellow spots. Legs orange to red. Abdomen black with yellow to white lateral spots on segments 2 or 3 to 8. Ovipositor contained in sheath projecting slightly beyond tip of abdomen. Wings grayish brown with black veins.

Larva. Yellowish white, cylindrical, except thorax and terminal segments slightly enlarged (figure 232B) (Furniss and Carolin 1977, Smith 1976, USDA FS 1985). Body straight to slightly S-shaped; abdomen ending in a brown, concave, hornlike projection; 18 to 20 mm long. Thoracic legs rudimentary teatlike structures.

Biology. In Ontario, adults emerge from mid-June to late July; in Indiana, adults begin to emerge in late May and finish by early July (Deyrup 1984, Harrington 1884). Adults emerge onto the bark and mate after a brief tapping ritual by both sexes. Females select a suitable host trunk or branch of recently dead or weakened tree and drill through the bark with their ovipositors, depositing one or more eggs at the interface between the bark and wood (figure 232A). Females deposit propagules of symbiotic fungus during oviposition. Upon hatching, the larvae bore immediately into the wood and tunnel mostly longitudinally, packing their galleries tightly with frass. Before pupation, larvae sometimes make bends or loops in the galleries and approach the surface. They overwinter in the larval stage and pupate in spring. New adults chew their way to the surface and emerge. There is one generation a year.

Injury and damage. Wasps attack weakened, dying, and recently dead trees and, less commonly, living trees over a range of sizes (Deyrup 1984, Harrington 1884, Knight 1968, Smith 1976). They mostly attack stems 2.5 to 9.0 cm in diameter, somewhat preferring saplings and branches 4 to 5 cm in diameter. Because the larvae do not eject frass, infestations are difficult to detect until the adults exit. Fallen branches under maple trees sometimes indicate attack; infestations can be confirmed by examining broken ends of branches for frass-filled galleries that weakened them. Dissection of infested stems reveals several galleries densely packed with whitish frass (figure 232C). Recently transplanted young trees with thin bark and branches of shade and ornamental trees have been riddled with galleries in Ontario.

Control. Seven insect parasites—*Aulacus burquei* (Provancher), *A. digitalis* Townes, *Coeloides rossicus betulae* Mason, *Orussus* sp., *Rhyssella nitida* (Cresson), *Spathius elegans* Matthews, and *Xiphydriophagus meyerinckii* (Ratzeburg)—have been recorded (Deyrup 1976, Rohwer 1918). The insect is generally of little economic importance, but in problem areas, wrapping or spraying the trunks of newly transplanted trees during May and June provides protection.

Family Cephidae—Stem Sawflies

The cephids are borers in tender shoots of trees and shrubs. Adults are small- to medium-sized sawflies with slender, compressed bodies and filiform antennae (Borror and others 1981, Craighead 1950). Most are dark colored; some are marked with yellow or red. Larvae are usually yellowish white and most are S-shaped. Their feeding typically causes shoot mortality and dieback. Damage is occasionally serious in localized infestations, but injury is seldom widespread.

Genus and Species

Hartigia
- *cressoni* (Kirby) *603*
- *trimaculata* (Say) *605*

Janus
- *abbreviatus* (Say) *608*
- *bimaculatus* (Norton) *611*
- *integer* (Norton) *613*
- *quercusae* Smith *616*
- *rufiventris* (Cresson) *618*

Hartigia cressoni (Kirby)

[raspberry horntail] (figure 233)

Hosts. Raspberry, blackberry, boysenberry, rose. Raspberry appears to be major host; both wild and cultivated varieties are attacked (Middlekauff 1969, Ries 1937).

Range. Western species common in California, with isolated collections from Oregon, Nevada, Montana, and Colorado (Smith 1986).

Description. ***Adult.*** Slender, black or dark brown and yellow, wasplike sawfly (figure 233A) (Essig 1912, Smith 1986). In females, head and eyes black with yellow markings. Antennae black with middle segments yellow orange to amber. Thorax black with small to large yellow spots mostly on sides. Legs black basally and mostly yellowish distally. Abdominal segments 1 and 5 entirely black, segments 6 and 9 entirely yellow, other segments partially yellow. Abdomen laterally compressed and equipped with a sheath; lancet broad and rounded dorsally. Wings hyaline, amber to orange tinged with brownish veins. Females 11 to 17 mm long; males 11 to 15 mm long and mostly black. Females easily distinguished from other members of genus by extensive yellow on abdomen and yellow markings on antennae. ***Egg.*** Glossy, pearly white, oval, somewhat flattened, curved, and sharp pointed at one end, about 1.5 mm long and two-thirds as wide (Essig 1912, Middlekauff 1969, Ries 1937). ***Larva.*** Yellowish green at first, becoming mostly white; cylindrical, somewhat S-shaped, with thoracic region somewhat enlarged dorsally and laterally; 22 to 25 mm long when mature (figure 233B) (Essig 1912, Middlekauff 1969, Middleton 1917). Head pale yellow to light brown with darkened mouthparts. Thorax with three pairs of vestigial, fleshy, teatlike legs without tarsal claws; abdominal prolegs absent. Abdomen ends in short tubular prong.

Biology. Adults begin emerging in early March; populations peak in April, May, and June, decline during July, and are gone by early August (Essig 1912, Middlekauff 1969, Ries 1937, Smith 1986). The adults are

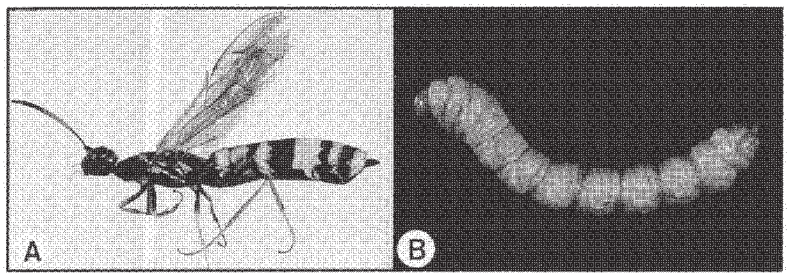

Figure 233—Hartigia cressoni, *[raspberry horntail]: A, adult; B, larva (specimens courtesy D. Smith).*

most active during midday (when temperatures are highest), feeding on nectar. Females oviposit by making a slit in tender shoots usually near the second or third leaf axil of new canes. They force single eggs slightly downward 1.5 to 6.0 mm from the opening and just beneath the epidermis. Areas surrounding the oviposition punctures become discolored and easily visible. Eggs hatch in a few days, and the young larvae feed on surrounding tissues, remaining near the points of hatching until they are about 6 mm long. Then, they begin to travel downward, burrowing in spirals encircling the shoot one to three times in the cambium for 25 to 30 mm. Next, they work into the pith and upward toward the tip of the young shoot, which soon withers and dies. As soon as the shoot tip dies, the larvae turn downward, working through the center of the pith to within 30 to 60 cm of the ground and sometimes into the roots. Larvae mature after about 4 to 6 months, usually in October. Mature larvae overwinter within the burrows. Pupation occurs during spring in a silken cocoon. New adults chew an opening in the cane to exit. There is apparently one generation per year (Middlekauff 1969), although there is some evidence of two (Essig 1912, Ries 1937).

Injury and damage. The earliest indications of infestation are oviposition niches just before and during the early flower stage. The oviposition sites discolor, usually becoming whitish to yellowish brown and slightly swollen (Essig 1912, Middlekauff 1969, Ries 1937, Smith 1986). Soon after young larvae girdle the stems, shoots wilt, droop, wither, and turn brown and black. Dying shoots promptly call attention to the infestations. Infested shoots may die back 15 to 50 cm. Two or more new shoots may issue from canes just below the girdle. Dissection of injured canes reveals the tight spiral galleries and long tunnels in the center of the stems. Some canes may be killed back to the ground. In California, the insect has been economically important in reducing fruit production, particularly at higher altitudes in the central and northern foothill counties of the Sierra Nevada. Shoot mortality rates of 90% or more have been recorded in commercial raspberry plantings in Placer County.

Control. Several unidentified parasites have been reared from the pupae (Essig 1958). In the past, a recommended control practice was to locate egg sites on shoots by the swollen, discolored areas and mash the stem between the thumb and forefinger to crush the eggs (Essig 1912). Some growers cut the infested shoots just below the girdle in spring, whereas others prune out the infested canes during winter. Insecticides may be needed in commercial plantings.

Hartigia trimaculata (Say)

[rose shoot sawfly] (figure 234)

Hosts. Rose, blackberry. Reared from rose and blackberry, and adults collected on raspberry and boysenberry; other *Rubus* species probably serve as hosts (Champlain 1924, Ries 1937, Smith 1986).

Range. Distributed across southern Canada from New Brunswick west; throughout the United States from Vermont south to

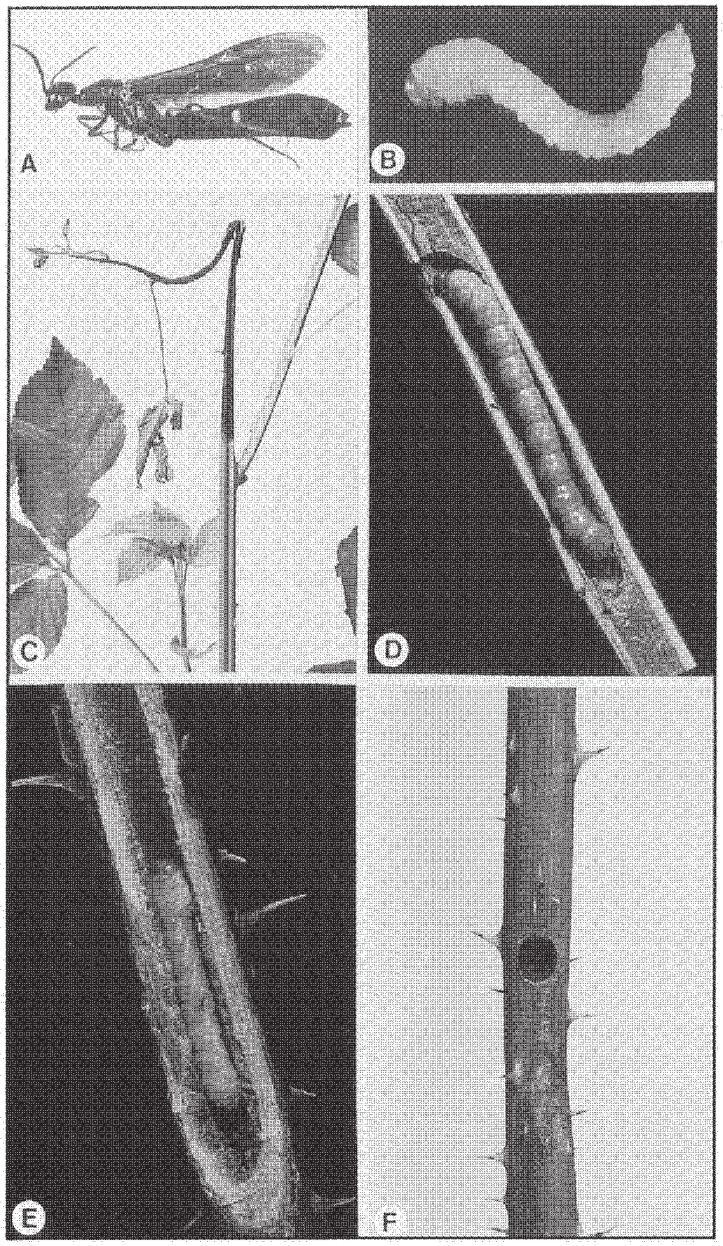

Figure 234—Hartigia trimaculata, *[rose shoot sawfly]: A, adult; B, S-shaped larva; C, infested blackberry shoot dying back; D, gallery with feeding larva in blackberry; E, gallery with frass and larva in rose; F, exit hole in cane (A, specimen courtesy D. Smith).*

Florida and Louisiana and west to the Great Plains; and in a small area in the West around Caldwell and Boise, Idaho (Smith 1986). Appears to be most common along Atlantic Coast and north central United States.

Description. ***Adult.*** Elongate, slender, mostly black, wasplike sawfly (figure 234A) (Ries 1937, Smith 1986). Head black with small, yellow spots around eye, mandible, and molar areas. Mandibles bidentate, translucent, yellowish with black tips and brown palpi. Antennae black and swollen beyond fourth segment. Legs black and lightly marked with yellow on inner surface of foretibia. Wings uniformly dark black infuscated with black veins. Thorax black. Abdomen compressed, elongate, widened dorso-ventrally toward apex, black with large, yellow spot laterally on fourth segment, and occasionally a smaller spot on third or sixth segment. Saw sheath reaches only slightly beyond tip of abdomen. Sheath narrow, not rounded dorsally. Saw not distinctly widened at base. Females range from 12 to 14 mm long; males 10 to 17 mm long. ***Larva.*** Pinkish white, cylindrical, somewhat S-shaped, with slightly enlarged thorax, and abdomen terminating in short, horny projection or prong (figure 234B) (Middleton 1917, Smith 1986). Head pale with mandibles and other mouthparts darkened. Thorax with three pairs of small teatlike, fleshy legs. Full-grown larvae are about 21 mm long.

Biology. Adults begin emerging in late April; numbers peak in May, June, and July, and are all dead by early to mid-August (Champlain 1924, Middlekauff 1969, Ries 1937, Smith 1986). Occasionally, the adult sawflies can be observed flying and alighting on terminals and new shoots. Females crawl downward from terminal tips along the shoot, stopping repeatedly to insert their ovipositors into succulent tender tissue. The punctures are made at short intervals along the stem. Several dozen punctures are often clustered within a small area. To oviposit, females insert the eggs singly deep in the shoot tissue. It seems likely that only one egg is laid in most terminals. When two or more eggs are placed in a shoot, the one that hatches first is the only one to survive. The larvae begin feeding in the succulent terminals, which soon wilt and die; then they feed in the pith, packing frass behind in their tunnels as they move down the stems. At frequent intervals, the larvae girdle the insides of the stems apically to their burrows, often causing the stems to break at that point. Fully grown larvae make a partial opening in the stem to the outside in the fall, then spin cocoons at the basal ends of burrows and overwinter within. Pupation takes place during spring inside the cocoons. This sawfly has one generation a year.

Injury and damage. Although the blackish adults may be seen flying and crawling about the succulent new growth of host plants, the earliest indications of injury are wilting and drooping of tender terminals (Champlain 1924, Middlekauff 1969, Ries 1937, Smith 1986). Close examination reveals ovipositor puncture marks along the shoots. Affected shoots promptly turn brown and black and sometimes break (figure 234C).

When infested shoots fail to break early from the punctures, they frequently break at girdled sites along the stem. Infested shoots may continue to die back as the larvae burrow further downward, repeatedly girdling the stem. Dissection reveals a frass-packed gallery and slightly S-shaped larva (figure 234D and E). Emerging adults leave circular exit holes in the stems (figure 234F). In the past, this borer has been an economically important pest in Pennsylvania. Infested rosebushes produce fewer flowers, and the loss of blackberry canes reduces fruit production.

Control. The infested terminal and shoot tips should be pruned and destroyed as soon as wilting and dying are noticed (Champlain 1924). When pruning is delayed, shoots must be cut lower to ensure that tunneling larvae are removed. Chemical control occasionally may be needed locally when high populations exist.

Janus abbreviatus (Say)

willow shoot sawfly (figure 235)

Hosts. Willow, poplar. Prefers black willow; two clones of the interspecific hybrid *Salix babylonica* x *S. alba* have been mentioned specifically as hosts; poplars, including eastern cottonwood, quaking aspen, bigtooth aspen, and balsam poplar have been recorded (Osgood 1962, Riley 1888, Solomon and Randall 1978).

Range. Southern Canada from New Brunswick west to Alberta and in the eastern and central United States from Maine west to Minnesota and south to Virginia, Arkansas, and Mississippi, and in Oregon (Smith and Solomon 1989, Solomon and Randall 1978).

