The Great Trinity Forest Management Plan

Volume 23

Insects and Disease

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Insects and Diseases

Native insects and diseases are a natural part of any ecosystem, even for an urban forest such as the Great Trinity Forest. In a healthy forest, these problems will be present but they rarely do excessive damage to the forest. This is because healthy trees are better able to withstand and recover from these natural attacks. However, when trees are under stress from extreme weather conditions, such as drought and flooding, or injuries from construction, logging, pruning or wildlife, they are more prone to succumbing to insect and disease attacks. Some insects and diseases can even attack and significantly damage healthy trees so it is important to immediately identify and manage insects and diseases that are causing significant damage to the forest. The following describe some insects and diseases that are causing significant damage to trees in the United States.

Oak wilt is a disease caused by the fungus *Ceratocystis fagacearum*. This disease attacks and kills all oak (Quercus spp.) species, but white oaks are moderately resistant. This fungus is spread by insects and root grafts, which are connected root systems that usually only occur between the same or closely related species. Oak wilt can be prevented by avoiding injuring trees, especially from February to June in Texas and, if a tree is injured, then the wound should be treated immediately with commercial tree paint or wound dressing. For high value trees, there are some fungicides available that prevent oak wilt. But these chemicals are costly and the tree must be injured to inject them. If trees in the forest are already infected then the root grafts between the infected and noninfected trees should be cut with a trencher, vibratory plow or biocidal chemicals before or soon after the tree dies. The wood should then be treated to prevent spores from developing. (O'Brien et al. 2000)

The emerald ash borer (EAB) is a dangerous insect from Asia which was discovered in the United States in 2002. This insect does not currently occur in Texas but it is causing significant damage to ash (*Fraxinus* spp.) trees in several northern states and may eventually spread to the south. If an area is near infected sites and it has a large number of ash trees then one option is to harvest, girdle or cut and leave the ash trees. This option will reduce the density of EAB populations in the area and may even slow its spread. Other tree species in the forest can be planted or naturally regenerated to create a diverse forest that is not susceptible to EAB. To protect healthy trees or save a mildly infect tree a manager can use insecticides but a tree must be treated every year. Therefore, this method is not appropriate over large areas or outside quarantined areas. (Smitley 2005, Michigan State University 2007)

Another disease is dutch elm disease which is caused by the fungus' *Ophisotoma ulmi* and *Ophisotoma novo-ulmi.* This introduced disease attacks elm (*Ulmus* spp.) trees. The American elm (*U. americana*) is the most susceptible. The fungus' are spread by root grafts and insects, especially the native (*Hylurgopinus rufipes)* and European (*Scolytus multistriatus)* elm bark beetles. This disease can be managed by cutting root grafts or by using insecticides to control bark beetles. Other preventative measures include using fungicides, planting resistant or tolerant elm trees, removing diseased, stressed, dead and dying elms and pruning weakened, dying or dead branches. A newly infected tree may even be saved by pruning infected branches and/or by using fungicide (but only if less than 5% of the crown is affected, the tree was infected by insect vectors and if the disease is not present in the main stem). In large natural or wild areas a trap tree can be used to reduce elm bark beetle populations. In this method a live, infected tree is treated with an herbicide that kills it and rapidly dries the bark. This attracts the beetles but is unsuitable for them to complete their life cycle. (Haugen 1998)

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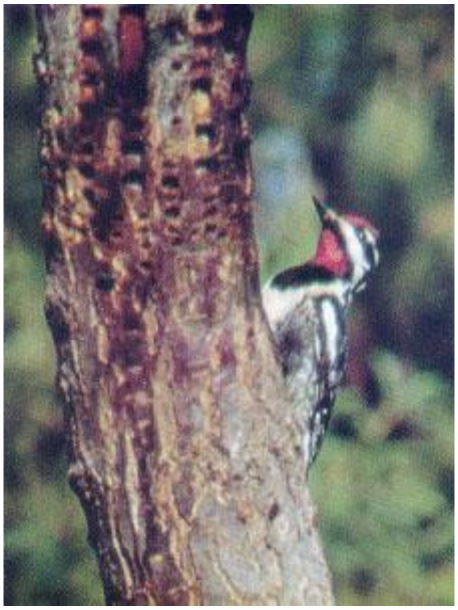

Identify and control sapsucker injury on trees

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The yellow-bellied sapsucker (*Sphyrapicus varius*), a member of the woodpecker family, is a migratory bird whose summer breeding range includes the Lakes States region. The identifying field markings of adult birds are a black crescent on the breast, pale yellow belly, white wing stripe, and a crimson crown. The male also has a crimson chin and throat, distinguishing him from the female whose chin and throat are white.

Although insects make up part of its diet, the sapsucker is better known for its boring of numerous holes in the bark of live trees to obtain sap, the activity from which it derives its name. The yellow-bellied sapsucker is the only member of the woodpecker family to cause this type of injury. More than 250 species of woody plants are known to be attacked. Birch, maple, and hemlock are the preferred species in the Lakes States.

The sapsucker bores neat rows of 1/4-inch holes spaced closely together through the bark of trees along and around portions of the limbs or trunk. As these holes fill with sap the sapsucker uses its brush-like tongue to draw it out.

These holes are periodically enlarged and portions of the cambium and inner bark, together with the fresh sap, are eaten.

Puncture wounds and resulting sap flow on branches and trunks of trees are the most obvious symptoms of injury inflicted by the sapsucker.

After repeated attacks on the same area of a tree, large patches of bark may be removed. If this area is girdled, the portion of tree above this point will die. Many small limbs are killed and some- times the trunk is girdled and the whole tree is killed.

Sapsucker feeding on shade and ornamental trees leaves unsightly bleeding wounds that attract bees, hornets, and other insects to the sweet, oozing sap. On forest trees these wounds may attract porcupines or red squirrels that further injure the trees through feeding.

Early in the spring the sapsucker tests many trees around its selected nesting site by making sample drillings before selecting ones it prefers. These trees, because of quantity or sugar content of the sap, are visited several times a day for the rest of the season and sometimes are used as a food source for several years.

Feeding wounds serve as entry courts for a wide variety of wood decay or stain fungi and bacteria. On high quality hardwoods, sapsucker wounds cause a grade defect called "bird peck" that lowers the value of the trees.

Many forest trees are attacked high in the crowns, making light feeding wounds or sample drillings less evident. A condition known as black bark may develop which results from certain fungi colonizing the sap flow and discoloring the bark, and is good evidence that injury exists. Black bands can develop on white birch as a result of a healing reaction to sapsucker injury.

Control

To discourage sapsuckers from feeding on a favorite shade tree, wrap hardware cloth or burlap around the area being tapped or smear a sticky repellent material, such as bird tanglefoot, on the bark.

In commercial forests or orchards, leave favorite feeding trees of the sapsucker untreated. Birds will concentrate their feeding activities on these favorite trees, which often protects nearby trees from serious injury.

Sapsuckers in search of nesting sites are especially attracted to aspen (*Populus tremuloides*) infected with *Fomes igniarius* var. *populinus*, which decays the heartwood and enables the birds to excavate a nest hole. To protect a valuable timber stand eliminate such infected trees within the stand during a precommercial thinning; this may discourage sapsuckers from using the area.

The Migratory Bird Treaty Act and Federal regulations promulgated under its authority prohibit shooting of sapsuckers. Shooting of this species would be an ineffective control anyway because transient birds tend to replace occasional losses to local sapsucker populations.

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U.S. Department of Agriculture • Forest Service

Mistletoes on Hardwoods in the United States

Forest Pest Leaflet 147
August 1974

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The traditional use of mistletoes during holiday seasons, their involvement in folklore and legend, their consumption by domestic and wild animals, and their use for medicinal purposes make mistletoes of widespread interest to the public. The fact that these plants are parasites that injure and eventually kill trees both conifers and hardwoods is not well known.

Two genera of mistletoes grow in the United States: the "dwarf mistletoes" (genus *Arceuthobium*),and the "true mistletoes" (genus *Phoradendron*). An introduced mistletoe, the European *Viscum album*, has been found only in northern California--the apple growing region around Sebastopol and Santa Rosa. This mistletoe was presumably brought into this area inadvertently in the early l900's on apple stock from Europe. Since then, it has spread over about a 16 square mile area, and is found on at least 20 other native and introduced hardwood tree and shrub species.