Description. ***Adult.*** Delicate, brown, wasplike sawfly 7 to 10 mm long, with wingspan of 12 to 16 mm in females and 10 to 12 mm in males (figure 235A and B) (Ries 1937, Smith and Solomon 1989, Solomon and Randall 1978). Head and thorax shiny black with tiny, white to yellow markings. Abdomen black with segments 2 and 3 (and sometimes part of 4) red to reddish brown in females; only venter red in males. Abdomen of females compressed, much deeper than wide; sharp sawlike ovipositor. Abdomen not compressed in males. Wings hyaline, without violaceous reflections; base of radial vein atrophied near base. ***Egg.*** Translucent to whitish, oval to elongate, 0.8 to 1.0 mm long and 0.3 to 0.5 mm in diameter (Solomon and Randall 1978). ***Larva.*** Cylindrical with thorax slightly enlarged dorsally and laterally; typically S-shaped; 8 to 11 mm long at maturity; white, except for pale yellow head, brownish mandibles, and brownish, short, tubular prong at tip of abdomen (figure 235C) (Middleton 1917, Solomon and Randall 1978). Thoracic legs short, fleshy, and without claws; abdominal prolegs absent. ***Pupa.*** White, 8 to 10 mm long, enclosed in partially transparent cocoon (figure 235D).

Biology. Adults from the overwintering brood emerge mid-April to mid-May in Mississippi and May to July in Michigan (Middlekauff 1969, Osgood 1962, Reighard 1985, Ries 1937, Solomon and Randall 1978). Adults are cautious and take flight

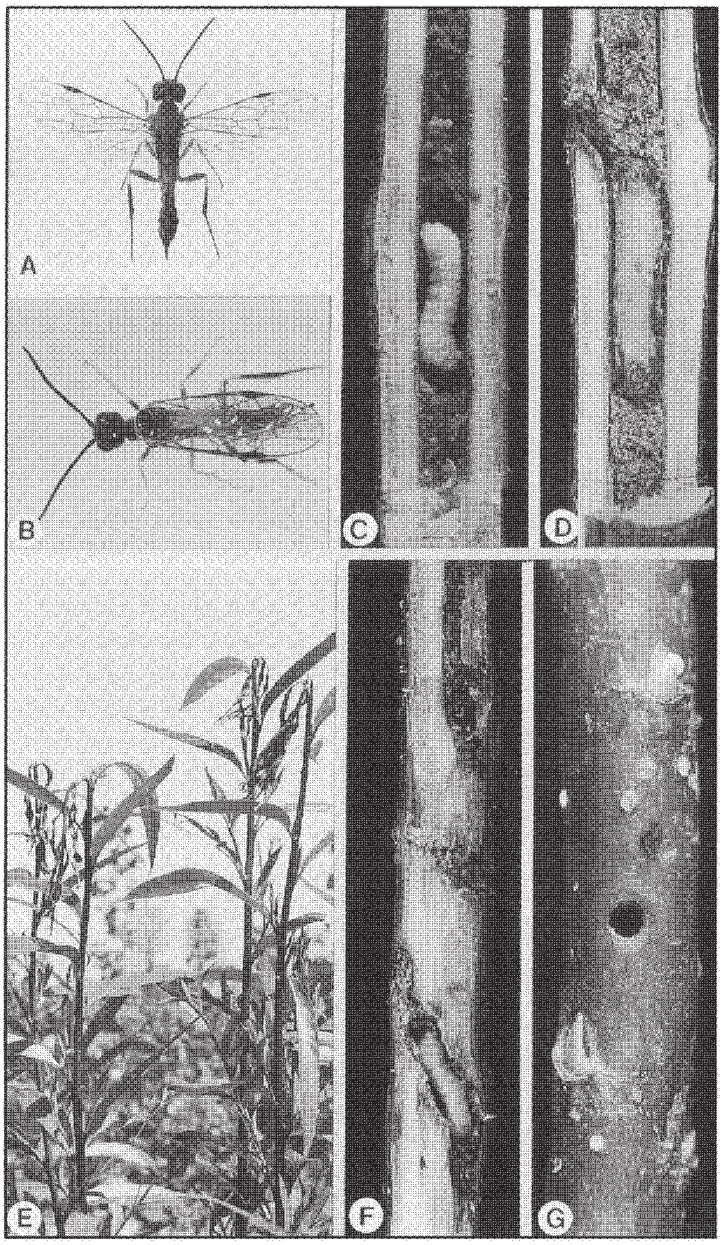

Figure 235—Janus abbreviatus, *willow shoot sawfly: A, adult with wings spread; B, adult with wings folded; C, S-shaped larva in gallery; D, cocoon in gallery; E, wilting and drooping shoots in black willow nursery bed; F, spiral girdling of stem; G, round exit hole in shoot.*

after slight disturbances. Females use their ovipositors to girdle succulent shoots by making a series of punctures encircling the stem and are selective about shoot diameter and distance from stem tip. They girdle willow shoots at an average of 44 mm from the tip; shoot diameter at the point of girdle averages 2.4 mm. Girdle sites on cottonwood average 50.1 mm from the tip and 3.2 mm in diameter. To girdle a shoot, females insert their ovipositors, withdraw them, move slightly around the stem, and puncture again, making 4 to 5 punctures in each of 1 to 3 trips around the stem for a total of 5 to 16 punctures per girdle. Shoot tips begin to wilt in 30 to 60 minutes after punctures are made. Females oviposit in the tender shoots 7 to 26 mm below the girdled site. Single eggs (rarely two) are deposited per shoot and typically are inserted at oblique angles into the pith. Eggs hatch in 7 to 12 days. Initially, young larvae tunnel toward the shoot apex near the girdled site, then turn and tunnel downward for 15 to 36 cm. In nursery stool beds, the entire length of the shoot is often tunneled, and occasionally the side of the rootstock. Larvae pack brownish frass in the gallery as they tunnel; they eject frass from the shoot only at breaks and girdled points along the stem. Before pupation, mature larvae cut a hole almost through the bark surface to permit emergence of the adult. Then they prepare a thin, somewhat transparent, membranous, cocoonlike structure in which to pupate. In its northern range, the insect reportedly requires 1 year to complete a generation; in Mississippi it has three generations per year, with first-generation adults emerging from mid-April to mid-May, second generation adults appearing from mid-June to mid-July, and third generation adults emerging from early August through September. Larvae of the last generation overwinter in cocoons, transforming to pupae and adults the following spring.

Injury and damage. The earliest evidence of injury is wilting and drooping terminals and branch ends (figure 235E) (Solomon and Randall 1978). Injured shoot tips wither and turn brown or black. Infested shoots gradually die back 30 to 60 cm; young shoots sometimes die back to the rootstocks. Peeling the bark off infested shoots reveals numerous spiral girdles made by the tunneling larva (figure 235F). Slicing through the center of infested shoots with a sharp knife reveals galleries filled with brown frass (figure 235C and D). Injured plants often produce many new branches just below the injured part, giving them a bushy appearance. The emerging adults leave behind round exit holes 1.5 to 2.5 mm in diameter (figure 235G). This insect is a major factor in the suppression and mortality of sucker shoots in cutover aspen stands in the Lake States, killing up to 9% of the dominant sucker shoots annually (Osgood 1962). In Mississippi, injury to cottonwood is usually minimal because most attacks occur on lateral branches. However, the pest severely damages nursery-grown willow; 90% of the shoots are sometimes killed by the first-generation sawflies (Solomon and Randall 1978). Damage to willow plantations in Maryland has been so

severe that the trees appeared to have been damaged by frost or fire. Repeated attacks in young plantations sometimes adversely affect tree form.

Control. In Mississippi, two hymenopterous parasites—*Bracon jani* Muesebeck and *Eupelmus* sp.—commonly kill 1 to 12% of the sawfly larvae in willow shoots (Solomon and Randall 1978). In the Lake States, up to 22% of the larvae in aspen shoots are parasitized by five species of hymenopterous parasites—*Bracon* sp., *Eurytoma* sp., *Scambus granulosus* Walley, *S. pterphori* (Ashmead), and *Tetrastichus productus* Riley (Osgood 1962). Three species of hymenopterous parasites—*Eurytoma* sp., *Microbracon* sp., and *Tetrastichus* sp.—have been reared in New Jersey (Middleton 1917). Up to 9% of the sawfly larvae in Mississippi have been killed by an unidentified fungus (Solomon and Randall 1978). Overwintering mortality of larvae in Mississippi has been estimated at 56%; mortality is most prevalent in the smallest, least vigorous shoots (Solomon and Randall 1978). Infestations can be reduced in nurseries by pruning and destroying infested shoots (Riley 1888). In Michigan's poplar nurseries and plantations, planting small blocks of willow (which the insect prefers over poplar) nearby as a trap crop, then annually coppicing the willow to destroy overwintering larvae and create a crop of succulent sprouts for next year's sawflies, has been recommended for control (Reighard 1985). Insecticides have reduced girdled shoots by 75 to 90%, but repeated applications are necessary (Reighard 1985).

Janus bimaculatus (Norton)

[viburnum stem sawfly] (figure 236)

Host. Viburnum. Blackhaw and nannyberry mentioned specifically as hosts, and other viburnum species are undoubtedly susceptible (Middlekauff 1969, Solomon 1982).

Range. Eastern North America from Quebec and Ontario south through Maine and New York to Maryland and Virginia and west to Illinois and Minnesota (Middlekauff 1969, Ries 1937, Smith and Solomon 1989).

Description. ***Adult.*** Small, mostly black, wasplike sawfly, 6 to 10 mm long (Ries 1937, Smith and Solomon 1989) (figure 236A). Head and pronotum black except lateral margin of pronotum translucent and whitish. Abdomen of females noticeably compressed, much deeper than wide; basal segments, venter, and legs reddish yellow to orange; ends in short, stout, amber-colored, sawtoothed ovipositor. Wings mostly hyaline and iridescent except for two, round, black, fuscous apical spots on each forewing. Males slightly smaller than females and radial vein of forewing atrophied at base. ***Larva.*** White with light amber head and mandibles, cylindrical, S-shaped, 7 to 10 mm long (figure 236B).

Biology. Adults are observed as early as May 9 in Illinois and as late as July 10 in Maine (Ries 1937). Adult activity seems greatest during early June across its range, when females are busy girdling and ovipositing in young viburnum stems. Females deposit eggs in tender shoots 15 to 40 mm from the apices. Larvae tunnel basally within

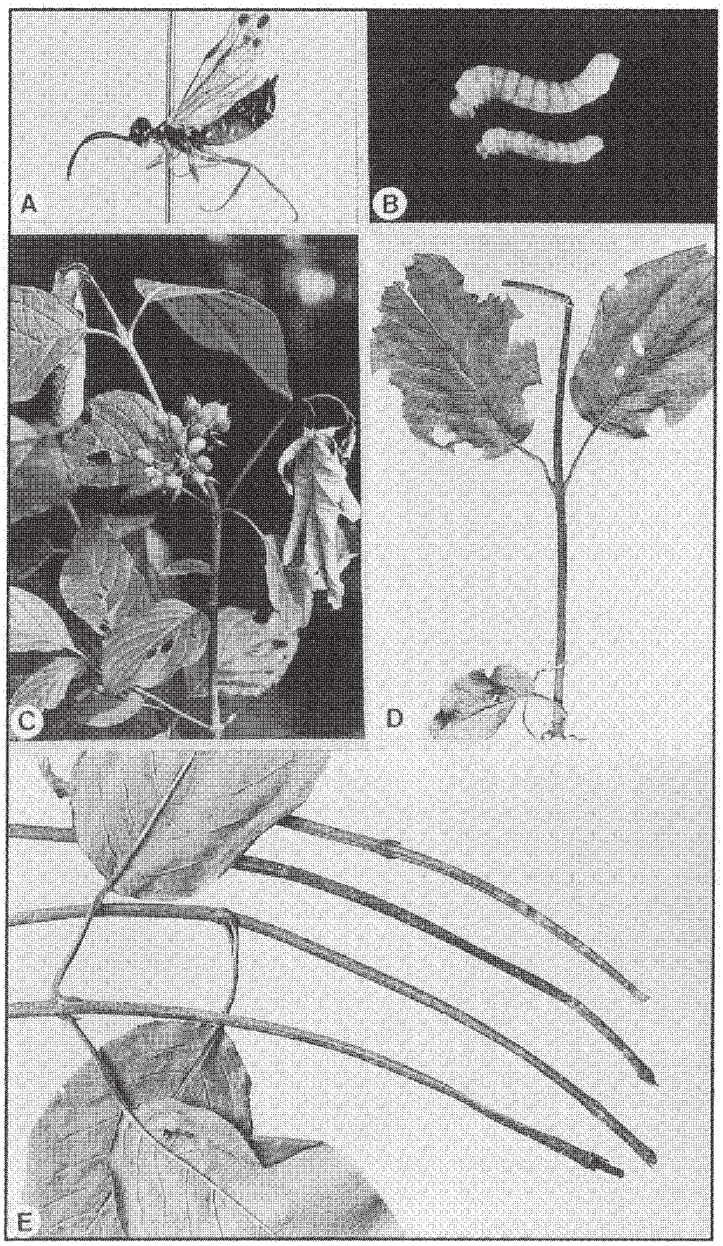

Figure 236—Janus bimaculatus, *[viburnum stem sawfly]: A, adult; B, larvae; C, wilting and drooping viburnum shoots; D, terminal leaves and shoot tip breaking away; E, dead, blackened, leafless shoots typical of infestation (A, specimen courtesy D. Smith).*

the shoots. Mature larvae prepare thin cocoons in the galleries where they overwinter. This stem sawfly has one generation a year.

Injury and damage. Wilting and drooping tender terminals and branch ends are the earliest evidence of infestation (figure 236C). Closely examining affected shoots reveals the girdle, the sawfly punctures, and the oviposition site. Leaves and shoot ends turn brown, then black, and soon begin breaking away (figure 236D). Dissection of infested shoots exposes hollowed stems with brown frass and sometimes the white, S-shaped larvae. Shoots gradually turn brown and black and die back 3 to 9 cm. Leaves die and shed along the affected stems as they die further back, typically leaving darkened, dead, leafless shoots projecting from infested plants (figure 236E). The insect has been reported as a nursery pest in Ohio and has killed up to 6% of the twig growth of blackhaw in Pennsylvania (Solomon 1982).

Control. Birds have been reported as predators in Wisconsin (Solomon 1982). Nothing else is known of natural controls, and direct controls have not been needed.

Janus integer (Norton)

currant stem girdler (figure 237)

Host. Currant. Both wild and cultivated currants are attacked; however, wild currant is the original host and appears to be favored over cultivated varieties (Marlatt 1895).

Range. Canada from Newfoundland and Quebec to British Columbia, across the northern United States from New Hampshire and New York west to Washington and Oregon and south to Virginia and Iowa (Middlekauff 1969, Smith and Solomon 1989). Seems most prevalent in the Northeast.

Description. ***Adult.*** Delicate, shiny, black and reddish, wasplike sawfly; female averages about 12 mm long with wingspan of 20 mm; male averages about 9 mm long with wingspan of 12 mm (figure 237A) (Ries 1937, Slingerland 1897, Smith and Solomon 1989). Head and pronotum black with yellowish mandibles and similar markings at base of wings on thorax. Abdomen noticeably compressed, being deeper than wide, and equipped with a stout, sharp, sawtoothed ovipositor at apex in females; basal three to four segments red to reddish orange with remaining segments black. Abdomen of male brownish yellow and not compressed. Legs brownish yellow in both sexes. Wings hyaline, without violaceous reflections, with one fuscous black spot below stigma on forewing. ***Egg.*** Elongate to oval, rounded at both ends; white to yellowish white when first laid, becoming transparent before hatching; delicate structure without surface sculpturing; 1.0 to 1.1 mm long (Marlatt 1895, Slingerland 1897). ***Larva.*** Cylindrical, slightly S-shaped with somewhat enlarged thorax; white to creamy white with pale yellow, rounded head, brown mandibles; short tubular prong at tip of abdomen; three pairs fleshy, unjointed, teatlike legs on thorax; abdominal prolegs absent; 10.0 to 12.7 mm long when mature (figure 237B) (Marlatt 1894, 1895; Middleton 1917).