Members of the genus *Phoradendron* are parasites of conifer and hardwood trees and shrub in the Western Hemisphere. Their area of greatest diversity is centered in the tropics. This leaflet describes seven species of native true mistletoe that are found on hardwoods in many parts of Eastern, Western, and Southern United States. The one most commonly known and widespread is *P. serotinum* (also known as *P. flavescens*) which occurs mainly in the East and Southeast. *P. rubrum* which occurs on mahogany in southern Florida is the only other species in the East. The other five species of mistletoe occur in the Southwest and along the Pacific Coast.

General Biology

The mistletoes are green, flowering plants that require a living host. Some are rather specific and grow on only a single genus of tree; others occur on a wide range of hardwood species. Even though they are completely parasitic, they do manufacture much of their own food materials by photosynthesis and in general require only water and mineral elements from the host plant. In the absence of the green aerial portions of the mistletoe plant, how ever, the root system of the parasite can utilize host nutrients and remain alive within an infected branch for many years. The mistletoes are dioecoius in that male and female flowers are borne on separate plants (figs. 1,2). Because male and female flowers are so similar in appearance it is difficult to tell the sex of the plant unless fruit are present.

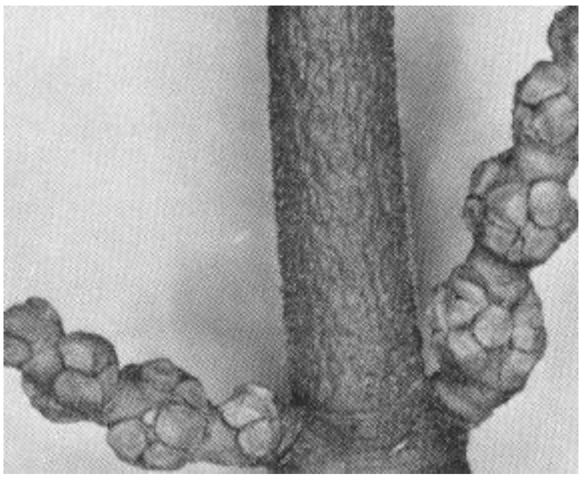

Figure 1. Unopened male flowers on an infloresence of *P. tomentosum* ssp. *macrophyllum*.

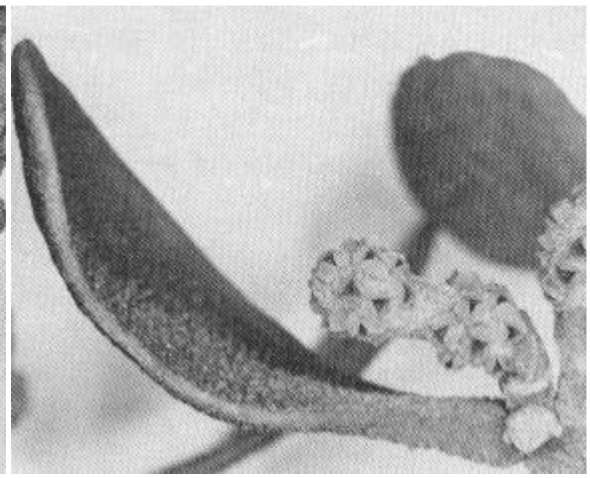

Figure 2. Mature female flowers on an infloresence of *P. villosum* ssp. *villosum*.

Mistletoe infections are spread mainly by birds (robins, bluebirds, thrushes, cedar waxwings, phainopeplas) that feed on the berries. The berries are round, white to pink in color, occur in spikes and are about one-quarter inch in diameter (fir.3). A berry usually holds a single seed surrounded by a sticky pulp. Birds digest the pulp of the berry and excrete the living seed. By this means seeds are often deposited on susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach excreted seeds firmly to tree branches. Upon germinating, the growing radicle becomes tightly pressed to the branch surface. Young or small trees are seldom infected by mistletoe. In nearly all cases, initial infection occurs on larger or older trees because birds prefer to perch in the tops of taller trees. Severe buildup of mistletoe often occurs within an infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

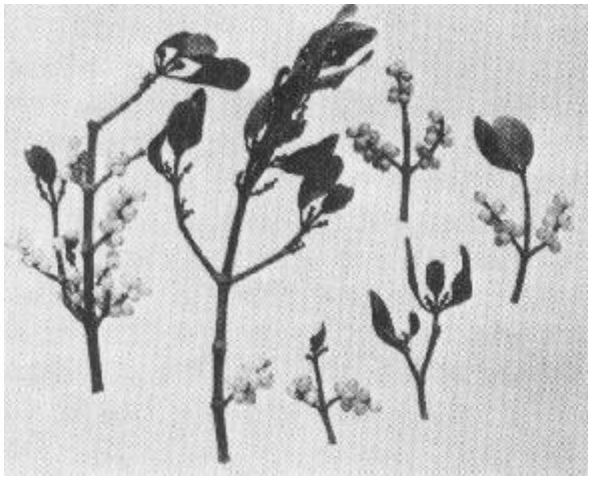
Figure 3. Shoots and mature fruit of *P. serotinum*.

Infection takes place by means of a specialized, penetrating structure that forces its way through the bark and into the living host tissues. Once infection has occurred, the root system of the parasite grows within the branch. The aerial shoot system begins to develop shortly after the root system is well established. Often several years are required after infection for a new seed bearing plant to develop. The parasite usually does not spread rapidly, but once a plant is established, the root system gradually extends up and down the branch. Defoliation or destruction of the aerial portion does not kill the mistletoe. New shoots may be produced from the root system or the parasite may survive and grow entirely within the infected host tissues. Not until the tree dies, or the infected portion dies or is removed, is the mistletoe killed.

The mistletoes are rather intolerant of cold and near their northern limits aerial shoots are frequently killed by low winter temperatures.

Description of the Species

In general, the mistletoes on hardwoods are not always easy to distinguish from one another. Characteristics of the shoots, leaves, fruit and flowers are features used to separate the species. Two other aids to identification are: (1) geographic distribution (figs. 4, 5) and (2) host species infected (Table 1).