Biology. The adults emerge during May and June and begin ovipositing soon after

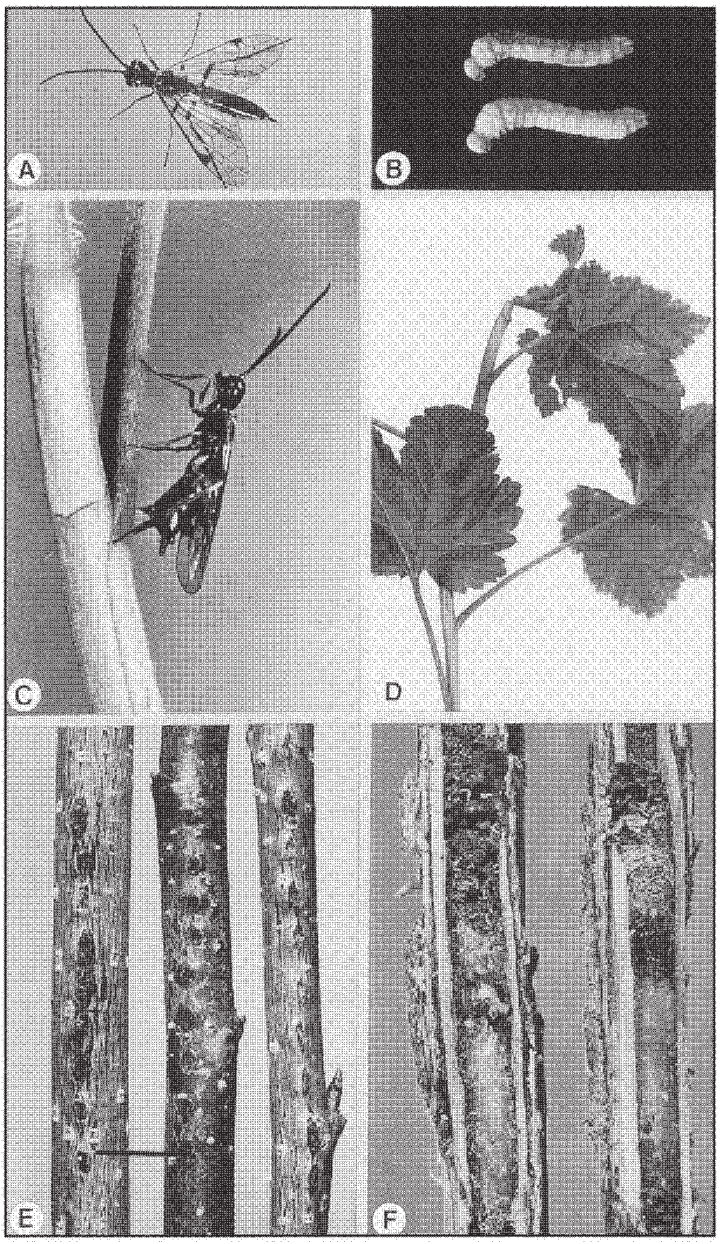

Figure 237—Janus integer, *currant stem girdler: A, adult; B, larvae; C, female ovipositing in shoot; D, currant shoot broken at girdled site; E, scars from probing punctures by female ovipositor; F, cocoons in frass-packed galleries (courtesy NY Agricultural Experiment Station).*

(Marlatt 1894, Slingerland 1897). Females may visit several plants before selecting terminals for oviposition and may begin depositing eggs within 2 hours of emergence. To oviposit, the females take a position with heads upward a few centimeters below the shoot tips (figure 237C). They quickly push the full length of their ovipositors into the tender shoots and deposit single eggs in the pith. They quickly withdraw their ovipositors, accomplishing the whole operation of laying an egg in about 1 minute. The slits cut by their ovipositor saws are so small that they can scarcely be found even with a hand lens until a few days later, when the sides of the shoots swell slightly. Immediately after ovipositing, females move up the shoots for 3 to 25 mm and girdle them by forcing their ovipositors in the shoots and withdrawing them in a twisting or sawing motion. They move around the stems and repeat the puncture-sawing action four to six times or until girdles are nearly complete, which takes about 4 minutes. Female can lay up to 30 eggs and girdle the same number of shoots. Eggs hatch in about 11 days. The young larvae feed and tunnel downward mostly in the pith, leaving enough of the woody stem to hold it upright. Larvae continue to feed for 75 to 150 mm, packing the dark brown frass behind them in the galleries. During fall, larvae prepare cells for overwintering and eventually pupate at the lower ends of the galleries. They chew round passageways nearly through the stem for later exit, then spin thin, glistening, silken cocoons around themselves to overwinter. Beginning in April, larvae pupate within the silken cocoons and emerge as adults after about 2 weeks. There is one generation a year (Middlekauff 1969, Ries 1937).

Injury and damage. The earliest symptoms of damage are sudden wilting and drooping of terminal shoots during spring and early summer after new growth is several centimeters long (Marlatt 1894, 1895; Middlekauff 1969; Slingerland 1897). Wilted shoots typically wither rapidly and die. Some shoots are so thoroughly girdled that, instead of wilting and drooping, they drop over immediately and hang suspended or fall to the ground (figure 237D). Careful examination of the wilted or broken terminals reveals that they were deftly girdled with several sharp, somewhat curved cuts encircling the stem and extending through or nearly through 5 to 10 cm below the tip. Sometimes when the terminal is quite large, the puncture cuts do not extend deep enough to sever the stem. Partially girdled terminals are slow to wilt and may or may not die and break off later. The girdled or severed terminals are the principal kind of injury, but another 15 mm of the infested shoot may die back from tunneling by the larva. Also, stems may have scars resulting from probing punctures made by the female (figure 237E). Dissecting infested stems reveals galleries densely packed with brown frass, except for the bottom portion, which is occupied by the larva or cocoon (figure 237F). Injuries stop the growth and disfigure or stunt the plant for the rest of the season. The insect has been particularly troublesome to currant growers in New

York and is especially objectionable in nursery cuttings.

Control. Six species of insect parasites have been recorded; up to a third of the sawfly larvae have been destroyed by parasites, largely by a braconid parasite—*Bracon apicatus* Provancher (Marsh 1979, Slingerland 1897). The greatest natural mortality rates (up to 85%) occur when eggs fail to hatch and newly hatched larvae die. Populations can be reduced by pruning and destroying the flagged (infested) shoots. Early pruning in May and June requires removal of only the top 5 to 8 cm of the shoot; late pruning from July to April requires removing the top 20 cm of the shoot to ensure getting all the larvae. Insecticides applied during the oviposition period should be effective against adults.

Janus quercusae Smith

[oak shoot sawfly] (figure 238)

Host. Oak. Found only in two species, Nuttall oak and water oak, which are in the red oak group (Smith and Solomon 1989). However, because this pest also occurs outside the range of Nuttall and water oaks, it likely infests other species in the red oak group.

Range. Newly discovered species known only from Mississippi, Maryland, and Virginia (Smith and Solomon 1989). It undoubtedly occurs elsewhere in the East, particularly between Mississippi and Maryland.

Description. ***Adult.*** Female delicate, black and red, wasplike sawfly, 6.5 to 8.0 mm long, with wingspan of 11 to 13 mm; male unknown (figure 238A) (Smith and Solomon 1989). Head, antennae, and thorax black with yellow mandibles, palpi, and indistinct markings on pronotum. Abdomen compressed, noticeably deeper than wide; black with at least segments 3 to 6 red; ends with a sharp, sawlike ovipositor. Forelegs and midlegs yellow; hindlegs black, yellow, and orange. Wings hyaline with indistinct, ochre markings and brownish veins; radial vein complete in forewing. ***Larva.*** Nearly cylindrical, thorax somewhat enlarged, slightly S-shaped with head and thorax most noticeably curved downward; white with yellowish head and light brown mandibles (figure 238B).

Biology. Adults emerge from mid-April in Mississippi to mid-May in Virginia (Smith and Solomon 1989). Females lay eggs in the tender terminals and branch ends during spring when shoots elongate. The shoots are girdled by a series of ovipositor punctures apically to the oviposition sites and 3 to 8 cm from the shoot tips. Larvae tunnel basally in the stem pith for 4 to 10 cm, eventually hollowing the shoots and packing frass behind them within the galleries (figure 238C). The larvae girdle the shoots from within one or more times in their travel down the shoots. Larvae are fully grown by mid- to late June and construct thin, white to light brown, partially transparent, cellophane-like cocoons around themselves near the basal ends of the galleries (figure 238D). They spend the rest of the summer, fall, and winter in the cocoons, and pupate in early spring. Adults emerge through round holes in the sides of the shoots. The oak shoot sawfly has one generation a year.

Injury and damage. Flagging shoots

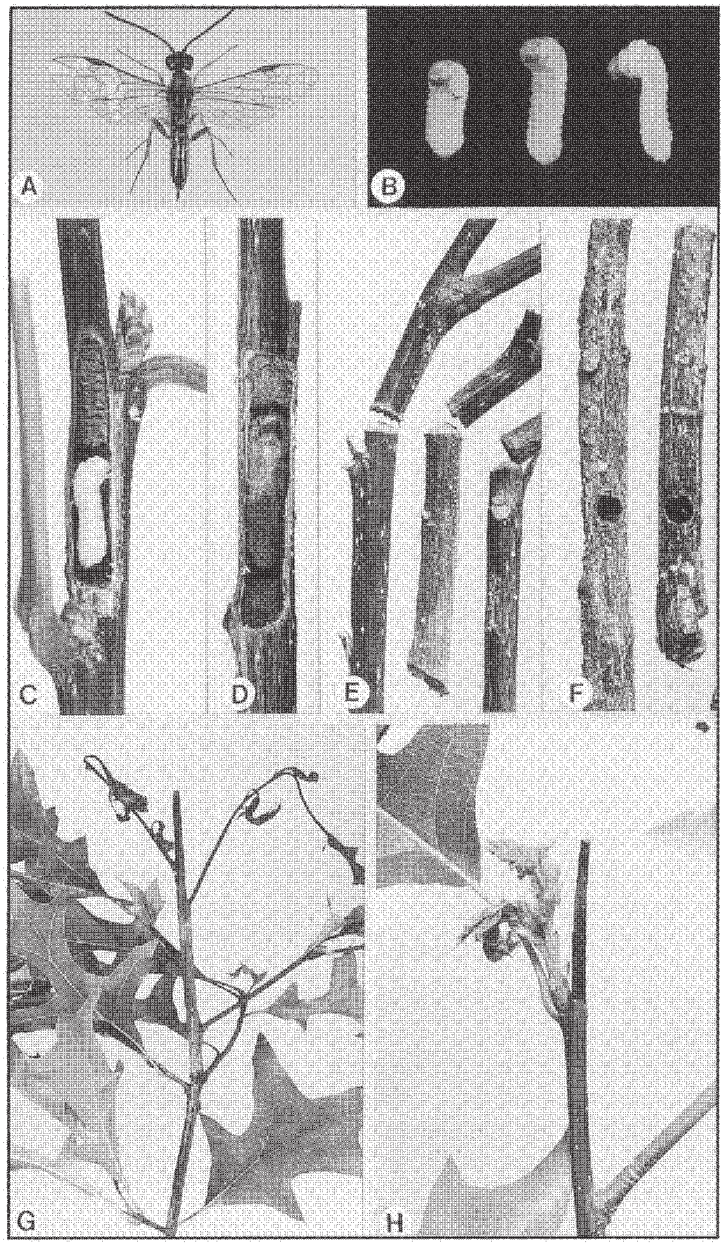

Figure 238—Janus quercusae, *[oak shoot sawfly]: A, adult; B, larvae; C, frass-packed gallery with S-shaped larva; D, cocoon in gallery; E, shoots with dome-shaped breaks at girdled sites; F, exit holes in shoots; G, flagging dying shoot; H, infested shoot with tip detached and new lateral shoot emerging.*

from mid-April to mid-July provide the earliest evidence of attack (figure 238G). New expanding leaves and succulent new growth of terminals and branch ends begin wilting and drooping soon after attack. Affected shoots turn yellowish brown then black, flagging the injured shoots. Most shoots break at girdled sites 3 to 8 cm from the apices and drop to the ground, leaving only blunt stubs (figure 238G and H). As the larvae tunnel down the stems, the shoot stubs gradually turn dark brown or black, and any succulent side shoots also wither, droop, and darken (figure 238G). By midsummer, new lateral shoots often issue from bud sites just below the blackened stubs (figure 238H). The tunneled portion of the shoot is easily broken at one or more sites that are girdled from the inside by the larva (figure 238E). The girdled site is always nearly perfectly round, with the tightly packed frass protruding from the branch stub in a dome shape; the site is concave in the end of the detached portion. The emerging adults leave round exit holes 1.2 to 1.6 mm in diameter in infested shoots (figure 238F).

Control. Parasitic larvae in sawfly cocoons and very small exit holes in the bark directly over sawfly cocoons have been observed, but no adult parasites have been obtained, and none have been identified. Direct controls will probably be needed for ornamental trees, but none have been investigated.

Janus rufiventris (Cresson)

[white oak shoot sawfly] (figure 239)

Host. Oak. Oregon white oak is only known host, but this pest probably attacks other oaks in the white oak group within its range (Hanson 1986).

Range. A western species known only from California and Oregon (Hanson 1986, Middlekauff 1969, Ries 1937).

Description. ***Adult.*** Small, delicate, black and red, wasplike sawfly, 7 to 8 mm long (figure 239A) (Ries 1937, Smith and Solomon 1989). Head and thorax shiny black with yellowish mandibles and whitish thoracic membranes laterally. Abdomen compressed, being deeper than wide, uniform brick red with brownish yellow cerci and amber saw and terminating with short, sawlike ovipositor. Legs blackish brown. Wings hyaline, slightly infuscated along margins and veins. Distinguished by only one preapical spur on hind tibia, entirely red abdomen, and wings infuscated toward tips and along veins. ***Larva.*** Cylindrical with slightly enlarged thorax, slightly S-shaped, head and thorax curved somewhat downward, whitish with slightly darker head and mandibles (figure 239B).

Biology. In California, adult emergence has been recorded from mid-March to early June (Middlekauff 1969, Ries 1937), whereas in Oregon emergence occurs from mid-April to mid-May (Hanson 1986). Females select current year's growth for oviposition (figure 239C), preferring succulent, vigorous shoots. They oviposit from late April to early June in the Willamette Valley of Oregon. Females insert one egg into the outer pith. Immediately after oviposition, the females girdle the stems with their ovipositors by making a series of deep punctures around the circumference 4 to

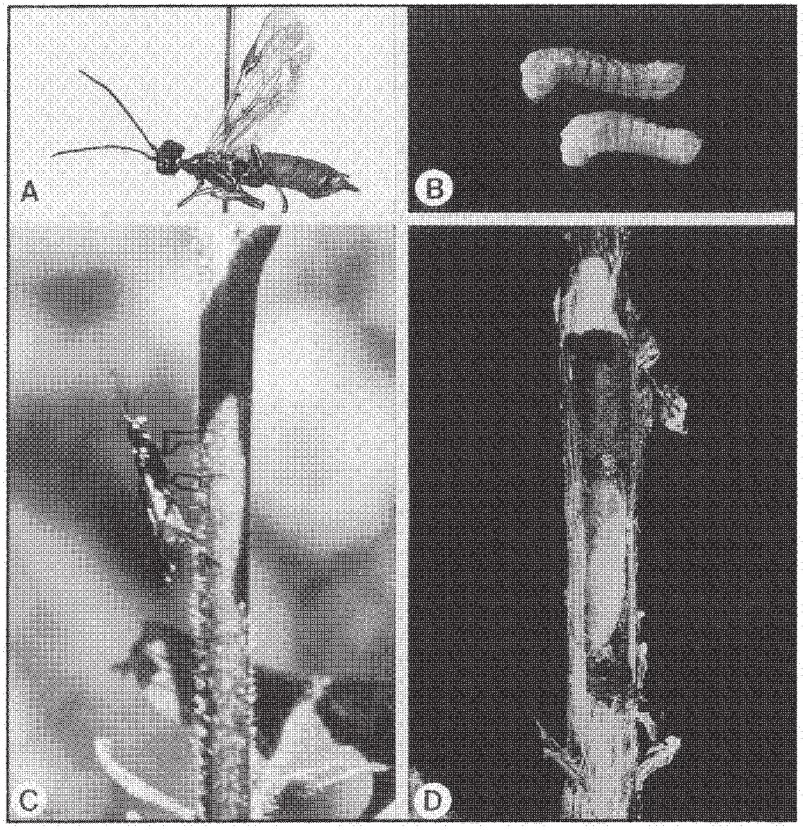

Figure 239—Janus rufiventris, *[white oak shoot sawfly]: A, adult; B, larvae; C, female ovipositing in Oregon white oak shoot; D, infested shoot with gallery containing cocoon (A, specimen courtesy D. Smith; B-D specimens courtesy P. Hanson).*

10 mm distal to the eggs. Girdling requires 4 to 7 minutes. These cuts almost totally sever the stem. Upon hatching, the larvae initially tunnel toward the apex (point of girdling); in subsequent instars, they turn and burrow toward the base of the stem. Feeding larvae consume almost all the interior of the shoot, packing the frass tightly in the vacated gallery. In late July and early August, fully grown larvae begin lining a chamber near the base of the shoot with silk, which is spread flat rather than spun into threads, resulting in a translucent, parchment-like cocoon (figure 239D). This insect overwinters as a postfeeding, last-instar larva or as a pharate pupa. Adults emerge in spring. There is one generation a year.

Injury and damage. Wilting and drooping shoots of terminals and branch ends during spring and early summer mark the beginning of injury (Hanson 1986). Most affected shoots, nearly severed by a ring of deep punctures 6 to 17 cm from the apex, quickly darken and usually detach within 1 week. Buds, leaves, and the shoot tissue die sequentially as larval tunneling and girdling proceed basally. Dissection of infested shoots reveals galleries tightly packed with brown frass, extending 4 to 9 cm, and containing one larva or a thin glazed cocoon with the mature larva or pupa inside. New adults cut emergence holes directly over the pupation chambers to exit. Tender, thick, stem shoots on vigorously growing young trees and especially stump sprouts are most susceptible to infestation. Damage has been negligible to date.

Control. Natural controls cause larval mortality rates estimated at about 34%, a third of which is by two hymenopterous parasites—*Eurytoma* sp. and *Pteromalus* sp. (Hanson 1986). Some mortality occurs in the egg and first-instar stages associated with cracking of the stem near the girdle, causing desiccation. Infested stems with irregular holes and peeled edges suggest some bird predation. Direct controls have not been needed.

Order Diptera—Flies

Members of the order Diptera constitute a large and diverse group with widely varied forms and habits. Many species are destructive crop pests; bloodsucking forms are injurious to humans and animals, and some are important vectors of serious diseases; some are parasites and predators of other insect pests and are beneficial; others are merely scavengers (Borror and others 1981, USDA FS 1985). Only a few species are destructive to trees and shrubs. The flies are readily recognized by their one pair of functional wings, the hindwings being reduced to mere knobs called halteres. Larvae, known as maggots, are legless and vary greatly in form from slender and elongate to stout and cylindrical.

Family

Agromyzidae *621*

Family Agromyzidae—Cambium Miners

The cambium miners are small, mostly black flies, with short antennae and hyaline wings, that are covered with bristly setae (Frick 1959, Furniss and Carolin 1977, USDA FS 1985). Larvae are soft, white, legless, and headless, with paired, hooklike mouthparts. The larvae pass through three larval instars; puparia are formed by shrinkage and hardening of the last larval skin. Larvae mine for long distances in the cambium region of host trees. Cambium miner defects detract from the appearance of clear wood and sometimes reduce its value. Fifteen species of *Phytobia* have been recognized in North America, but only the five species with known hosts and biologies are covered in this manual (Spencer and Steyskal 1986, Teskey 1976).

Genus and Species

Phytobia
- *setosa* (Loew) *621*
- *betulivora* Spencer *624*
- *pruni* (Grossenbacher) *626*
- *amelanchieris* (Greene) *629*
- sp. *631*

Phytobia setosa (Loew)

[maple cambium miner] (figure 240)

Host. Maple. Sugar maple favored, but red maple recorded (Greene 1917, Hanson and Benjamin 1967, Ward and Marden 1964). Other maple species probably serve to a lesser extent.

Range. Recorded from Quebec and nine states from Massachusetts and New York south to Virginia and west to Wisconsin and Iowa (Frick 1959, Hanson and Benjamin 1967, Spencer and Steyskal 1986). Probably occurs throughout the natural range of sugar maple and possibly red maple, but distribution records, particularly in the South, are lacking.

Description. ***Adult.*** Small, mostly black fly with indistinct, yellowish to red markings, large eyes, and 4.0 to 4.5 mm long (figure 240A) (Greene 1917, Spencer and Steyskal 1986). Head sooty black, often suffused with red around lunule; ocelli and first segment of antennae pale yellow; third segment of antennae reddish brown. Dorsum of thorax black, slightly shiny, and thickly covered with bristly setae. Halteres

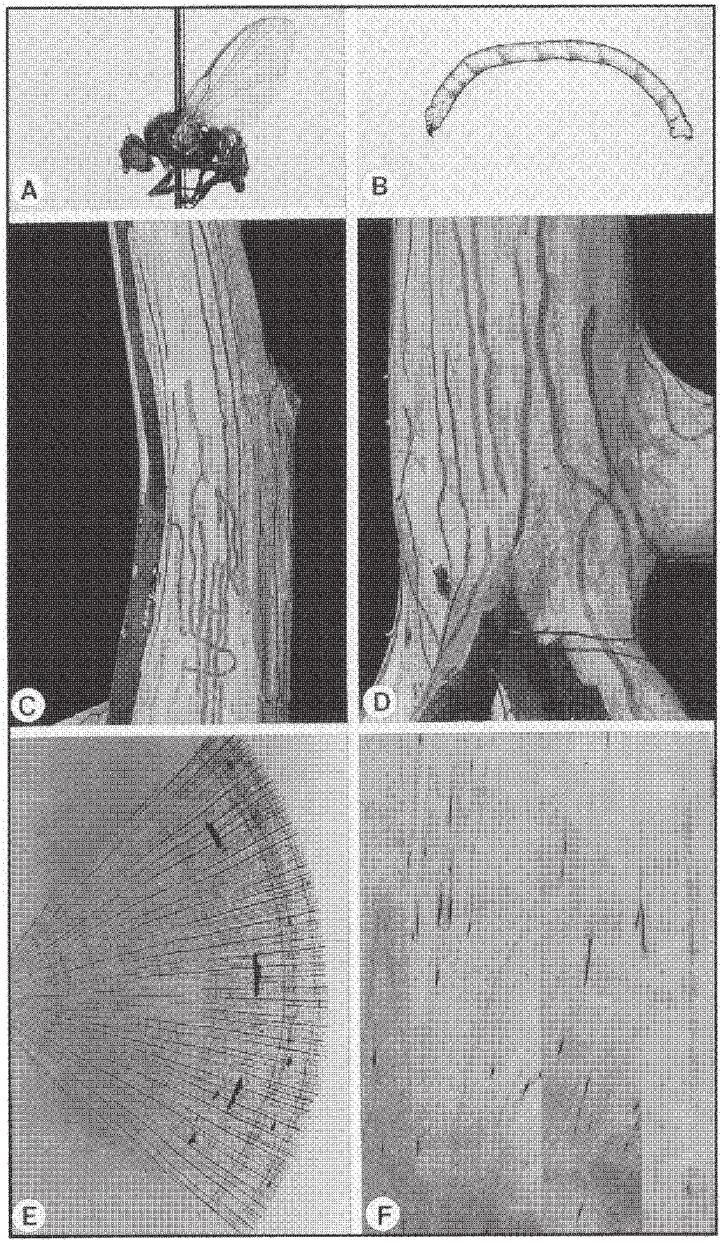

Figure 240—Phytobia setosa, *[maple cambium miner]: A, adult; B, larva; C, bark removed exposing larval mines on sapwood; D, mines extending into roots; E, cross section of stem with pith flecks; F, brown streak defects in maple veneer (A, specimen courtesy R. Peterson; E, specimen courtesy W. Wallner).*

with yellowish brown stems and whitish knobs. Abdomen concolorous and covered with numerous setae. Legs black with yellowish knees. Wings hyaline with yellowish brown to dark brown veins. ***Larva.*** Narrowly elongate, cylindrical to slightly flattened in cross section, tapered slightly at each end, legless, opaque white, 15 to 22 mm long, and 0.7 to 1.0 mm in diameter (figure 240B) (Greene 1917, Hanson and Benjamin 1967, Teskey 1976). Mouthparts small; mandibles with two black, clawlike hooklets, one much larger than the other. Thoracic (and usually all) abdominal segments, have bands of minute spinules that are better developed laterally than dorsally or ventrally; spinules in four or five rows on last abdominal segment and in three rows on next-to-last abdominal segment. ***Puparium***. Coarctate, cylindrical, tapered slightly at both ends, 3.6 to 5.4 mm long, and 1.5 to 2.2 mm wide. Black, chitinized mouthparts visible at anterior end. Anal area marked by circular depression with black center. All body segments, except head, clearly defined by transverse grooves.

Biology. Adults emerge late April to early May, about the time that sugar maple buds begin to swell (Greene 1917, Hanson and Benjamin 1967). Eggs are deposited singly near lenticels on 1-year-old twigs, 2 to 8 cm below current year's growth. Newly hatched larvae bore through the bark and mine toward the new growth and then reverse direction and mine toward the main stem and down the bole toward the roots. Previously thought to mine in the cambium; they actually mine narrow areas of newly differentiating xylem just below the cambial zone. These narrow zones are the paths of least resistance for larval mining and are metabolic sinks rich in carbohydrates (Gregory and Wallner 1979). First-instar larvae mine 1.8 to 2.1 m by early June. Second-instar larvae mine downward another 3.6 m by mid-June to early July. Final- (or third-) instar larvae mine an average of 2.4 m by late June to mid-July. If larvae reach the base of the tree before the time to pupate, they usually reverse directions and mine upward. Some may reverse directions two or more times, causing a zigzag pattern of mines. Mature larvae mine along roots for about 22 cm, then bore out through a slit in the bark. Larvae exit the roots from early July to late August. Some larvae exit through the bark of the bole instead of the roots. Most larvae form puparia in the litter or mineral soil near the root, but some move 5 to 7.6 cm away from the root to pupate. The puparia overwinter in the soil. This cambium miner has one generation a year.

Injury and damage. It is almost impossible to detect cambium miner infestations in standing trees without some destructive sampling. Peeling bark from the trunk or roots exposes the elongate, serpentine larval mines on the white surface of the sapwood and inner phloem (figure 240C) (Gregory and Wallner 1979, Hanson and Benjamin 1967, Wallner and Gregory 1980, Ward and Marden 1964). Mines made by first-instar larvae in the branches and upper bole are very narrow and threadlike, making them difficult to discern, but those made by larger larvae further down the trunk are

larger and easier to detect. The largest, most prominent mines occur near the root collar (figure 240D) and at 8 to 12 m on the bole. Larval mining produces parenchyma flecks, also known as pith flecks. The serpentine mines appear as brown streaks in lathe-turned veneer and as light-colored, oblong to flattened blemishes on log ends (figure 240E). Pith flecks on log ends generally decrease the value of veneer products. Parenchyma flecks mar the natural color and pattern of the wood grain. Numerous pith flecks (more than 1/ft^2) or flecks that cross the grain make wood unsuitable for face-grade veneer (figure 240F), downgrading it to core stock. Up to 89% of sugar maples sampled in Wisconsin show some flecking, which causes as much as 40% degrade in face veneer and furniture wood and results in losses of 1 to 14% in monetary value. Pith flecks affect wood quality but not sap-sugar concentrations for maple syrup.

Control. A hymenopterous parasite—*Symphyta agromyzae* Rohwer—has been reared from this miner, but it apparently has little effect on populations (Hanson and Benjamin 1967). Three systemic insecticides have given 71 to 100% control of the larvae in experimental trials, but further tests are needed to refine these controls (Hanson and others 1965).

Phytobia betulivora Spencer

[birch cambium miner] (figure 241)

Host. Birch. River birch is possibly the only host (Greene 1914, Spencer and Steyskal 1986). Sweet birch, red maple, and wild cherry have been mentioned, but references are not clear on *Phytobia* species (Frick 1959, MacAloney and Ewan 1964, USDA FS 1985).

Range. Canada and New York south to the District of Columbia and west to Illinois and Kansas (Spencer and Steyskal 1986). Probably throughout the range of river birch. Identical injury in river birch has been found in North Carolina, Mississippi, Arkansas, and the Great Lakes region, but the miner species has not been confirmed as *P. betulivora* (Beal and others 1952, MacAloney and Ewan 1964).

Description. ***Adult.*** Small, blackish fly with large compound eyes that occupy most of head; measures 3 to 4 mm long (figure 241A) (Greene 1914, Spencer and Steyskal 1986). Females slightly larger and more robust with a shiny, black, slightly flattened ovipositor that extends about 0.5 mm beyond end of abdomen and slightly wider at apex than at base. Head blackish gray with reddish orange frons and five or six long bristles. All antennal segments reddish orange; arista slightly swollen at base. Legs blackish brown with pale orange "knees." Wings hyaline with dark veins. ***Larva.*** Opaque white, elongate, filiform to cylindrical, 20 to 30 mm long, and 1 mm wide when mature (figure 241B). Anterior and posterior ends of body taper slightly. Head small; mouthparts consist of a large, shiny, black, chitinized, hooklet with two smaller toothlike processes, one on each side and slightly back of the large hooklet (Greene 1914). Two slightly raised padlike surfaces covered with brown hooklike setae on the

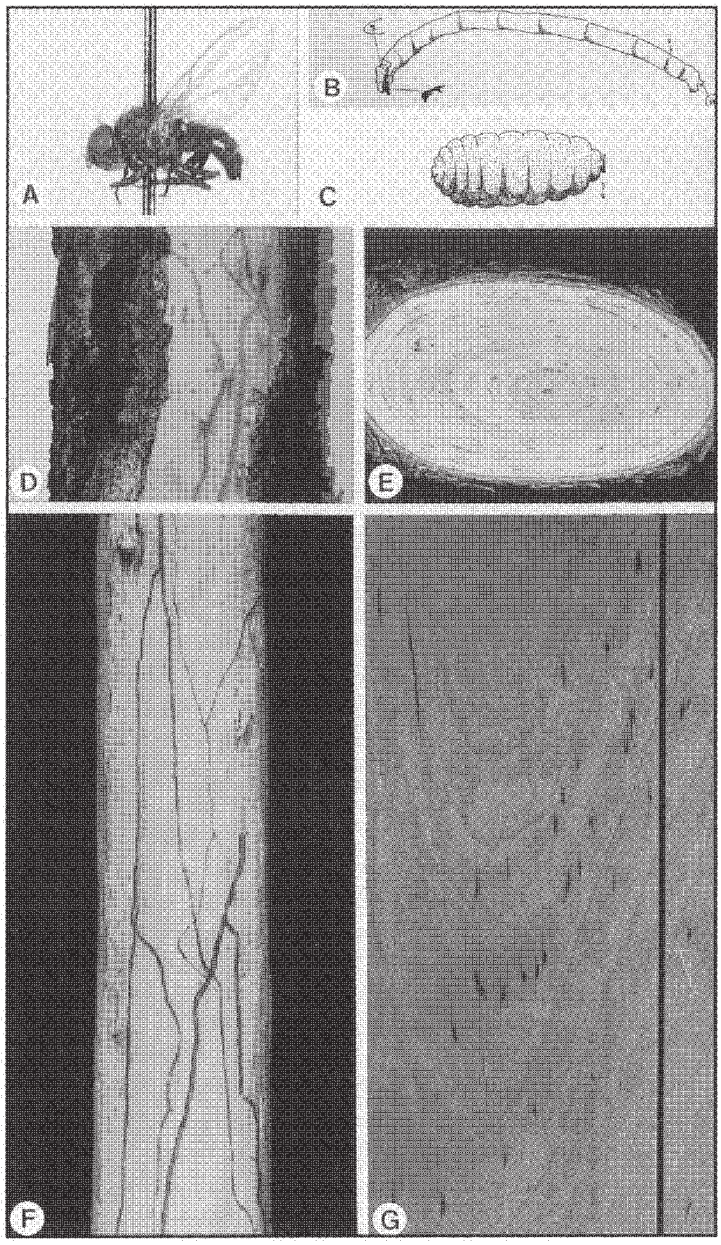

Figure 241—Phytobia betulivora, *[birch cambium miner]: A, adult; B, larva; C, puparium; D, bark removed to expose larval mines; E, cross section with many pith flecks; F, long, narrow mines on bole; G, brown streak defects in lumber (A, specimen courtesy R. Peterson; B & C, after Greene [1914]).*

last two abdominal segments. ***Puparium.*** Barrel shaped, 4 to 5 mm long, and 2 mm in diameter (figure 241C). Posterior spiracles have three bulbs each but are slightly less prominent than the anterior pair.