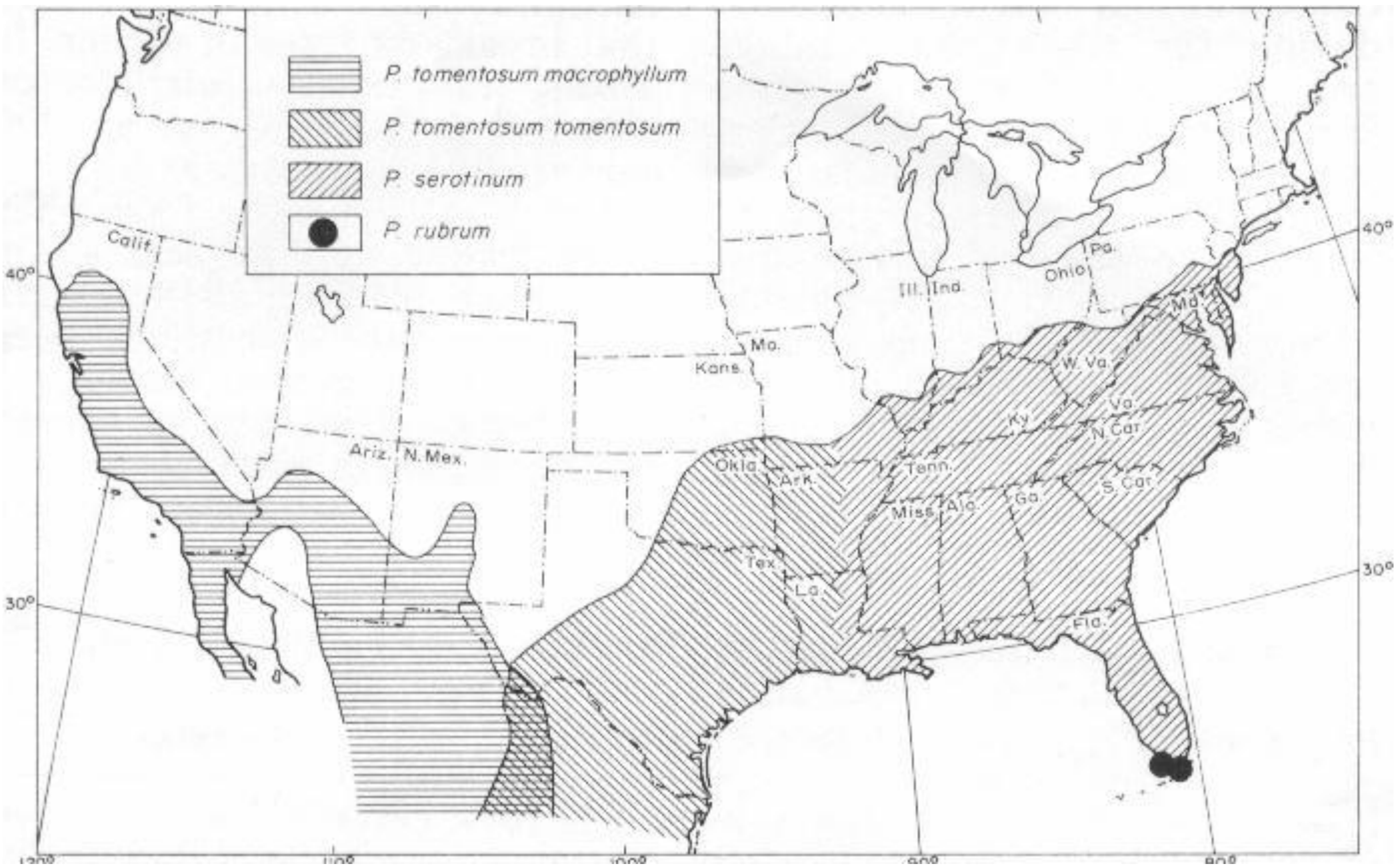

Figure 4. Geographic distribution of *Phoradendron tomentosum macrophyllum, P. tomentosum tomentosum, P. serotinum,* and *P. rubrum*.

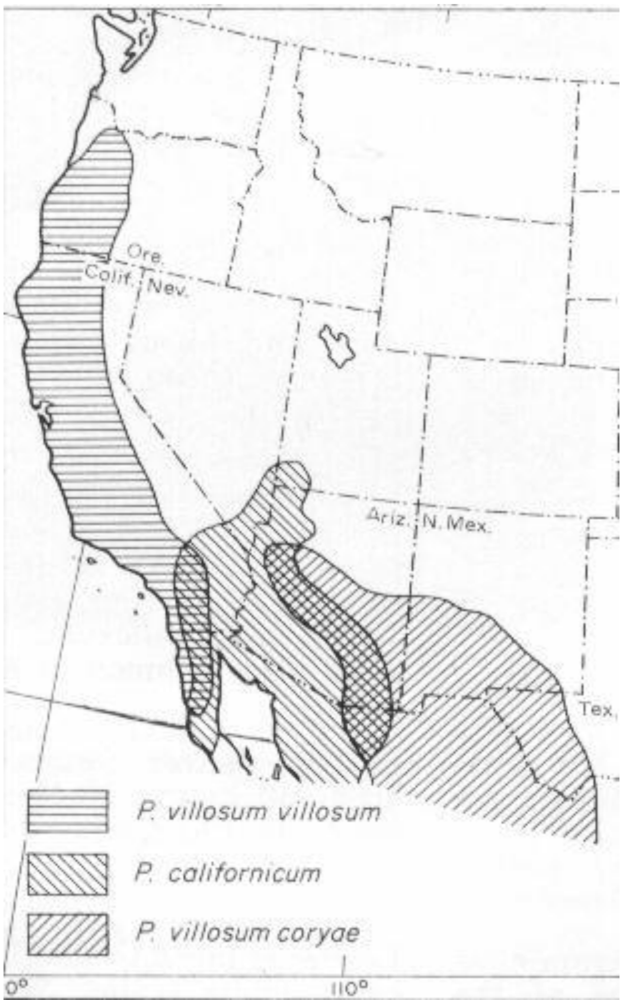

Figure 5. Geographic distribution of *Phoradendron villosum villosum, P. californicum*, and *P. villosum coryae*.

Table 1. Mistletoes Found on Hardwoods in the United States

Phoradendron	**Hosts and Distribution**	**Remarks**
P. serotinum (P. flavescens)>	Known on more than 100 species of 50 genera of native and introduced trees. Eastern United States.	Leaves smooth. The western limits of *P. serotinum* and the eastern limits of *P. tomentosum* subsp. *tomentosum* have not been precisely determined. They tend to grade into each other in Arkansas and Louisiana.
P. tomentosum ssp. *tomentosum* (fig. 6)	Hackberry and mesquite; less common on oak and elm. Primarily Texas and	Similar to *P. serotinum* except mature leaves slightly hairy, and less than 28 mm long or 18 mm wide.

	Oklahoma.	
P. tomentosum subsp. *macrophyllum*	At least 60 hardwood species of about 30 genera including willow, poplar, black locust, maple, ash, walnut, alder, and sycamore; not found on oaks. California to west Texas.	Mature leaves slightly hairy, usually more than 28 mm long and 18 mm wide and about twice as large as those of ./TR>
P. villosum subsp. *coryae*	On oaks from extreme west Texas to western Arizona	Except for the difference in structure of leaf hairs, this subspecies is indistinguishable from *P. villosum* ssp. *villosum*. Locally very common in Arizona.
P. villosum subsp. *villosum* (fig. 7)	Mainly on oaks, but occasionally on manzanita, buckeye, and a few other western hardwood species. California and Oregon.	Mature leaves somewhat stiff and hairy; 15-45 mm long and 10-22 mm wide.
P. californicum (fig. 8)	Mostly on leguminous trees and shrubs of the Southwest.	Leaves reduced to small inconspicuous scales. Stems reddish.
P. rubrum	Mahogany, Florida Keys	A Caribbean species, rare in the United States.

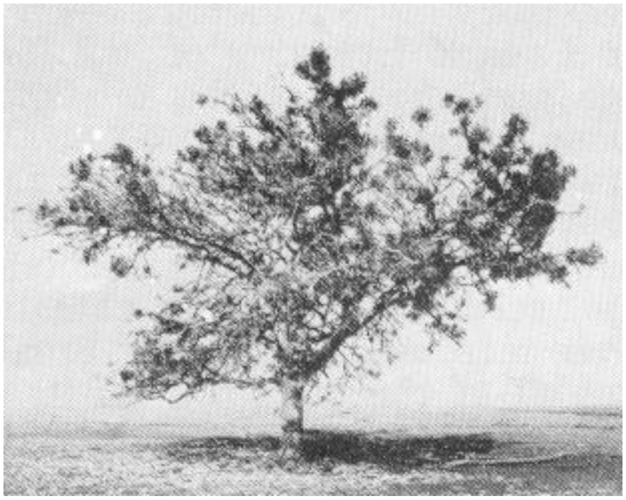

Figure 6. Hackberry *(Celtis* sp.) heavily infected by *P. tomentosum* ssp. t*omentosum* in Texas. Photo taken in winter. The foliage on the tree is entirely that of the evergreen mistletoe.

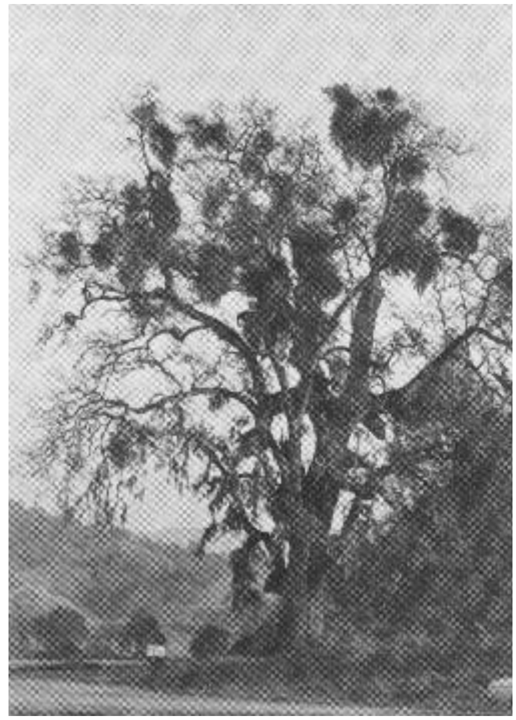

Figure 7. Large California black oak (*Quercus kelloggi*) bearing massive clumps of *P. villosum* ssp. *villosum* (Sonoma County, Calif.)

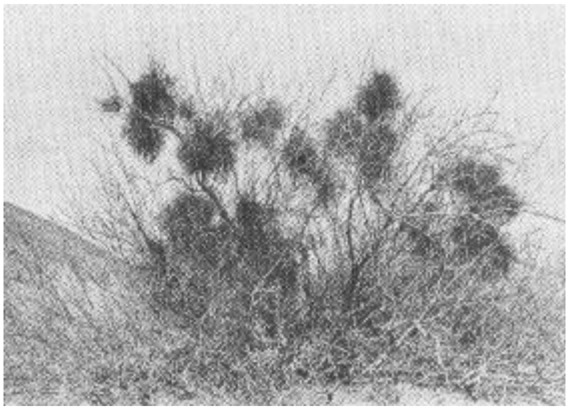

Figure 8. *P. californicum* on mesquite*(Prosopsis* sp.) in the Southwest.

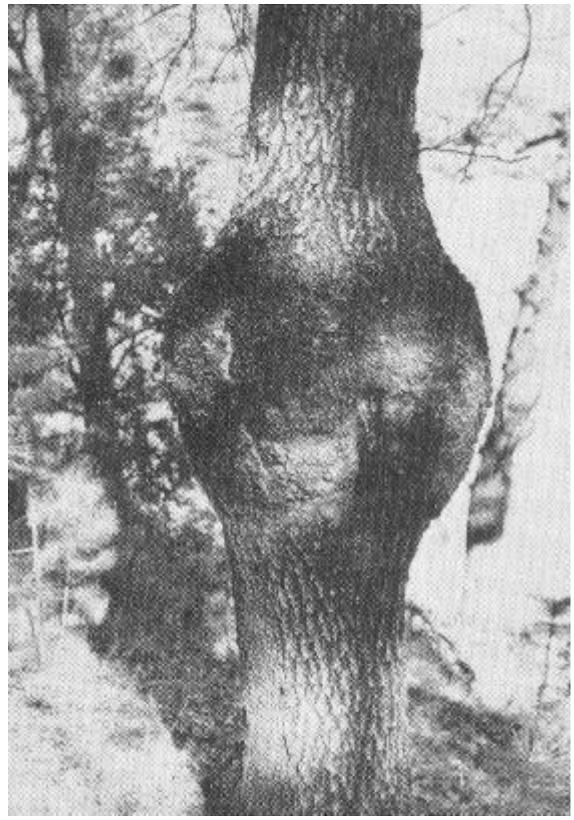

Figure 9. Trunk swelling of California black oak (*Quercus kelloggi*) by *P. villosum* ssp. *villosum*.

Economic Factors

Uses --Mistletoes have some economic as well as social values. Collection and sale of mistletoes during the Christmas holidays provide a limited income in some States, particularly in Texas. Certain animals use mistletoes for food. Mistletoe berries appear to be a favored food of several species of birds, particularly during winter when other food sources are in short supply. Deer and even cattle are known to supplement their winter diets with mistletoe on trees and shrubs that are low enough to reach or from mistletoe that breaks off trees in winter. In Texas, for example, mistletoe on mesquite is regarded as an "insurance" forage crop and is cut out of trees for cattle food when other forage may be scarce. On the other hand, mistletoes in California have sometimes been reported to be toxic to cattle.

Damage -- The damage caused by mistletoes in most cases outweighs their economic values. Trees heavily infected by mistletoe are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attack by insects and often succumb during periods of drought or other adverse conditions.

Branch and trunk swellings frequently result from mistletoe infection (fig. 9). Trees with trunk swellings are of reduced timber quality and may even be unmerchantable. Trunk swellings also provide an entrance point for decay fungi.

Branches heavily laden with mistletoe often break off during storms or periods of high wind. As a result, damage to property from falling branches can be costly--particularly in heavily populated urban areas.

In some areas, native mistletoes are a problem in orchard crops, for example, P. tomentosum subsp. macrophyllum is found on walnut trees in the Sacramento Valley of California.

Control

Control of mistletoe may be difficult in forests. To eliminate the parasite, the infected limbs must be pruned off or, if badly infected, the tree should be cut. Pruning should be undertaken in forest stands only when it is considered economically feasible. Some measure of control can be accomplished by harvesting infected trees. Mistletoe that has been removed from the tree cannot cause new infections; therefore, it need not be burned or disposed of. However, subsequent cleanup and removal may be desirable for other reasons. Detection and control of mistletoes can best be done in fall and winter when the leaves are off the trees and the mistletoe is readily seen. But eradication of the pest will not insure protection from further infection. Birds, the natural vector, are likely to reintroduce the parasite from nearby infected trees. About 5 to 10 years are required, however, for the parasite to build up to damaging proportions before control would again be necessary.

Homeowners with only a few to several infected trees will not find control difficult. Infected limbs can be pruned off, if possible. If this is not practical for esthetic or other reasons, the mistletoe shoots can be broken off periodicallly. Shoot removal will not be necessary more than once every 2 or 3 years. Breaking off the foliage and shoots of the mistletoe alone will reduce the drain on the branch by the parasite and also prevent localized spread and buildup of mistletoe by reducing the seed source. For valuable trees infected in the trunk, breaking off of the mistletoe shoots is the only method of control now available.

Another method of direct control that has been tried is removing shoots and covering the affected part of the branch with creosote or opaque material, such as tar paper. However, none of these has been particularly effective. Coverings, such as tar paper, only temporarily limit shoot production and are esthetically not very pleasing.

Planting resistant trees that are not susceptible to local species of mistletoes is a sound approach to control.

Several chemicals have been tested for control of *Phoradendron* on hardwoods. Some are apparently effective, although no chemicals have been registered by the Federal Environmental Protection Agency for control of mistletoe.

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Adapted for the Internet August 1998
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Updated July 2002 by Katharine A. Sheehan

Management strategies and tactics discussed in older publications may be outdated. Contact your nearest Forest Health Protection office for current information.

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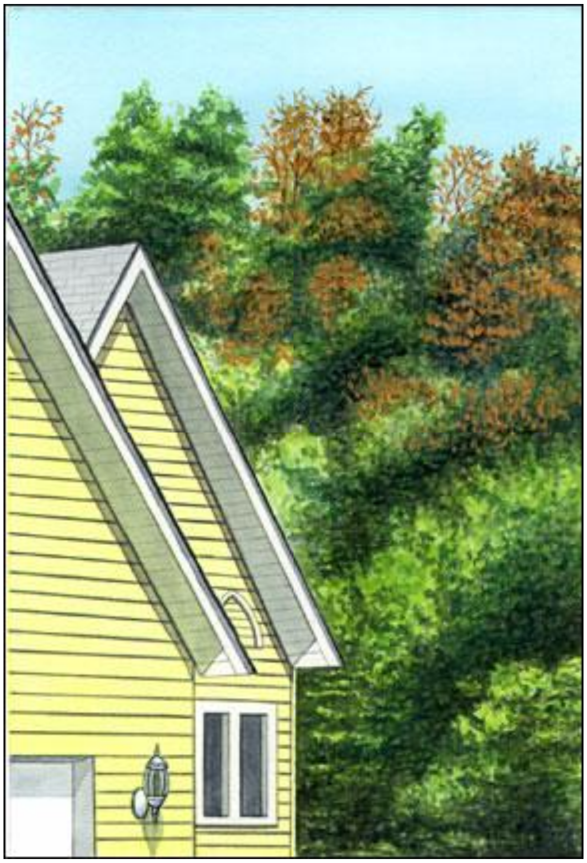
How to

Identify, Prevent, and Control Oak Wilt



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Introduction

Oak wilt is an aggressive disease that affects many species of oak (*Quercus* spp.). It is one of the most serious tree diseases in the eastern United States, killing thousands of oaks each year in forests, woodlots, and home landscapes.

Distribution

Oak wilt was first identified in 1944. The fungal pathogen that causes the disease, *Ceratocystis fagacearum*, is thought by most to be native to the eastern United States, but difficulty in isolating and identifying the fungus delayed recognition of the extent of its impact until the 1980's. Some plant pathologists think that oak wilt is an exotic disease, arriving in North America in the early 1900's, but the fungus has never been reported from any country other than the United States. The disease has also become much more apparent in some local areas since the 1980's because of increased tree wounding, due primarily to home construction in oak woods. The current known distribution of oak wilt is shown in red in Fig. 1.