Biology. Adults emerge from mid-April to mid-May (Beal and others 1952, Brown and others 1949, Greene 1914, Snyder 1954). Oviposition apparently occurs most commonly in branch forks in the upper portion of tree crowns. To oviposit, females perforate the periderm of young branches with the ovipositor and deposit an egg in the living tissue beneath. Newly hatched larvae burrow directly into the cambial area between the phloem and xylem where they feed throughout their development. As they grow, larvae mine from the branches down the bole to the basal part of the trunk and finally into the roots. When larvae reach the root collar, many turn and mine upward for 1 to 2 m or more before turning again and mining into the roots. Larvae mine along the roots, sometimes encircling them, and move as far as 60 cm from the root collar. When maturing, larvae burrow through the bark to exit, sometimes on the top or side, but usually on the underside of the root. Puparia are formed in the soil from 12 to 25 mm from the exit sites on the roots. Pupation occurs during August, and puparia overwinter in the soil. Although 3 years are reportedly required for development, a 1- or 2-year life cycle seems likely.

Injury and damage. There are no external symptoms of miner infestations on standing trees; larval mines can only be detected by peeling bark (figure 241D) (Beal and others 1952, Brown and others 1949, Greene 1914, MacAloney and Ewan 1964). Mines begin in branches as tiny, hairline burrows, pale and difficult to detect. Mines become larger and darker as larvae progress down the bole (figure 241F) and may be more than 12 m long and 2.2 to 3.2 mm in diameter at the base of the tree. Mining larvae reverse directions in the basal part of the trunk, damaging the butt log, which is typically the most valuable part of the tree. In cross section, mines are small semicircular or lunate pith flecks orientated so that the long diameter is directed tangentially (figure 241E). Damage is visible in sawn wood products as brown to yellowish brown flecks, marks, and streaks (figure 241G) (known in the lumber industry as "pith ray flecks") that degrade the product and reduce its value. Logs with numerous pith fleck defects are unsuitable for veneer. The defects do not affect the strength of the wood but detract from its beauty.

Control. One hymenopterous parasite—*Sympha agromyzae* Rohwer—is the only recorded natural enemy of this miner (Greene 1914). No direct controls have been developed.

Phytobia pruni (Grossenbacher)

[cherry cambium miner] (figure 242)

Hosts. Cherry, plum, hawthorn. Mahaleb cherry, sour cherry, black cherry, chokecherry, mazzard, garden plum, and several species of hawthorn listed (Grossenbacher 1910, 1915; Hough 1963; Spencer and Steyskal 1986). Black cherry with cambium miner injury receives most notice

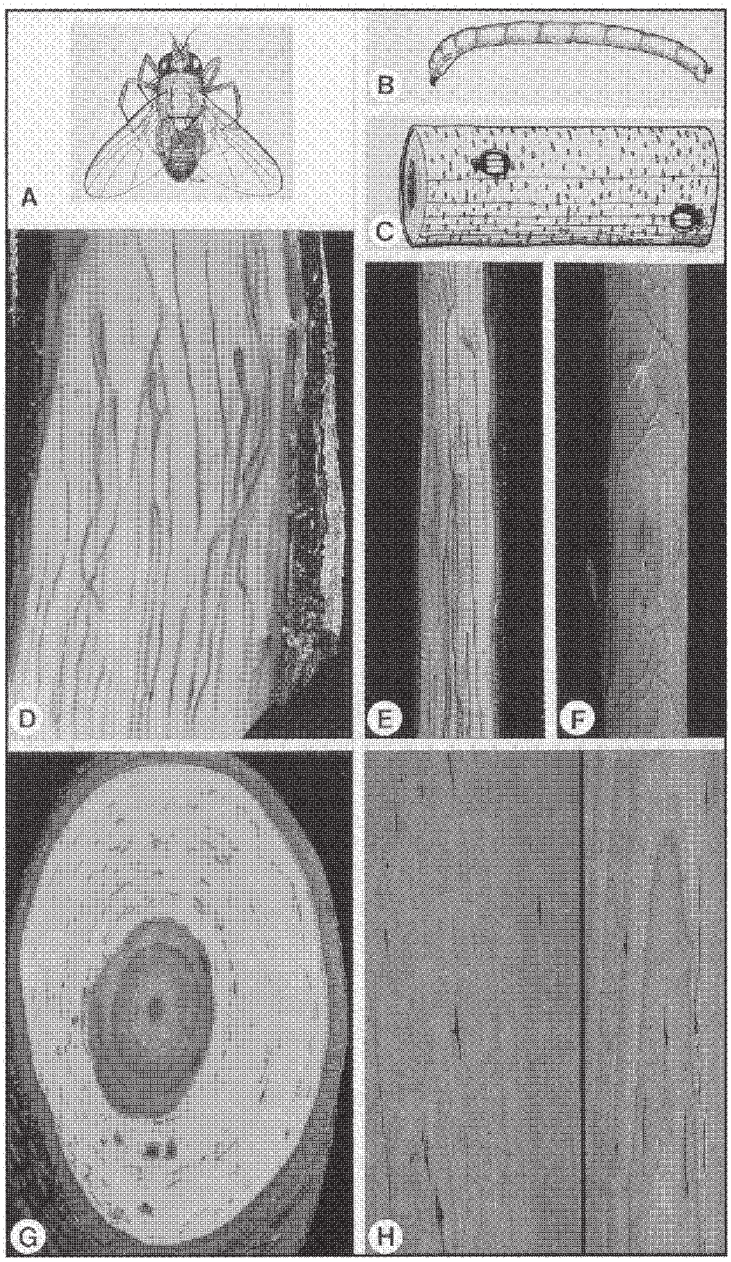

Figure 242—Phytobia pruni, *[cherry cambium miner]: A, adult; B, larva; C, eggs; D, wide larval mines near tree base; E, threadlike mines in upper bole; F, crisscrossing mines beginning to heal in midbole; G, cross section with pith-fleck defects; H, pith fleck and gum spots in cherry lumber (A-C, after Grossenbacher [1915]).*

(Hough 1963; Kulman 1964; Rexrode and Baumgras 1980, 1984).

Range. Eastern species occurring in New York, Pennsylvania, West Virginia, and Maryland; mentioned in the Northeast and mid-Atlantic regions (Grossenbacher 1910, Hough 1963, Kulman 1964, Rexrode and Baumgras 1984); and recently discovered by the author in North Carolina, Arkansas, and Mississippi. It is probably found throughout much of eastern and central North America.

Description. ***Adult.*** Small black fly, about 4 mm long; frons blackish to blackish brown, wider than eyes, but not projecting above the eyes as in *P. setosa* and *P. betulivora* (figure 242A) (Frick 1959; Grossenbacher 1910, 1915; Hough 1963; Spencer and Steyskal 1986). ***Larva.*** Whitish, long, narrow, cylindrical to filiform, wormlike maggot (figure 242B). Body devoid of setae, anterior four segments each have one irregular, platelike girdle; other segments each have two to nine incomplete girdles of tiny rectangular plates. Pair of prominent, large, black hooklets as mouthparts. Thorax slightly larger diameter than abdomen. Newly hatched larva 2.0 to 2.5 mm long and 20 mm or more when grown.

Biology. Adults emerge during May and June and as late as July in the Finger Lakes region of New York (Grossenbacher 1910, 1915; Hough 1963). Females mate and begin laying eggs within 2 to 3 days in lenticels in the bark of young, mostly 2- to 3-year old twigs in the upper tree crown (figure 242C). Females insert eggs in groups of one to three downward or upward in lenticels mostly on the underside of twigs. Eggs hatch within 2 to 3 days, and young larvae feed on the cortex just beneath the periderm before penetrating the cambial area. Larvae burrow apically or basally in the cambium, depending on the orientation of egg depositions. Larvae from eggs inserted upward in the lenticels mine apically for short distances, then turn and mine basally. After reaching the main stem from major branches, most larvae continue to mine downward, but a few mine upward for a time before turning and mining basally. Larvae generally follow nearly straight courses, especially in rapidly growing trees, whereas a few meander or zigzag, particularly in trees of poor vigor. They reportedly overwinter as partially grown larvae within mines in the tree, then resume feeding in spring. Larvae reach the base of the tree, turn and move upward for varying distances, then back downward. In late spring or early summer, mature larvae bore outward, usually exiting at a bark fissure between thick plates. Pupation occurs in the soil and lasts about 3 weeks. There is one generation a year.

Injury and damage. There is no visible bark injury on living trees. Removing bark exposes larval mines (figure 242D, E, and F) (Grossenbacher 1910; Hough 1963; Kulman 1964; Rexrode and Baumgras 1980, 1984). Long, narrow mines are almost hairline in the branches and upper bole but gradually widen and darken as they progress down the trunk. Most mines are nearly straight, and several parallel each other down the stem with little crisscrossing

(figure 242E), but few mines meander and crisscross (figure 242F). Mines are widest (1 to 3 mm) and darkest near the stump and about twice as wide at points where larvae reverse direction (figure 242D). In cross section, the crescent mines are called "pith-ray flecks," or "parenchyma flecks," and are about 2.0 to 3.0 mm long and 0.5 mm wide, extending across several rays in the spring wood (figure 242G). Yellow to brown amorphous material (mostly ray parenchyma cells, damaged cells, and insect excrement) is present in the pith fleck, but many flecks are blackened by gum. When gummosis occurs, pith flecks filled with gum are called "gum spots." Gum spots in valuable wood are far more serious defects than pith flecks (figure 242H). Studies in New York and Pennsylvania indicate that *P. pruni* is the major cause of solid wood defects in black cherry (Hough 1963). Recent studies in West Virginia indicate that *P. pruni* is less important than bark beetles in causing gum spot defects in the lower bole, the most valuable part of the tree (Kulman 1964; Rexrode and Baumgras 1980, 1984). Recent prices paid for gum-free black cherry veneer logs in the Northeast range up to $2,000 per thousand board feet. Veneer log buyers inspect each log end carefully for evidence of gum-spot defects. Logs rejected for veneer stock because of gum spots lose 50 to 70% of their value. In Pennsylvania, up to 90% of logs are rejected for veneer because of gum spots. Such defects are so common in some areas that buyers will not bid at timber sales.

Control. Heaviest cambium miner populations have been associated with fast-growing trees of sprout origin and those with large, branchy, dominant crowns (Rexrode and Smith 1990). Thus, in stand management operations, favoring seedlings and removing superdominants are recommended practices (Hough 1963). With fewer spreading "wolf" trees and better natural pruning for crop tree uniformity, there will be fewer entry points for miner attacks. Nothing is known of natural enemies, and direct controls have not been investigated.

Phytobia amelanchieris (Greene)

[serviceberry cambium miner] (figure 243)

Host. Serviceberry. Downy serviceberry and western serviceberry recorded as hosts; other species of serviceberry will probably prove to be hosts as more is learned about the insect (Brown 1913, Spencer and Steyskal 1986).

Range. Massachusetts, North Carolina, Tennessee, West Virginia, Washington, and Canada (Frick 1959, Spencer and Steyskal 1986). Very common in downy serviceberry in Arkansas. Probably occurs over much of the range of serviceberry species in North America.

Description. ***Adult.*** Small, mostly black fly closely resembling *P. setosa* but smaller; 3.0 to 3.5 mm long (figure 243A) (Greene 1917, Spencer and Steyskal 1986). Head black with narrow red and pale yellow markings and ocellar triangle with long, black setae. Antennae with segments 1 and 2 dark reddish brown, third segment rounded and dull black, arista black. Dor-

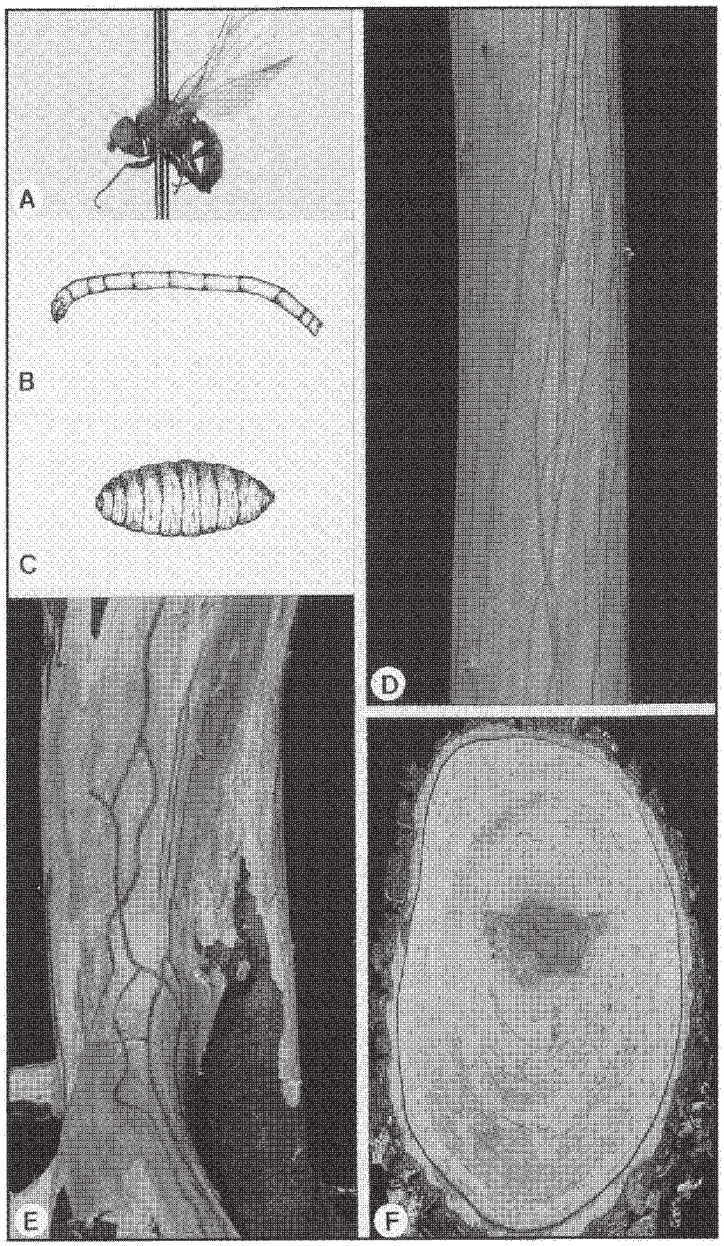

Figure 243—Phytobia amelanchieris, *[serviceberry cambium miner]: A, adult; B, larva; C, puparium; D, narrow, straight larval mines in upper bole; E, broad, meandering mines at base of tree; F, cross section with many pith flecks (A, specimen courtesy R. Peterson; B & C, after Greene [1917]).*

sum of thorax opaque. Abdomen blacker and shinier than thorax with black legs, except femora reddish distally. Wings 3.0 to 4.3 mm long, hyaline; veins nearly black. ***Larva.*** Opaque white, slender, cylindrical or tubelike, tapering very slightly at extreme anterior and posterior ends; 20 to 25 mm long and 0.65 to 0.85 mm diameter (figure 243B). Mouthparts small; mandible consists of two black hooklets, one considerably larger than the other. ***Puparium.*** Barrel shaped, pale yellow, and clearly segmented with the anterior and posterior segments much narrower than others (figure 243C).

Biology. Adults emerge from April 13 to 17. Adults can be collected from branches and buds in West Virginia on April 18 (Greene 1917, Spencer and Steyskal 1986). Eggs are apparently deposited at lenticel sites on twigs and small branches in the upper portion of hosts. Larvae make pale, red, threadlike mines in the cambium and progress toward the base of the plant and into the roots. Larvae develop rapidly; nearly full-grown larvae have been observed from mid-June to mid-July. To pupate, larvae burrow out through the bark of roots and form puparia in the soil. Although the time of pupation is unknown, based on larval collections and sizes, it apparently occurs during fall. Puparia overwinter in the soil. This cambium miner has one generation a year.

Injury and damage. Infestations and injury are detectable only by destructive sampling. Removing bark reveals larval mines or tracks. In the upper and mid-stems, the miner tracks are very narrow, threadlike, reddish (figure 243D) (Spencer and Steyskal 1986). Tracks exposed beneath the bark may number 1 to 20 on a 6 to 8 cm diameter stem and usually parallel each other, crisscrossing down the stem. Those made by nearly mature larvae at the base of the tree and in the roots are larger in diameter and meander considerably (figure 243E). In stem cross section, the ends of mines appear as small "pith ray flecks" and may number 250 or more per 8-cm-diameter stem (figure 243F). The damage is of little consequence because serviceberry is not a commercial species for lumber and veneer, and the injury does not kill or affect tree growth.

Control. Nothing is known of natural enemies or controls.

Phytobia sp.

[ash cambium miner] (figure 244)

Host. Ash. White ash preferred in the North, green ash in the South (Skelly and Kearby 1969, 1970). Other ash species are probably attacked to a lesser extent.

Range. Previously reported in only eight counties in south central Pennsylvania (Skelly and Kearby 1970), but the author has found it commonly in Arkansas, Louisiana, and Mississippi. Probably occurs over much of the eastern United States.

Description. ***Adult.*** No adults have been reared for description. ***Larva.*** Narrow, elongate, cylindrical, slightly flattened, tapered slightly toward the anterior and posterior ends (figure 244A) (Skelly and Kearby 1970). Anterior end small, not retractile, curved. Mandible has two notice-

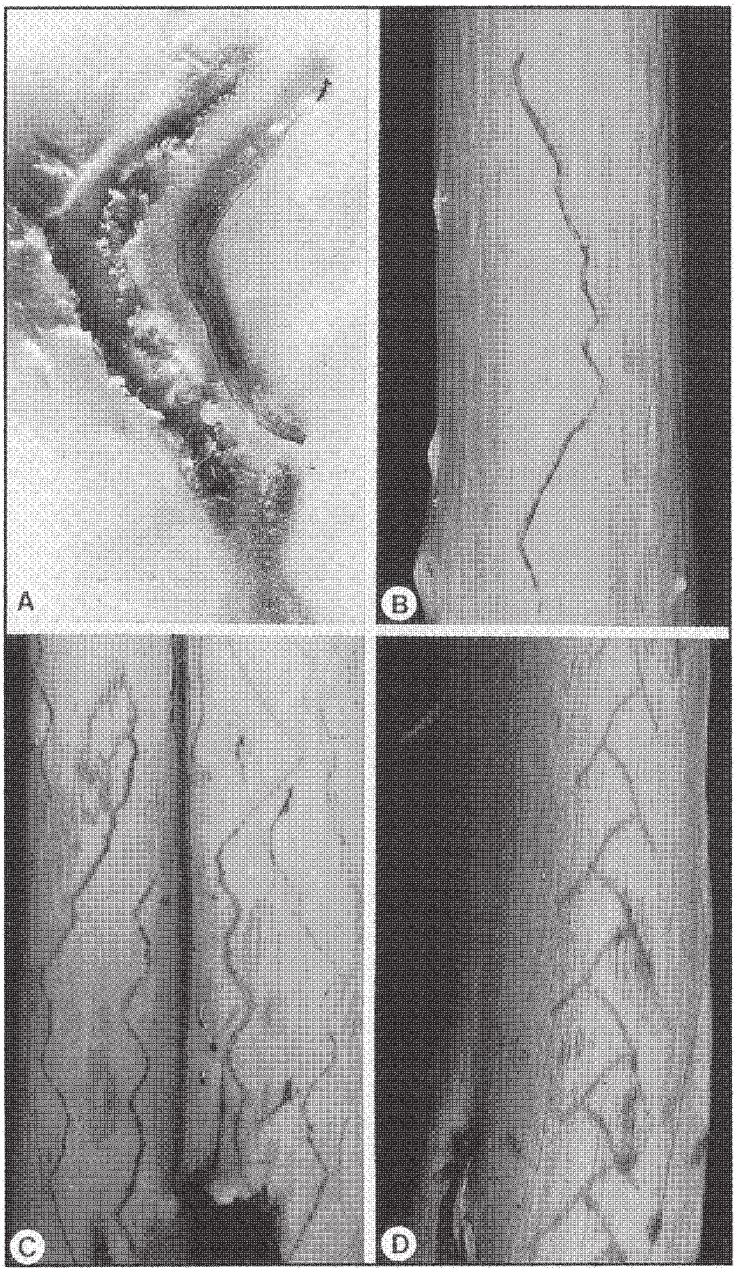

Figure 244—Phytobia *sp., [ash cambium miner]: A, larva beside its burrow in cambium and phloem; B, sinuate mine on surface of green ash sapwood; C, multiple zigzag mines on underside of bark; D, bipectinate larval mine in ash root.*

able, black, clawlike teeth or hooklets. Larvae distinguished from those of *P. setosa* by small, oblique tooth on the left side that is bidentate and other teeth that are similar in size. Body opaque white, segments almost indistinct without magnification, posterior spiracles consist of three short bulbs. Mature larvae 20 to 25 mm long and 1.1 to 1.25 mm diameter.

Biology. Adults apparently emerge during late spring and summer and presumably oviposit in small twigs and branches (Skelly and Kearby 1969, 1970). Young larvae mine rapidly downward in the cambium of the branches and bole, eventually reaching the roots. They spend about 10 months in the lower trunk and roots. Larval burrowing habits differ from other *Phytobia* cambium miners. Although young larvae burrow in long, narrow paths and meander little, they eventually mine in serpentine paths and finally in distinct zigzags. Once in the roots, many larvae make pectinate or bipectinate mines, a habit not reported for other *Phytobia* species. Moreover, larvae feed at times in layers of the phloem, as indicated by the disappearance of mines from the cambium and reappearance several centimeters away. In contrast, detailed studies of *P. setosa* show that larvae mine in narrow zones of newly differentiating xylem just below the cambium (Gregory and Wallner 1979). Although larvae have been found in roots to 7.6 m from the root collar, most of their root burrowing is in the nearest 1.5 m of roots. Second-stage larvae overwinter within the mines in the roots. Larvae are somewhat active during winter, as indicated by fresh, white or slightly tan frass deposits in the mines. Feeding is resumed in spring, with larvae reversing directions in the roots and lower trunk. In Pennsylvania, mature larvae cut holes in the bark or roots and enter the soil to pupate in May and June. In Mississippi, the larvae appear to exit the bark much earlier, and many mine upward from the roots to the root collar or above to cut holes and exit the bark. This miner has one generation a year.

Injury and damage. In standing trees, injury is virtually undetectable (Hardwood Research Council 1987; Skelly and Kearby 1969, 1970). When bark is removed, tan to brown mines on both the white, inner phloem and surface of the xylem become visible. In the branches and upper bole, the mines are mostly narrow, threadlike, and straight to serpentine. In the middle and lower bole, many mines become more sinuate and some distinctly zigzag (figure 244B and C). In the roots, in addition to these patterns, pectinate and bipectinate-shaped mines may be present (figure 244D). As mines fill and heal over, the wood grain covering the mines becomes distorted and slightly bulging or swollen. Moreover, much of the brown deposit in most mines fades or bleaches, becoming nearly colorless. Consequently, the pith flecks in cross sections and log ends of ash are hardly noticeable in contrast to those caused by *Phytobia* species in maple and other trees. The reason may be that ashes are ring porous, whereas all other hosts attacked by cambium miners are diffuse porous. In sawn lumber and sliced veneer of ash, most

mines do not show up as brown streaks and marks as in other host species. Instead, they are most noticeable as zigzag tracks varying from slightly lighter to slightly darker than the natural wood. However, the distorted wood grain gives it a characteristic "gothic arch" grain pattern. Such tracks viewed from one direction may be almost indistinct, but when the board is tilted or the angle of light changed, the tracks become distinct. Grain distortions interfere with the milling and fine finishing process of infested wood and is objectionable in international markets. These mines are referred to in the lumber industry as "worm tracks, "pith flecks," "pith ray flecks," "medullary spots," and sometimes as "glassworm" or "glass tracks," especially in Europe. Although not recognized as grading defects in lumber, in face veneers, they are considered defects by the Fine Hardwood Veneer Association.

Control. Dead larvae have been found in their mines following unusually cold winters. No other natural controls are known, and direct controls have not been investigated.

Glossary

Acuminate—gradually tapering to a sharp point.
Ambrosia—mycelium cultured in galleries as food by 17 species in the families Scolytidae and Platypodidae.
Ampulla, **ampullae**—a blisterlike structure on abdominal segments of larvae of some members of Cerambycidae.
Antenna, **antennae**—a segmented sensory appendage borne one on each side of the head.
Arcuate—arched or bowlike.
Arista—a large dorsal bristle on the apical antennal segment of members of Diptera.
Asperate—roughened; surface roughenings of tiny dotlike elevations are termed **asperites**.
Attenuate—gradually tapering apically.
Bark scar—a healed-over injury in the bark.
Biordinal crochets—crochets on the proleg of a uniserial circle of two lengths, alternating.
Bipectinate—having comblike teeth on the side of the antennal segments.
Biramous—having two branches.
Bispinose—armed with two spines.
Bole—a tree trunk once it has grown to large poletimber or sawtimber size.
Bristle—a stiff hair, usually short and blunt.
Brood—all individuals that hatch from eggs of one parent or series of parents and normally mature about the same time.
Cambium—a thin layer of meristematic cells between the bark and wood that gives rise to new phloem and xylem cells.
Canker—a localized necrotic lesion of the bark and cambium and sometimes the wood.
Carina, **carinae**—an elevated ridge or keel.
Caudal—pertaining to the rear end of the insect body.
Cell—(1) the closed area bounded by veins in an insect wing. (2) a nest, chamber, or compartment.
Cephalad—toward or in direction of the head.
Cercus, **cerci**—an appendage (generally paired) of the tenth abdominal segment, usually slender and segmented.
Cervical shield—a hardened plate on the prothorax of caterpillars just behind the head.
Chaetotaxy—arrangement and nomenclature of the setae on the insect.
Chlorosis—an abnormal yellowing of foliage.
Chorion—the outer shell or covering of an insect egg.
Ciliate—fringed with a row of parallel hairs.
Clavate—clubbed, usually toward the tip.
Coarctate—a pupa having all appendages and body parts concealed by a thickened, usually cylindrical case.
Cocoon—a covering composed of silk, other viscid fiber, and debris constructed by larva for protection of pupa.
Colleterial—a viscid secretion during oviposition by an accessory gland connected to the oviduct.
Concentric—circles or spheres, one within another.
Coppice—reproduction from sprouts arising from stools, rootstocks, or stumps.
Costa, **costae**—the thickened anterior vein or margin of an insect's wing.
Coxa, **coxae**—the basal segment of the insect's leg.
Cradle—a small chamber or niche along the gallery where the immature stages of some members of Scolytidae and Platypodidae develop.
Cremaster—the apex of the last abdominal segment, often with spined hooks.
Crenulate—evenly rounded and rather deeply curved.
Crochets—the curved spines or hooks on the prolegs of caterpillars and on the cremaster of pupae.
Cuprous—coppery; metallic copper red.
Diameter at breast height—diameter of a tree at 1.37 m above ground.
Deciduous—having leaves that fall at the end of a growing season.
Declivity—the sloping rear end of the elytra of members of Coleoptera, especially in the Scolytidae family.
Decumbent—bending downward.

Defect—a blemish or imperfection in wood such as a hole, a bark pocket, decay, or stain.
Deflexed—abruptly bent downward.
Degrade—a reduction in quality and grade caused by defects in the wood.
Dentate—toothed.
Denticulate—set with little teeth (denticles) or notches.
Depressed—flattened down as if pressed.
Dieback—progressive dying from the extremity of part of the plant.
Discal—a large median cell in the wing extending from the base to the center.
Distal—toward the free end of any appendage.
Dorsum—the upper surface of the insect body; referring to the dorsal surface.
Eclosion—emergence of the adult from the pupa or the act of the larva hatching from the egg.
Ellipsoidal—oblong-oval, ends equally rounded.
Elytron, **elytra**—hard or leathery forewings of beetles that usually meet in a straight line down the middle of the dorsum.
Emarginate—notched.
Entomogenous—growing in or on an insect.
Excrement—waste products eliminated by an insect mainly from digestion.
Exudation—a discharge of sap, gum, and fine frass from minute openings.
Exarate—a type of pupa in which the legs and wings are free from the body.
Exuvium, **exuviae**—the cast skin of larvae at metamorphosis.
Falcate—convexly curved.
Fascia—a transverse band, usually crossing forewings.
Femur, **femora**—the upper part or thigh of the insect leg.
Fibrous—consisting of or including long, narrow pieces or fibers of wood.
Filiform—threadlike.
Flagging—conspicuous dead twigs and branches with the foliage still present and discolored.
Forceps—hook- or pincerlike processes terminating the abdomen.
Frass—wood fragments mixed with excrement produced by insect larvae.
Frons—the upper anterior portion of the head.
Funicle—the slender stalk portion of the antenna.
Fuscous—a mixture of black and red.
Gall—an abnormal growth or swelling of plant tissue caused by insects or other external stimuli.
Gallery—a long narrow passage, chewed in the bark, cambium, and/or wood by a tunneling larva.
Gena, **genae**—part of the head below the eyes.
Generation—the time required to complete the life cycle of an insect.
Genitalia—sexual organs and associated structures.
Girdle—a cut in the living phloem or xylem or both, which encircles a stem, branch, or root.
Glabrous—smooth, without hairs.
Globose—nearly spherical; globular.
Granular—small chips or grains of wood, as in insect frass with a grainy texture.
Gregarious—living close together, but not social.
Grub—an insect larva; usually the larva of Coleoptera and some members of Hymenoptera.
Gummosis—formation of gummy exudates, often in masses.
Haltere—small filament on each side of the thorax representing the hindwings in Diptera.
Heartwood—the nonliving inner core of wood, usually darker than sapwood.
Hibernaculum, **hibernacula**—silken-trash shelter in which a larva hibernates.
Hibernation—a period of inactivity occurring during seasonal low temperatures.
Hooklet—minute, black, hook-shaped mouthpart in larvae of the order Diptera.
Hyaline—transparent or nearly so.
Incubation—the hatching period of an egg.
Infection—the establishment of a parasite in a host plant.

Infestation—borer attacks usually occuring in numbers.

Inquiline—an insect living habitually as a guest in the nest of another insect.

Instar—the period or stage between molts in a larva, usually numbered.

Larva, **larvae**—a young insect that hatches from the egg and differs fundamentally in form from the adult.

Lenticel—a lens-shaped cortical pore on the stem; serves for the exchange of gases.

Life cycle—the time between fertilization of an insect egg and the death of the individual adult that proceeds from that egg.

Lunule—a crescent-shaped mark around the eye.

Maggot—a legless larva of the order Diptera.

Mandibles—the first pair of jaws of insects, usually stout and toothlike.

Marginate—having an elevated margin with a flat border.

Mesothorax—middle segment of the thorax.

Midrib—the central vein of a leaf.

Mimic—the resemblance of one animal to another that is not closely related.

Molt—to shed the outer skin to accommodate growth of the body.

Monogamous—a union where a female is fertilized by one male only.

Mycelium—the threadlike vegetative part of fungi.

Mycetangia—pouchlike structures on insect bodies for storing fungi as in members of Scolytidae and Platypodidae.

Nuptial chamber—a cavelike opening made by bark beetles in the inner bark beneath the entrance hole and from which the egg tunnels originate.

Ocellus, **ocelli**—lateral simple eyes of insects.

Ochreous—yellowish with a slight tinge of brown.

Opaque—without surface luster; not transparent.

Ornamental—a plant grown for its esthetic qualities.

Ovipositor—a tubular structure at the rear end of a female insect, used to deposit eggs on or in a suitable material.

Palpus, **palpi**—a jointed sensory appendage of the mouth.

Parasite—an organism living in or on, and nourished by, another living organism, which is injured or killed.