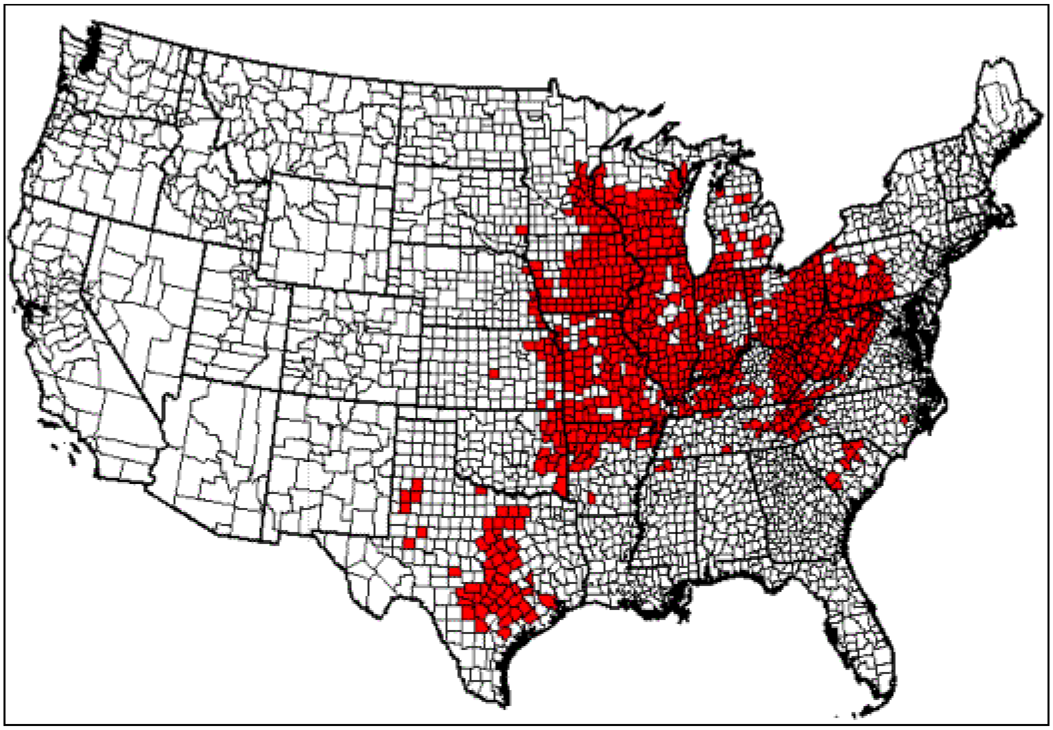


Figure 1. In 1998, oak wilt was distributed over much of the eastern United States.

Hosts

Oaks can be organized into three main groups, based on leaf shape: red oaks, white oaks, and live oaks. Trees in the red oak group have fan-shaped leaves with sharply pointed tips; those in the white oak group have fan-shaped leaves with rounded or blunt tips; and trees in the live oak group have oval leaves with rounded tips (Fig. 2). Oaks most commonly killed by the disease are listed in Table 1.

All species in the white oak group are moderately resistant to oak wilt, but if infected, trees can be killed over a period of one to several years. Resistance in white oaks appears to be related to characteristics of physiology and morphology. Upon wounding, infection, or as a part of the natural aging process, white oaks tend to form minute plugs called ***tyloses*** in their sapwood vessels. These plugs make the wood of white oaks impermeable to water, and also appear to prevent the fungus from moving throughout the vascular system of the tree.

The tendency for white oaks to form tyloses also explains why these are the species of choice for wood used in cooperage for storing wine and whiskey. The presence of tyloses ensures that barrels made from white oak wood will not leak.

Throughout the range of oak wilt in the United States, red oaks are the most important hosts, but susceptibility varies somewhat by species. Mortality in red oaks can occur within 3 weeks after infection by the oak wilt pathogen under some circumstances. Recovery from oak wilt infections in red oaks can occur, but is rare. Texas live oak *(Q. virginiana)* is moderately susceptible to the disease, but because of its tendency to form large, root-connected clones through which the disease can spread, it is also considered to be an important host.

Although the disease is not known west of Texas, inoculation studies have shown that most oaks in the red oak group, including several western species, are susceptible to the disease, and are at risk should the fungus ever be transmitted to them in their native habitat (Appel, 1994).

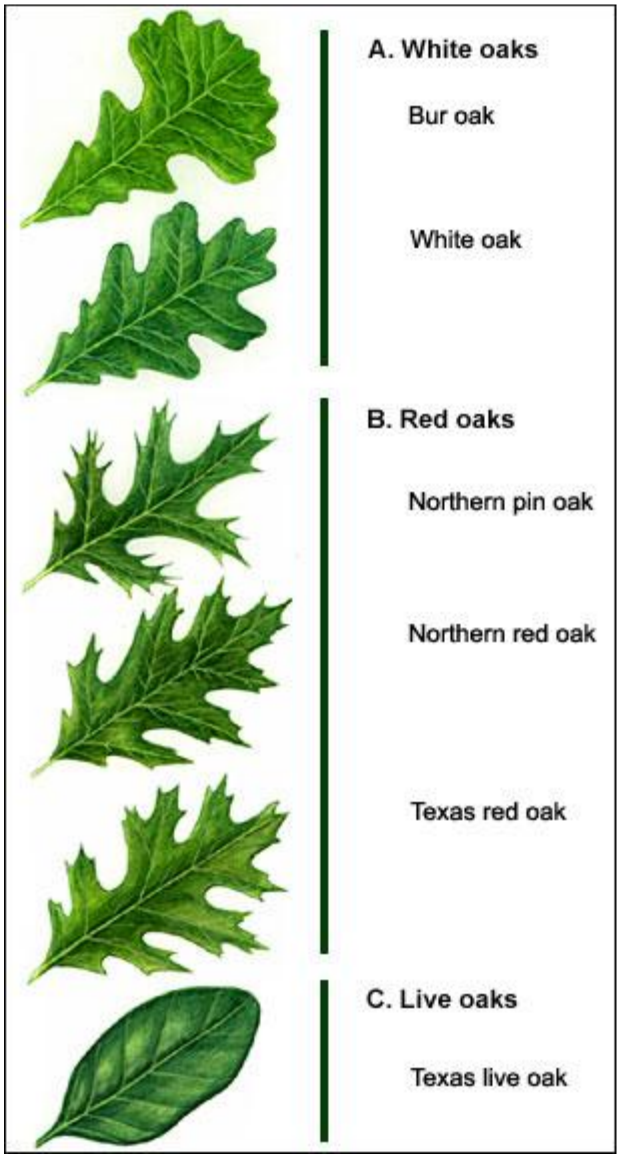


Figure 2. The three main groups of oaks are organized by leaf shape.

Table 1. Oak species commonly killed by oak wilt[1]

Common name(s)	Scientific name
Northern species	
Black oak	*Q. velutina*
Bur oak[2]	*Q. macrocarpa*
Northern pin oak	*Q. ellipsoidalis*
Northern red oak	*Q. rubra*
White oak[2]	*Q. alba*
Southern species	
Blackjack oak	*Q. marilandica*
Scrub live oak	*Q. fusiformis*
Shumard oak	*Q. shumardii*
Southern red oak	*Q. falcata*
Texas live oak	*Q. virginiana*
Texas red oak (Spanish oak)	*Q. buckleyi*

1 All red oaks in the eastern United States are considered susceptible to oak wilt

2 Infections are less common in these species and may take years to run their course.

How Infection Occurs: The Disease Cycle of Oak Wilt

The oak wilt fungus moves from tree to tree in two ways: transported underground through the roots or overland by insect vectors.

Local spread of oak wilt

Most new tree infections occur as a result of the fungus moving from an infected tree to a nearby healthy tree through connected root systems, a process called **"local spread"** (Fig. 3, lower pathway). The roots of trees in each oak group commonly graft to roots of other trees in the same group, forming a continuous underground network. When one tree in a group becomes infected and dies, the fungus spreads through the connected root systems, killing more trees and creating an **"infection center."**

Root grafts do not commonly occur between trees of different species groups, although exceptions occur. Usually a mix of species in a given location will retard local spread and limit the impact of the disease. However, root grafts often do occur between Texas live oaks and red oaks in mixed stands.

Depending upon soil type and the mix of tree species in a forest or yard, infection of healthy trees through root grafts can occur at some distance (up to 100 feet or more) from an infected tree. Sandy soils are conducive to the formation of widespread root systems, increasing the likelihood of root grafts occurring farther away from a diseased tree. Some oak species, including northern pin oak and Texas live oak, often grow in large groups of similar-aged trees that share a common root system. Such situations can lead to rapid expansion of oak wilt centers if even one tree in the group becomes infected.

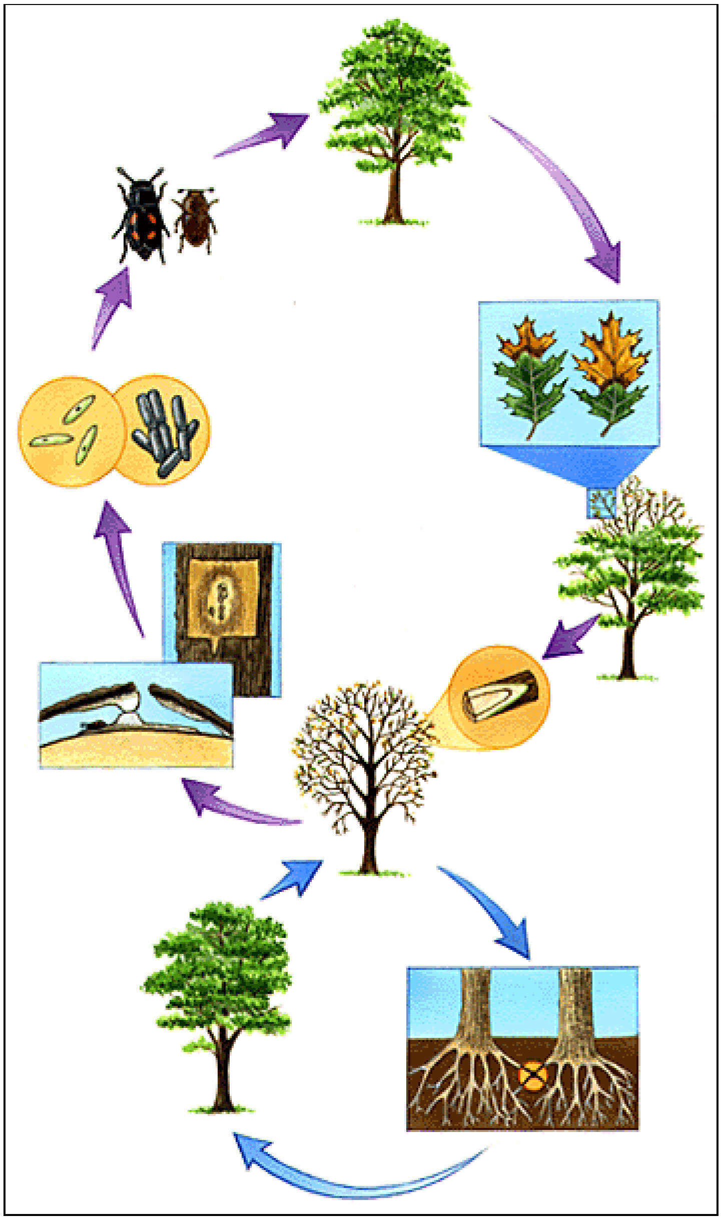


Figure 3. The disease cycle of oak wilt.

Figure 3, upper pathway. Long distance spread of oak wilt occurs when nitidulid beetles carry spores of the fungus from spore mats on infected trees to wounds on healthy trees, causing infection and death of the tree. Time from infection to mortality may be very short for red oaks and Texas live oak, or many years for members of the white oak group.

Figure 3, lower pathway. Local spread of oak wilt occurs when the fungus travels through the interconnected roots of infected and healthy trees.

Long-distance spread of oak wilt

New infection centers can occur if the fungus is carried from an infected tree to a fresh wound on a healthy tree by an insect, a process called "**overland spread**" (Fig. 3, upper pathway).

Figure 4. Bark section showing an exposed spore mat on both surfaces.

Figure 5. Bark split caused by pressure pad of the oak wilt fungus.

Under certain moisture and temperature conditions, compact masses of spore-producing fungal material, variously called "**spore mats**," "**spore pads**," "**pressure mats**," or "**pressure pads**" are sometimes formed on oak trees that have been killed by oak wilt (Fig. 4). These mats form just under the bark, in contact with both the bark and the infected sapwood of the tree. As the mats mature, they produce specialized structures that exert outward pressure on the bark (the "pressure pads") and cause it to split, providing a route for insects to reach the mats (Fig. 5).

Oak wilt spore mats emit a strong fruity or wine-like odor that attracts many different species of **nitidulid beetles** (Fig. 6), also known as sap beetles. As they feed on or tunnel through the spore mats, nitidulid beetles often accumulate fungal spores on the surface of their bodies.

Oak trees often sustain wounds caused by construction equipment, storms, pruning tools, or vandalism. Fresh wounds usually leak sap. The sap attracts insects, including nitidulid beetles that have visited oak wilt spore mats. The overland movement of nitidulid beetles from spore mats on infected trees to wounds on otherwise healthy trees thus creates most new infection centers.

Not all nitidulid beetles are vectors of the oak wilt pathogen. In the North, nitidulids in the genera *Carpophilus*, *Colopterus* and *Epurea* are most often associated with both oak wilt spore mats and fresh wounds on healthy oaks. The common picnic beetle in the genus *Glischrochilus* (the larger beetle in Fig. 6) has often been implicated in the oak wilt disease cycle, but does not appear to be an important vector of the disease.

Figure 6. Nitidulid beetles are primarily responsible for overland spread of oak wilt.

Spore mats can form only within a year after tree death, and only when air temperature and wood moisture are within a certain range. In the northern United States this combination of wood moisture and temperature commonly occurs in spring of the year after the tree dies, or sometimes in autumn of the year the tree dies. The period of time during which mats are formed increases with decreasing latitude. In Texas, mat formation occurs at any time during the year, but is most common in late fall and winter when the weather is cooler and wetter.

Spore mats usually do not form on trees smaller than 6 inches in diameter at breast height, although smaller trees can occasionally support mats. In Texas, spore mats are formed only on Texas red oak and blackjack oak, and never on Texas live oak. For this reason, the red oaks are important for establishing new infection centers in Texas.

Another group of insects, oak bark beetles (not pictured), can also carry spores of the oak wilt pathogen and help to create new infection centers. These beetles acquire spores of the fungus while feeding on infected branches, and subsequently transmit them when feeding on healthy trees.

Symptoms

Oak wilt disease symptoms progress differently in red oaks, white oaks, and Texas live oak.

Red oak group

Oak wilt is usually identified in red oaks by the symptoms of rapid leaf discoloration and wilting. Often the initial symptom is a subtle off-green color shift that may be visible in the upper portion of the tree crown. This symptom is apparent in the northern part of the disease range in late June to early July. Shortly after this initial color shift, the leaves begin to wilt from the top of the crown downward. As the disease progresses, individual leaves quickly discolor, taking on a "bronzed" appearance. The discoloration progresses around the margins of the leaf from the tip to the base (Fig. 7B). The progressing discoloration may be interrupted by the leaf veins, as shown in the white oak leaf in Fig. 7A, or may affect the entire upper portion of the leaf, as shown in the red oak leaf in Fig. 7B.

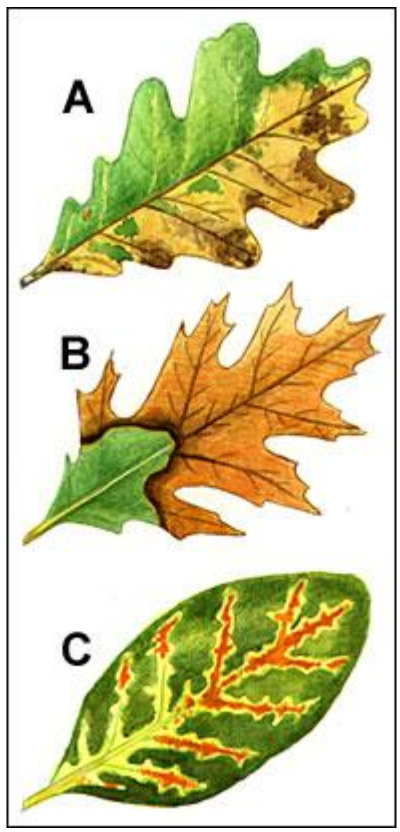


Figure 7. Symptoms of oak wilt in A. white oak, B. red oak and C. Texas live oak.

Leaves are cast rapidly as the infection progresses. Commonly, infected trees are almost entirely defoliated within a few weeks of symptom onset. Fallen leaves usually are brown at the tips and margins, and sometimes green at the base and along the lower veins. Trees are often killed in groups or disease "centers," when infection occurs through grafted roots.