Pathogen—an organism that causes a disease.

Pectinate—comblike; even processes on the antennae like the teeth of a comb.

Pheromone—an insect-produced chemical that stimulates a specific reaction by the receiving individuals; i.e., sex attractants.

Phloem—inner bark; tissue concerned with translocation of foodstuffs.

Pinaculum, **pinacula**—an enlarged seta-bearing papilla forming a flat plate.

Pith fleck—a small discolored spot, mark, or streak of mineral, gummy, or pithlike tissue embedded in the xylem.

Plumose—feathery.

Pole—a young tree 10.2 cm in diameter at breast height (dbh) and up to 20.3 or 30.5 cm in dbh.

Polygamy—the condition of a single male having three or more female mates.

Predator—any animal that preys on (kills and eats) other animals.

Proboscis—any extended mouth structure in members of Diptera and Lepidoptera.

Proleg—an appendage that serves the purpose of a leg, as with the abdominal legs of caterpillars and sawflies.

Pronotum—the upper surface of the prothorax.

Prosternum—the forebreast between the forelegs.

Prothoracic shield—a hardened darkened plate extending transversely across the first thoracic segment.

Prothorax—the first thoracic segment; it bears the first pair of legs but no wings.

Pubescence—short, fine, soft hairs.

Punctate—set with small puncture-like impressions.

Pupa, **pupae**—the resting stage of an insect intermediate between the larva and adult stages.
Puparium, **puparia**—the thickened, hardened, barrel-like larval skin within which the pupa is formed in Diptera.
Recumbent—lying down; reclining.
Resistance—qualities possessed by a plant that function to minimize damage by insects.
Rachis, **rachises**—extension of the petiole bearing the leaflets in compound leaves.
Reticulate—covered with a network of raised lines.
Rufous—brilliant reddish yellow.
Rugose—wrinkled.
Sapling—a young tree less than 10.2 cm in diameter at breast height.
Sapwood—living outer layers of wood, usually light in color.
Saw—a median pair of flattened plates of the ovipositor.
Sawlog—a log of suitable size (generally 30.5 cm in diameter at the small end) and quality for sawing into lumber.
Sawtimber—trees of size and quality to yield sawlogs.
Scale—flattened and modified hairs, as on wings of members of Lepidoptera.
Seedling—a young tree grown from seed, up to the sapling stage.
Serpentine—winding or turning one way then the other.
Serrate—notched like the teeth of a saw.
Serrulate—finely serrated; with minute teeth or notches.
Seta, **setae**—bristlelike hair.
Sheath—a structure enclosing the saw in sawflies.
Shelterbelt—a strip of trees or shrubs maintained to provide shelter from wind.
Shoot—any young, tender, succulent, current-year, aerial outgrowth from a plant.
Silviculture—the art and science of growing and tending forest tree crops.
Sinuate—wavy.
Spine—a large seta or thornlike process.
Spinule—a minute pointed spine.
Spiracles—breathing pores located along sides of the insect body.
Stemma, **stemmata**—simple eyes of larvae.
Sternite—the ventral part of a body segment.
Stool—a living stump (usually willow or poplar) maintained in nuserybeds to produce cuttings.
Striae—parallel, fine, longitudinal, impressed lines as on the elytra of members of Coleoptera.
Sulcate—deeply grooved.
Symbiosis—the coexistence of different species without disadvantage to either and often with mutual benefit.
Tarsus, **tarsi**—the insect foot; the outermost jointed division of the leg.
Teneral—newly transformed adult not entirely hardened or fully colored.
Tergite—the dorsal part of a segment.
Termen—the outer margin of a wing.
Tibia, **tibiae**—a single-segmented division of the insect leg between the femur and the tarsus.
Tridente—three-toothed.
Truncate—cut off squarely at the tip.
Tubercle—a small rounded projection from the surface sometimes bearing setae.
Uniordinal crochets—crochets on the proleg that are uniform in length and in a single series circle.
Vector—a carrier of a disease-producing organism.
Venter—the undersurface of the abdomen.
Vertex—the top of the head.
Vestiture—the surface covering of insects such as hairs or scales.
Windthrow—uprooting of trees by the wind.
Xylem—the principal strengthening and water-conducting tissue of branches, stems, and roots.

Diagnostic Host Index

This index should enable foresters and others not trained in entomology to identify many of the borers that cause injury to broadleaf trees and shrubs. The index serves in lieu of keys to borers and their damage and provides a means of narrowing the search for the identity of a borer observed on a particular host. **Using this index involves the following steps:**

1. Identifying the host tree or shrub,
2. Determining the part or parts that are injured,
3. Consulting the habit groups to see which one most closely describes the insect,
4. Referring to the text pages on which insects in the selected habit group are discussed and illustrated to decide which description best fits the insect and/or its injury.

Plant parts on shrubs are designated like those of trees, with trunk indicating the main stem, and the difference between twigs and small branches versus large branches based on relative size. The habit group refers to the characteristics of the larvae or adults, the type of injury caused, or the particular habits exhibited by various borer groups.

The following 16 habit groups are described and used:

Beetle, *ambrosia*—adult small, compact, cylindrical, with head largely hidden beneath thorax; larva white, legless, usually C-shaped, in frass-free gallery in xylem.

Beetle, *bark*—adult small, compact, cylindrical, with head largely hidden beneath thorax; larva white, legless, C- shaped, in frass-packed gallery in cambium region.

Beetle, *false powderpost*—adult elongate, cylindrical, with head largely hidden beneath thorax, with rasplike pronotum; larva white, C-shaped, with thoracic legs, in gallery filled with powderlike frass in xylem.

Beetle, *timber*—adult elongate, subcylindrical, with deflexed narrow head; larva elongate, cylindrical, with taillike structure, in mostly frass-free gallery deep in xylem.

Borer, *clearwing*—larva white, pink, or brown, elliptical spiracles, with thoracic legs and abdominal prolegs, in frass-free galley in phloem and/or sapwood.

Borer, *flatheaded*—larva white, elongate, slender, legless, with or without thoracic segments enlarged and flattened, in long, narrow, winding gallery in phloem and/or xylem.

Borer, *roundheaded*—larva white, fleshy, cylindrical, with or without thoracic legs and abdominal ampullae, in large frass-free or frass-packed gallery in phloem and xylem.

Carpenterworm—larva pink to white, with thoracic legs and abdominal prolegs, strong mandibles, disagreeable goatlike odor, in large, mostly frass-free gallery in phloem and xylem.

Caterpillar—larva variable in color and size, cylindrical, 13 body segments, with thoracic legs and fleshy abdominal prolegs, usually in frass-free gallery in shoots or phloem and/or xylem of roots and stems.

Gallformer—larva white to brown, size and form variable, gallery with or without frass, in galls.

Girdler/pruner, *flatheaded*—larva white, thoracic segments enlarged and flattened, narrow frass-packed gallery, xylem of stem severed leaving phloem intact, which usually breaks.

Girdler/pruner, *roundheaded*—larva white, fleshy, cylindrical, frass-free or frass-packed gallery, xylem of stem severed leaving phloem intact, which usually breaks; in a few species, the adult girdles the stem from the outside.

Horntail—larva white, cylindrical, slightly S-shaped, abdomen ending in hornlike projection, in frass-packed gallery in xylem.

Miner, *cambium*—larva white, long, slender, legless, headless, with hooklike mouthparts, in long, narrow, frass-packed mine in cambium region.

Sawfly—larva yellowish white to purplish green, curved to S- shaped, cylindrical, with small thoracic legs, in frass- packed gallery, usually in tender shoots and stems.

Weevil—larva white, subcylindrical, fleshy, C-shaped, legless, in gallery containing some

dark frass in shoots, stems, or under bark.

(For additional details on habit groups, see the introductory text at the beginning of each order and family).

Acacia
Twigs, small branches
Girdler/pruner, roundheaded
Oncideres rhodosticta 329
Trunk, large branches
Beetle, ambrosia
Xyleborus dispar 564
Borer, flatheaded
Chrysobothris merkelii 273

Alder
Buds, shoots, petioles
Caterpillars
Achatodes zeae 209
Epinotia nisella 151
Twigs, small branches
Girdler/pruner, roundheaded
Xylotrechus quadrimaculatus 457
Trunk, large branches
Beetles, ambrosia
Trypodendron betulae 556
Xyleborus dispar 564
Xyloterinus politus 551
Beetle, bark
Alniphagus aspercollis 527
Borers, clearwing
Paranthrene asilipennis 40
Synanthedon culiciformis 97
Borers, flatheaded
Agrilus burkei 230
Agrilus pensus 232
Chrysobothrus mali 270
Eupristocerus cogitans 262
Borers, roundheaded
Neoptychodes trilineatus 314
Saperda obliqua 359
Stenodontes dasytomus masticator 401
Weevils
Cryptorhynchus lapathi 492
Magdalis aenescens 495
Roots, root collar
Borer, clearwing
Paranthrene asilipennis 40
Borer, roundheaded
Prionus californicus 393
Caterpillar
Sthenopis argenteomaculatus 6

Alder, black
Trunk, large branches
Borer, roundheaded
Saperda obliqua 359

Alder, Italian
Trunk, large branches
Borer, flatheaded
Agrilus burkei 230

Alder, mountain
Trunk, large branches
Borer, flatheaded
Agrilus burkei 230

Alder, Oregon
Trunk, large branches
Beetle, bark
Alniphagus aspercollis 527

Alder, speckled
Trunk, large branches
Borers, flatheaded
Agrilus pensus 232
Eupristocerus cogitans 262
Roots, root collar
Caterpillar
Sthenopis argenteomaculatus 6

Alder, white
Trunk, large branches
Borer, flatheaded
Agrilus burkei 230
Beetle, bark
Alniphagus aspercollis 527

Alkali blite
Roots, root collar
Carpenterworm
Comadia suaedivora 131

Almond
Buds, shoots, petioles
Caterpillar
Anarsia lineatella 22
Twigs, small branches
Beetle, false powderpost
Melalgus confertus 288

Caterpillar
Anarsia lineatella 22
Trunk, large branches
Borer, clearwing
Synanthedon exitiosa 59
Roots, root collar
Borer, clearwing
Synanthedon exitiosa 59
Borer, roundheaded
Prionus californicus 393
American cranberrybush
Trunk, large branches
Borer, clearwing
Synanthedon fatifera 96
Antelope brush
Twigs, small branches
Pruner/girdler, roundheaded
Aneflomorpha lineare 421
Apple
Buds, shoots, petioles
Caterpillars
Grapholita molesta 160
Grapholita packardi 162
Ostrinia nubilalis 189
Papaipema nebris 202
Spilonota ocellana 147
Twigs, small branches
Beetles, false powderpost
Amphicerus bicaudatus 284
Melalgus confertus 288
Xylobiops basilaris 286
Borers, roundheaded
Oberea bimaculata 376
Oberea ocellata 383
Carpenterworm
Zeuzera pyrina 127
Caterpillars
Grapholita molesta 160
Grapholita packardi 162
Ostrinia nubilalis 189
Girdlers/pruners, roundheaded
Anelaphus parallelus 429
Anelaphus villosus 431
Oncideres cingulata cingulata 324
Trunk, large branches
Beetles, ambrosia
Monarthrum fasciatum 548
Monarthrum mali 546
Xyleborus dispar 564
Xyleborus xylographus 563
Xylosandrus germanus 572
Beetle, bark
Scolytus rugulosus 506
Beetle, false powderpost
Xylobiops basilaris 286
Borers, clearwing
Synanthedon pyri 78
Synanthedon scitula 65
Borers, flatheaded
Agrilus vittaticollis 254
Chrysobothris femorata 267
Chrysobothris mali 270
Borers, roundheaded
Neoclytus acuminatus 464
Parandra brunnea 385
Saperda candida 346
Saperda cretata 349
Synaphaeta guexi 316
Carpenterworm
Zeuzera pyrina 127
Caterpillars
Euzophera semifuneralis 169
Hepialus californicus 10
Horntail
Tremex columba 597
Weevils
Conotrachelus anaglypticus 490
Magdalis aenescens 495
Roots, root collar
Borer, flatheaded
Agrilus vittaticollis 254
Borers, roundheaded
Archodontes melanopus melanopus 396
Prionus californicus 393
Prionus imbricornis 388
Prionus laticollis 390
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Hepialus californicus 10
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Caterpillars
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Melalgus confertus 288
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Xyleborus dispar 564
Beetle, bark
Scolytus rugulosus 506
Borer, clearwing
Synanthedon exitiosa 59
Borers, flatheaded
Chrysobothris femorata 267
Chrysobothris mali 270
Caterpillar
Euzophera semifuneralis 169
Roots, root collar
Borer, clearwing
Synanthedon exitiosa 59
Arrowwood
Trunk, large branches
Borer, clearwing
Synanthedon viburni 94
Ash
Buds, shoots, petioles
Borer, clearwing
Podosesia syringae 30
Caterpillars
Papaipema furcata 207
Papaipema nebris 202
Twigs, small branches
Beetle, ambrosia
Xyleborus sayi 565
Beetles, bark
Hylesinus californicus 517
Hylesinus criddlei 519
Beetles, false powderpost
Amphicerus bicaudatus 284
Xylobiops basilaris 286
Carpenterworm
Zeuzera pyrina 127
Trunk, large branches
Beetles, ambrosia
Xyleborus dispar 564
Xyleborus ferrugineus 561
Xylosandrus germanus 572
Xyloterinus politus 551
Beetles, bark
Hylesinus aculeatus 514
Hylesinus californicus 517
Hylesinus criddlei 519
Hylurgopinus rufipes 512
Borers, clearwing
Paranthrene asilipennis 40
Podosesia aureocincta 33
Podosesia syringae 30
Borer, flatheaded
Chrysobothris mali 270
Borers, roundheaded
Neoclytus acuminatus 464
Saperda lateralis 363
Tylonotus bimaculatus 413
Carpenterworms
Prionoxystus robiniae 112
Zeuzera pyrina 127
Miner, cambium
Phytobia sp. 631
Roots, root collar
Borer, clearwing
Paranthrene asilipennis 40
Miner, cambium
Phytobia sp. 631
Ash, black
Buds, shoots, petioles
Caterpillar
Papaipema furcata 207
Trunk, large branches
Borer, roundheaded
Parandra brunnea 385
Ash, Carolina
Trunk, large branches
Borer, clearwing
Podosesia syringae 30
Ash, European
Trunk, large branches
Borer, clearwing
Podosesia syringae 30
Ash, green
Buds, shoots, petioles
Borer, clearwing
Podosesia syringae 30

Caterpillar
Papaipema furcata 207
Twigs, small branches
Beetles, bark
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Trunk, large branches
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Podosesia syringae 30
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Beetle, bark
Hylesinus californicus 517
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Trunk, large branches
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Podosesia syringae 30
Ash, white
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Caterpillar
Papaipema furcata 207
Twigs, small branches
Beetle, bark
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Beetles, bark
Hylesinus californicus 517
Hylesinus criddlei 519
Trunk, large branches
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Podosesia syringae 30
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Miner, cambium
Phytobia sp. 631
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Borers, roundheaded
Oberea schaumii 367
Saperda inornata 339
Trunk, large branches
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Agrilus horni 220
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Sesia tibialis 51
Borer, flatheaded
Agrilus horni 220
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Beetle, false powderpost
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Xylosandrus compactus 569
Trunk, large branches
Borer, clearwing
Synanthedon resplendens 72
Borer, flatheaded
Chrysobothris mali 270
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Oberea tripunctata 374
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Borer, clearwing
Synanthedon rhododendri 75
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Hepialus californicus 10
Baccharis
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Chrysobothris bacchari 272
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Stenodontes lobigenis 402
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Common and Scientific Names of Host Plants

acacia	*Acacia* spp.
ailanthus	*Ailanthus altissimia* (Mill.) Swingle
alder	*Alnus* spp.
black	*Alnus glutinosa* (L.) Gaertn.
Italian	*Alnus cordata* Desf.
mountain	*Alnus tenuifolia* Nutt.
Oregon	*Alnus* sp.
speckled	*Alnus rugosa* (Du Roi) Spreng.
white	*Alnus incana* Moench.
alkali blite	*Suaeda fruticosa* (L.) Forsk.
almond	*Prunus dulcis* (Miller) D.A. Webb
American cranberrybush	*Viburnum trilobum* Marsh.
antelope brush	*Purshia* sp.
apple	*Malus domestica* Borkh.
apricot	*Prunus armeniaca* L.
Arizonia cypress	*Cupressus arizonica* Greene
arrowwood	*Viburnum dentatum* L.
ash	*Fraxinus* spp.
black	*Fraxinus nigra* Marsh.
Carolina	*Fraxinus caroliniana* Mill.
European	*Fraxinus excelsior* L.
green	*Fraxinus pennsylvanica* Marsh.
Oregon	*Fraxinus latifolia* Benth.
white	*Fraxinus americana* L.
aspen	*Populus* spp.
bigtooth	*Populus grandidentata* Michx.
European	*Populus tremula* L.
quaking	*Populus tremuloides* Michx.
(see also poplar)	
(see also cottonwood)	
Australian pine	*Casuarina equesitifolia* L.
avocado	*Persea americana* Mill.
azalea	*Rhododendron* spp.
baccharis	*Baccharis* spp.
eastern	*Baccharis halimifolia* L.
seepwillow (mulefat)	*Baccharis glutinosa* Pers.
baldcypress	*Taxodium distichum* (L.) Rich.
basswood	*Tilia* spp.
American	*Tilia americana* (L.)
(see also linden)	
bayberry	*Myrica pensylvanica* Lois.
beech	*Fagus* sp.
American	*Fagus grandifolia* Ehrh.
birch	*Betula* spp.
gray	*Betula populifolia* Marsh.

paper	*Betula papyrifera* Marsh.
river	*Betula nigra* L.
sweet	*Betula lenta* L.
western paper	*Betula papyrifera* var. *commutata* (Regel) Fern.
white	*Betula* sp.
yellow	*Betula alleghaniensis* Britton
blackbead	*Pithecellobium* spp.
blackberry	*Rubus* sp.
blackgum (see also black tupelo)	*Nyssa sylvatica* Marsh.
blackhaw	*Viburnum prunifolium* L.
blueberry	*Vaccinium* spp.
blue paloverde	*Cercidium floridum* Benth. ex Gray
Boston ivy, Japanese ivy	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planchon
boxelder	*Acer negundo* L.
box-thorn	*Lycium* sp.
boysenberry (loganberry)	*Rubus loganobaccus* L.H. Bailey
buckeye	*Aesculus* spp.
California	*Aesculus californica* (Spach.) Nutt.
Ohio	*Aesculus glabra* Willd.
burdock	*Arctium* spp.
bursera	*Bursera* spp.
butternut	*Juglans cinerea* L.
buttonbush	*Cephalanthus occidentalis* L.
California boxelder	*Acer negundo* ssp. *californicum* (Torr. & Gray) Wesmael
camphor-tree	*Cinnamomum camphora* (L.) J.S. Presl
catalpa	*Catalpa* spp.
catclaw	*Acacia greggii* Gray
ceanothus	*Ceanothus* spp.
blueblossom	*Ceanothus thyrsiflorus* Eschsch.
cedar	
eastern redcedar	*Juniperus virginiana* L.
Spanish	*Cedrela odorata* L.
cherry	*Prunus* spp.
black	*Prunus serotina* Ehrh.
mahaleb	*Prunus mahaleb* L.
sour	*Prunus cerasus* L.
wild	*Prunus* spp.
chestnut	*Castanea* spp.
American	*Castanea dentata* (Marsh.) Borkh.
chokecherry	*Prunus virginiana* L.
coralbean	*Erythrina fusca* Lour.

corn	*Zea mays* L.
cotoneaster	*Pyracantha coccinea Roem.*
cottonwood	*Populus* spp.
black	*Populus trichocarpa* Torr. & Gray
eastern	*Populus deltoides* Bartr. ex Marsh.
Fremont	*Populus fremontii* Wats.
lanceleaf	*Populus acuminata* Rydb.
narrowleaf	*Populus angustifolia* James
plains	*Populus deltoides* var. *occidentalis* Rydb.
swamp	*Populus heterophylla* L.
(see also: poplar and aspen)	
coyote brush	*Baccharis pilularis* DC.
crabapple	*Malus sylvestris* (L.) Mill.
currant	*Ribes* spp.
dewberry	*Rubus* spp.
dogwood	*Cornus* spp.
red-osier	*Cornus stolonifera* Michx.
ebony	*Pithecellobium* spp.
blackbead	*Pithecellobium flexicaule* (Benth.) Coult.
elder	*Sambucus* spp.
American	*Sambucus canadensis* L.
blackbead	*Sambucus* sp.
blue	*Sambucus cerulea* Raf.
European	*Sambucus nigra* L.
Pacific red	*Sambucus callicarpa* Greene
elm	*Ulmus* spp.
American	*Ulmus americana* L.
cedar	*Ulmus crassifolia* Nutt.
English	*Ulmus procera* Salisb.
slippery	*Ulmus rubra* Muhl.
eucalyptus	*Eucalyptus* spp.
Blakely's red gum	*Eucalyptus blakelyi* Maiden
Blue gum	*Eucalyptus globulus* Labill.
manna gum	*Eucalyptus viminalis* Benth.
sugar gum	*Eucalyptus cladocalyx* F. Muell.
fig	*Ficus* spp.
fringetree	*Chionanthus virginicus* L.
giant ragweed	*Ambrosia trifida* L.
gingko	*Gingko biloba* L.

goldenrod	*Solidago* spp.
golden-shower	*Cassia fistula* L.
gooseberry	*Ribes* spp.
grape	*Vitis* spp.
greasewood	*Sarcobatus* sp.
black	*Sarcobatus vermiculatus* (Hook.) Torrey
great leucaena	*Leucaena pulverulenta* (Schlecht.) Benth.
guajillo	*Acacia berlandieri* Benth.
gumbo-limbo	*Bursera simaruba* (L.) Sarg.
hackberry	*Celtis* spp.
netleaf	*Celtis reticulata* Torr.
hawthorn	*Crataegus* spp.
cockspur	*Crataegus crus-galli* L.
pear	*Crataegus calpodendron* (Ehrh.) Medic.
hazel (hazelnut)	*Corylus* spp.
hemlock	*Tsuga* spp.
hickory	*Carya* spp.
bitternut	*Carya cordiformis* (Wangenh.) Koch
mockernut	*Carya tomentosa* (Poir.) Nutt.
pignut	*Carya glabra* (Mill.) Sweet
shagbark	*Carya ovata* (Mill.) Koch
water	*Carya aquatica* (Michx.) Nutt.
(see also pecan)	
holly	*Ilex* spp.
American	*Ilex opaca* Ait.
honeylocust	*Gleditsia triacanthos* L.
hop	*Humulus lupulus* L.
hophornbeam	*Ostrya* spp.
eastern	*Ostrya virginiana* (Mill.) Koch
hornbeam	*Carpinus* sp.
American	*Carpinus caroliniana* Walt.
horsebean	*Parkinsonia aculeata* L.
horsechestnut	*Aesculus* spp.
(see buckeye)	
huisache	*Acacia farnesiana* (L.) Willd.
indigobush	
(see smokethorn)	
Jerusalem-thorn	*Parkinsonia aculeata* L.
kapok	*Ceiba pentandra* (L.) Gaertner
larch	*Larix* spp.

laurel (mountain-laurel)	*Kalmia* spp.
laurelcherry	*Prunus* spp.
Carolina	*Prunus caroliniana* (Mill.) Ait.
leadplant	*Amorpha canescens* Pursh.
lilac	*Syringa vulgaris* L.
linden	*Tilia* spp.
European	*Tilia cordata* Mill.
(see also basswood)	
lindheimer mimosa	*Mimosa lindheimeri* Gray
locust	*Robinia* spp.
black	*Robinia pseudoacacia* L.
New Mexico	*Robinia neomexicana* Gray
loquat	*Eriobotrya japonica* (Thunb.) Lindley
lupine	*Lupinus* spp.
madrone	*Arbutus* spp.
magnolia	*Magnolia* spp.
southern	*Magnolia grandiflora* L.
mahogany	*Swietenia* spp.
mango	*Mangifera indica* L.
mangrove	*Rhizophora mangle* L.
manzanita	*Manzanita* spp.
maple	*Acer* spp.
bigleaf	*Acer macrophyllum* Pursh.
black	*Acer nigrum* Michx.
Florida	*Acer barbatum* Michx.
mountain	*Acer spicatum* Lam.
Norway	*Acer platanoides* L.
planetree	*Acer pseudoplatanus* L.
red	*Acer rubrum* L.
Rocky Mountain	*Acer glabrum* Torr.
silver	*Acer saccharinum* L.
southern sugar	*Acer barbatum* Michx.
(see Florida maple)	
striped	*Acer pensylvanicum* L.
sugar	*Acer saccharum* Marsh.
mazzard (sweet cherry)	*Prunus avium* (L.)
mesquite	*Prosopis* spp.
honey	*Prosopis glandulosa* Torr.
western honey	*Prosopis glandulosa* var. *torreyana* (L. Benson) M.C. Johnst.
mimosa	*Albizia julibrissin* Durazzini
mistletoe	*Phoradendron* spp.
mountain-ash, American	*Sorbus americana* Marsh.
mountain-laurel	*Kalmia latifolia* L.
mountain-mahogany	*Cercocarpus* spp.

mulberry	*Morus* spp.
red	*Morus rubra* L.
Russian (see white)	
white	*Morus alba* L.
nannyberry	*Viburnum lentago* L.
nectarine	*Prunus persica* var. *nuciperscia* (Suckow) C. Schneider
ninebark	*Physocarpus opulifolius* (L.) Maxim.
oak	*Quercus* spp.
Arizona white	*Quercus arizonica* Sarg.
bear	*Quercus ilicifolia* Wangenh.
black	*Quercus velutina* Lam.
blackjack	*Quercus marilandica* Muenchh.
bur	*Quercus macrocarpa* Michx.
California black	*Quercus kelloggii* Newb.
California scrub	*Quercus dumosa* Nutt.
canyon live	*Quercus chrysolepis* Liebm.
cherrybark	*Quercus falcata* var. *pagodifolia* Ell.
chestnut	*Quercus prinus* L.
chinkapin	*Quercus muehlenbergii* Engelm.
coast live	*Quercus agrifolia* Nee
Dunn	*Quercus dunnii* Kellogg
Emory	*Quercus emoryi* Torr.
Engelmann	*Quercus engelmannii* Greene
Gambel	*Quercus gambelii* Nutt.
interior live	*Quercus wislizeni* A. DC.
laurel	*Quercus laurifolia* Michx.
live	*Quercus virginiana* Mill.
Mexican blue	*Quercus oblongifolia* Torr.
northern red	*Quercus rubra* L.
Nuttall	*Quercus nuttallii* Palmer
Oregon white	*Quercus garryana* Dougl. ex Hook.
overcup	*Quercus lyrata* Walt.
pin	*Quercus palustris* Muenchh.
post	*Quercus stellata* Wangenh.
scarlet	*Quercus coccinea* Michx.
scrub	*Quercus* sp.
Shumard	*Quercus shumardii* Buckl.
silverleaf	*Quercus hypoleucoides* A. Camus
southern red	*Quercus falcata* Michx.
swamp chestnut	*Quercus michauxii* Nutt.
swamp white	*Quercus bicolor* Willd.
turkey	*Quercus laevis* Walt.
water	*Quercus nigra* L.

white	*Quercus alba* L.
willow	*Quercus phellos* L.
olive	*Olea europaea* L.
orange (sweet)	*Citrus sinensis* (L.) Osbeck
Osage-orange	*Maclura pomifera* (Raf.) Schneid.
paperbark-tree (bottlebrush or cajeput-tree)	*Melaleuca quinquenervia* (Cav.) S.T. Blake
paulownia	*Paulownia tomentosa* (Thunb.) Sieb. & Zucc. ex Steud.
peach	*Prunus persica* Batsch.
peanut	*Arachis hypogaea* L.
pear	*Pyrus communis* L.
pecan (see also hickory)	*Carya illinoensis* (Wangenh.) K. Koch
pentstemon	*Pentstemon* spp.
peppertree (California)	*Schinus molle* L.
persimmon	*Diospyros* spp.
common	*Diospyros virginiana* L.
Japanese	*Diospyros kaki* L.
photinia	*Heteromeles* spp.
pigeon plum	*Coccoloba diversifolia* Jacq.
pine	*Pinus* spp.
plum	*Prunus* spp.
beach	*Prunus maritima* Marshall
Chickasaw	*Prunus angustifolia* Marshall
Chinese	*Prunus* sp.
garden	*Prunus domestica* L.
wild	*Prunus* sp.
poison ivy	*Toxicodendron radicans* (L.) Kuntze
poison oak	*Toxicodendron diversilobum* (Torrey & A. Gray) E. Greene
pomegranate	*Punica granatum* L.
poplar	*Populus* spp.
balsam	*Populus balsamifera* L.
Lombardy	*Populus nigra* var. *italica* Muenchh.
white (silver) (see also aspen and cottonwood	*Populus alba* L.
privet	*Ligustrum* spp.
pyracantha	*Pyracantha* spp.
quince	*Cydonia oblonga* Miller
raspberry	*Rubus* spp.

redbay	*Persea borbonia* (L.) Spreng.
redbud	*Cercis* spp.
eastern	*Cercis canadensis* L.
rhododendron	*Rhododendron* spp.
rose	*Rosa* spp.
rush bebbia	*Bebbia juncea* (P.H. Timberlake)
Saltbush	*Atriplex* sp.
fourwing	*Atriplex canescens* (Pursh.) Nutt.
Gardner	*Atriplex gardneri* (Moq.) D. Dietr.
Parry	*Atriplex parryi* Wats.
shadscale	*Atriplex confertifolia* (Torr. & Frem.)
sassafras	*Sassafras albidum* (Nutt.) Nees
seagrape	*Coccoloba uvifera* (L.) L.
serviceberry	*Amelanchier* spp.
downy	*Amelanchier arborea* (Michx.) Fern.
western	*Amelanchier alnifolia* (Nutt.) Nutt.
smokethorn	*Dalea spinosa* Gray
sneezeweed	*Helenium* sp.
sourwood	*Oxydendrum arboreum* (L.) DC.
Spanish cedar	*Cedrela odorata* L.
spicebush	*Lindera benzoin* (L.) Blume
spruce	*Picea* spp.
sugarberry (see also hackberry)	*Celtis laevigata* Willd.
sumac	*Rhus* spp.
smooth (common)	*Rhus glabra* L.
poison-sumac	*Rhus vernix* L.
sweetfern	*Comptonia* peregrina (L.) J.M. Coulter
sweetgum	*Liquidambar styraciflua* L.
sweetleaf	*Symplocos tinctoria* (L.) L'Her.
sycamore	*Platanus occidentalis* L.
Arizona	*Platanus wrightii* Wats.
California	*Platanus racemosa* Nutt.
thistle	*Carduus* spp.
tupelo	*Nyssa* spp.
water	*Nyssa aquatica* L.
black (see also blackgum)	*Nyssa sylvatica* Marsh.
viburnum	*Viburnum* spp.
Virginia creeper	*Parthenocissus quinquefolia* L. Planch.

walnut	*Juglans* spp.
black	*Juglans nigra* L.
English	*Juglans regia* L.
Japanese	*Juglans sieboldiana* Maxim.
willow	*Salix* spp.
acute leaf	*Salix* sp.
arroyo	*Salix lasiolepis* Benth.
black	*Salix nigra* Marsh.
Bonpland	*Salix bonplandiana* H.B.K.
crack	*Salix fragilis* L.
European yellow	*Salix* sp.
golden leaf	*Salix* sp.
laurel leaf	*Salix pentandra* Lorbeerweide
meadow	*Salix petiolaris* J.E. Sm.
Pacific	*Salix lasiandra* Benth.
sandbar (coyote)	*Salix exigua* (Nutt.)
Scouler	*Salix scoulerana* Barrett ex Hook.
weeping	*Salix babylonia* L.
wisteria	*Wisteria* spp.
witch-hazel	*Hamamelis virginiana* L.
yellow-poplar	*Liriodendron tulipifera* L.
Zelkova	*Zelkova* sp.
Japanese	*Zelkova serrata* (Thunb.) Makino

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