Occasionally the outer ring of vessels of diseased trees will be plugged with a brown substance that may be visible in cross sections as a ring or a series of dark spots through the outer sapwood, and in tangential cuts as longitudinal streaking of wood exposed after removing the bark. However, this is not always obvious to an untrained observer, especially in the red oaks. The discoloration may be very light or appear as flecks in such sections. Discoloration is most readily seen in tangential cuts on branches.

White oak group

White oaks usually die slowly, one branch at a time, over a period of one to many years. Wilting and death of leaves on individual branches occur in a similar fashion to the disease in red oaks, but usually progresses much more slowly. Affected leaves exhibit a pattern of discoloration similar to that seen in red oaks, with discoloration proceeding from the margins to the base, sometimes interrupted by the leaf veins (Fig. 7A). Brown streaking in the outer growth rings is often readily apparent even to an untrained observer in infected white oaks and bur oaks, but may be missing.

Texas live oak

Texas live oaks can wilt and die rapidly or slowly, depending on the timing of infection and weather conditions, but generally succumb within 1-6 months of infection. Diagnostic leaf symptoms are usually produced somewhere on the tree (especially in spring and fall). Leaves develop yellow ("**chlorotic**") veins which eventually turn brown ("**necrotic**"), a symptom termed **veinal necrosis** (Fig. 7C). Affected leaves fall, and the tree crown progressively thins out until the entire tree is dead. Fallen leaves under the tree may show darker brown veins for months. Sometimes just the tips, margins, or interveinal portions of leaves will turn yellow or brown, but these symptoms are not necessarily the result of oak wilt, and not as useful in diagnosing the disease. A small percentage of Texas live oaks may survive oak wilt infection indefinitely, while suffering varying degrees of crown loss.

Diagnosis

Accurate diagnosis of oak wilt is essential before costly control efforts are begun. Foresters, arborists, or pathologists experienced with oak wilt can often diagnose the problem in the field using host species, symptoms and mortality patterns. Properly sampling suspect trees and culturing in a qualified laboratory may be necessary in some cases. See the publication, "How to Collect Field Samples and Identify the Oak Wilt Fungus in the Laboratory" for additional information.

Other disorders of oaks

These oak disorders may sometimes be confused with oak wilt: anthracnose, decline, and infestation with twolined chestnut borer.

Oak Anthracnose

Trees in the red or white oak group are susceptible to a group of fungal leaf diseases collectively called "**anthracnose**," that may be locally severe if weather conditions in the spring are cool and wetfor an extended period during leaf expansion, which favors development of such diseases. Anthracnose diseases are usually more severe in the lower portions of the crown, often causing the affected leaves to fall early in summer. Leaves in the upper portion of the crown may remain attached. Leaf symptoms usually include brown spots or patches that expand outward to the leaf margins. Although the leaves may be curled and distorted, they usually do not wilt.

Oak Decline

Oaks throughout the eastern and southern United States are susceptible to a "decline" syndrome, which is defined as a disease caused by the interaction of several injurious agents working simultaneously. In the case of oak decline these factors can include drought, defoliation, fungi that cause stem cankers or root diseases, and wood-boring beetles. The interaction of these factors may result in the decline and death of oak trees over a local or regional area.

Symptoms vary greatly, and differentiating oak decline from oak wilt can be quite difficult. The absence of the typical leaf symptoms of oak wilt and the retention of dead leaves on the tree are indicators of oak decline. Trees killed by oak wilt are usually completely defoliated and retain few living or dead leaves, but this may not be a consistent symptom for red oaks in the South.

Oak wilt usually occurs in discrete, spreading pockets of mortality, with trees on the margins of the infection center becoming infected over time. Declines may occur in discrete pockets, or over a fairly large area, but do not typically spread outward from an initial infection center. Trees in decline may die over a period of years, or may ultimately survive a decline episode with only dead branches in the crown.

Twolined Chestnut Borer

The twolined chestnut borer (*Agrilus bilineatus*) is an insect that attacks oaks, especially those weakened by drought or defoliation. Larvae of the insect make tunnels in the inner bark, causing branch or even tree mortality. Symptoms usually begin in the upper portion of the crown and proceed downward, but this pattern is variable. The insects leave a distinctive "D-shaped" exit hole about 1-2 mm in diameter when they mature and leave the tree. Initial symptoms are usually single or scattered dying branches that often retain brown leaves until autumn.

Integrated Management of Oak Wilt

Oak wilt can be managed by a variety of strategies that prevent new infection centers and limit the expansion of existing infection centers. A good management program for oak wilt will include all of these strategies for combating the disease.

1. Preventing new infection centers

Once an oak tree becomes infected with oak wilt, there is no known chemical treatment that is capable of "curing" the disease; however, fungicide research is continuing. The development of new oak wilt pockets can be avoided, however, either by preventing the development of spore mats of the fungus on diseased trees, or by preventing the transfer of fungal spores by beetles to healthy trees. In practice this involves removing dead or diseased trees and avoiding injury to healthy trees.

Remove infected trees

Trees that are infected with or have died from oak wilt should be removed and properly treated to prevent development of spore mats. These treatments include debarking, chipping or splitting, and drying the wood. Covering dead wood with plastic, burying the edges for 6 months, and then air-drying for a similar time will kill the fungus and any associated insects. Trees that die in summer should be removed and treated before the following spring, when new spore mats can develop. If the wood is sufficiently dried, however, spore mats will not develop.

A word of caution: Removing a diseased tree that is still living may actually spread the infection by accelerating the movement of the fungus into adjacent trees that are grafted to it by the roots. To avoid this problem, before removing living diseased trees disrupt interconnected roots as described in the section on "Controlling existing infection centers."

Avoid injuring healthy trees

Trees with fresh wounds outside existing oak wilt centers are visited by beetles transporting spores of the fungus. Because open wounds create avenues for infection, damage to trees from construction, pruning or severe storms may lead to new infection centers. Avoid injury to oaks during favorable conditions for infection, which in the North occur in spring and early summer, when spore mats are present, and the beetles are flying. Favorable conditions usually occur between April 15 and July 1 in the Lake States, and over a correspondingly longer period of time to the South. In Texas, avoid damage to oak trees from February through June.

Preventing injury caused by human activity is especially effective in avoiding the establishment of new infection centers. In particular, pruning or construction activities in or near oak woodlots during the susceptible period often results in injury to oak trees that leads to infection.

If construction activity or pruning are unavoidable, or if storms injure oak trees during the critical period, the wounds should be treated immediately with a commercial tree paint or wound dressing. Tree paints are normally not recommended for general use, but in this instance use of these products can protect trees from oak wilt. In the North, if trees are wounded during the dormant season tree paints are not necessary, but judicious use during the rest of the year is acceptable. From Missouri to Texas, tree paint should be used immediately after trees are wounded, at any time of the year.

2. Controlling existing infection centers

Once the oak wilt fungus becomes established in a stand that includes a high proportion of oak, it will often continue to spread through the grafted root systems of the trees, causing infection in healthy oaks.

Disrupting the connections between roots of infected and healthy trees limits the spread of oak wilt, and is an effective control measure. Infected trees and their roots will usually die before root grafts can be reestablished. The fungus that causes oak wilt does not survive in the root systems of dead trees for more than a few years.

The potential for spread of oak wilt through grafted roots is especially high after a diseased tree is removed or dies. While a diseased tree is still living and intact, there is some resistance to fungal spores moving through root grafts into roots of healthy trees. Either removal or death of a diseased tree removes this natural resistance to spore movement, and spores may then travel more freely through interconnected roots. Therefore, timing of root disruption treatment is critical. Roots should be disrupted before an infected tree dies or is removed, or within a short time of tree death, for maximum protection of healthy trees.

Interconnected root systems can be disrupted with a trencher, vibratory plow, or other equipment.

Trenching and vibratory plowing

Cutting roots by using a trenching or cutting tool effectively controls the expansion of oak wilt pockets. In the Lake States, using a **vibratory plow** with a five-foot blade (Fig. 8) is the most common method of disrupting grafted root systems. The vibratory plow consists of a mechanical shaker unit with an attached blade that is pulled behind a tractor. The blade penetrates to a depth of about 5 feet, and cuts through the roots of oaks that may be grafted together. While oak roots may extend deeper than 5 feet in the soil, most root grafts are disrupted by trenching or plowing to that depth. Standard trenching tools do considerably more damage to the site, and the result is a much more apparent plow line than that caused by the vibratory plow. In Texas, shallow, rocky soils and even layered rock often make the use of a rock saw necessary for disrupting oak roots. A chain trencher, backhoe or ripper bar can sometimes be used. Trench depth should be at least 3 feet, although this may be difficult to achieve.

The lines cut by these trenching implements are usually referred to as "**barrier lines**" (Fig. 9). Successful disruption of root grafts to protect healthy trees close to an oak wilt infection center often requires that two or more parallel or intersecting lines be made. **Primary barrier lines** are those expected to have a good chance of protecting trees outside the lines. In addition, **secondary barrier lines** are often used to help ensure that the root graft disruption is effective (Fig. 9).

The efficacy of root graft disruption can be enhanced by removing all oak trees inside the barrier lines following plowing or trenching. Removing these trees and optionally treating the stumps with an herbicide helps to ensure that all of the oak roots inside the barrier will die before root grafts can be reestablished. This practice is sometimes referred to as "**cut to the line**." Although this is a radical treatment, it may be useful in areas where oak wilt eradication is the goal. Assume that all trees removed are infected with the oak wilt fungus, and destroy or treat them on site.

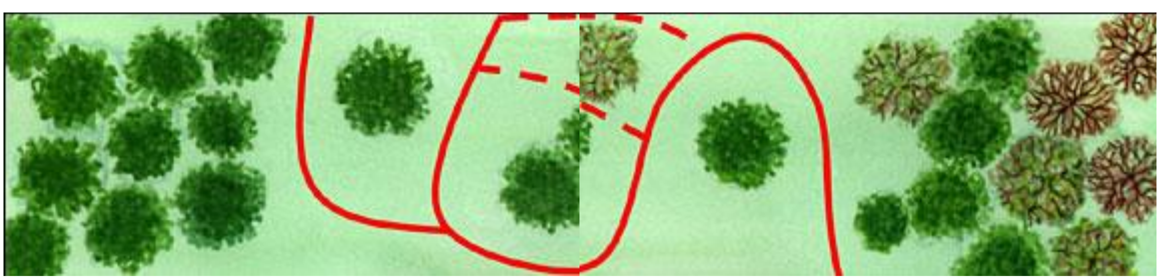
Chemical root disruption

Biocidal chemicals have been used in the past to disrupt root grafts in trees, including oaks. These chemicals are very dangerous and difficult to work with, but can sometimes be used in areas where vibratory plowing or trenching is not an option because of buried utilities, septic tanks or steep slopes. Holes are drilled into the soil at prescribed intervals, and the chemical is poured into the holes, where it diffuses into the soil and kills the roots in a localized area. These chemicals are restricted-use pesticides, they must be applied by a licensed pesticide applicator, who has been trained in their use. In addition, these chemicals are costly, may cause damage to the trees, and are effective only in uniform-textured soils where the chemical distribution is even and predictable.

3. Chemical control using fungicides

Fungicides have been developed that may be effective in preventing oak wilt when injected into living oak trees without active symptoms. These fungicides are apparently unable to stop an already infected oak tree from dying. Those currently available utilize some form of a chemical called propiconazol in the formulation. Such treatments create their own problems, including the necessity of wounding the tree to inject the fungicides.

The cost of the fungicide is high, so only high-value trees should be considered for treatment. Contact your county extension office for current advice on the use of chemicals for control of oak wilt.



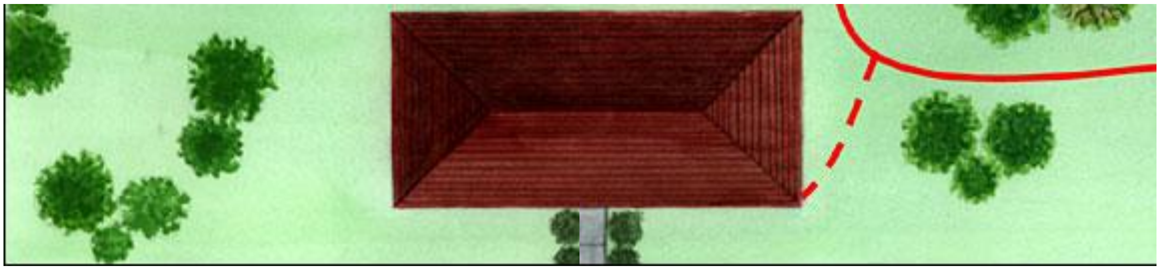


Figure 9. This plan of a home landscape shows possible locations of vibratory plow lines for control of oak wilt. All trees are oaks. Brown trees are infected or dead; green trees are healthy. The solid red lines indicate primary barriers, the dotted lines are secondary barriers.

Summary of integrated oak wilt management strategies

Effective oak wilt management programs use a variety of strategies to limit the spread of oak wilt. Some of the practices and policies that can be used in combination to effectively manage oak wilt include the following:

Avoid wounding oaks during critical infection periods.

- If pruning is necessary, or if wounds occur on oak trees during the critical infection period, use tree wound dressings or paints to prevent transmission of oak wilt.
- Develop and enforce construction ordinances and utility pruning guidelines that minimize wounding of oak trees.
- Use public service announcements, billboards and flyers to raise awareness of the dangers of wounding oaks during susceptible periods.

Use vibratory plow line, trench barriers or chemical disruption of roots to isolate pockets of oak wilt.

- Communities and neighbors should join together to lower the cost of these tools and achieve more complete and effective local control.
- Use root graft disruption, cut-to-the-line practices, and treat stumps with herbicides to greatly reduce or eradicate oak wilt in local areas.

Remove and properly treat oaks killed by oak wilt by debarking, chipping or splitting and drying the wood before the spring following the tree's death.

- Do not move infected wood off-site without debarking, chipping, or properly drying it. Do not move or store firewood from infected stands near healthy oaks without proper treatment.
- Use and enforce city codes and ordinances that mandate removal and treatment of dead oak trees. Such ordinances can significantly reduce the chances for long-distance

transmission of oak wilt.

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Glossary

Anthracnose

A fungal disease of the leaves of many tree species. On oak, this disease may be confused with oak wilt.

Chlorosis (chlorotic)

A loss of green color in leaves, that results in a yellow discoloration.

Cut-to-the-line

The practice of removing all oaks, living or dead, inside the primary barrier line when using trenching for controlling local spread of oak wilt.

Infection Center

A localized group of trees that has been affected by a disease. The disease may spread from the margins of the infected group.

Local Spread

Spread of oak wilt from diseased to healthy trees through root grafted, interconnected root systems.

Long-distance Spread

Spread of oak wilt by nitidulid beetles from spore mats on infected trees to open wounds on healthy trees. Oak bark beetles can also facilitate the spread of oak wilt.

Nitidulid Beetles

Beetles in the family Nitidulidae, sometimes called sap beetles. These beetles have been implicated as the primary carriers of fungal spores of the oak wilt pathogen to healthy trees.

Necrosis (necrotic)
A brown discoloration of leaves that indicates dead tissue.

Overland Spread
See *"long-distance spread."*

Pressure Mat, Pressure Pad
See "Spore Mat"

Primary Barrier Line
A trench cut to disrupt grafted roots of oak. If two lines are used, the primary barrier line is the one expected to have the better chance to protect trees outside the line (see "Secondary Barrier Line").

Root Graft
Roots that have grown together so that a graft union is made between the conducting tissues of both roots. The oak wilt pathogen can move through grafted roots between infected and healthy trees to cause new infections.

Secondary Barrier Line
A trench cut to disrupt grafted roots of oak. If two lines are used, the secondary barrier line is the one expected to have the lesser chance to protect trees outside the line (see "Primary Barrier Line").

Spore Mat, Spore Pad
A structure produced by the oak wilt fungus at the bark-wood interface in oaks killed by the disease. Development of the structure causes the bark to split, exposing the mat below. The mat is covered with the spores of the oak wilt pathogen, which are picked up by visiting nitidulid beetles.

Tyloses
Microscopic structures that are produced in the conducting vessels of white oaks, which block the movement of water and fungal spores within the tree. The rapid development of tyloses may explain the difference in susceptibility between white oaks and red oaks.

Vector
An organism, such as an insect, mite, nematode or higher animal such as a bird or rodent that carries a pathogenic agent to a susceptible host.

Veinal necrosis
Dark yellow or brown discoloration that occurs along the veins of leaves.

Vibratory Plow
A shaker unit with a 5-foot blade pulled behind a tractor, that is used to disrupt the grafted root systems of oaks to prevent spread of oak wilt.

Companion Publication

Pokorny, J. 1999. **How to Collect Field Samples and Identify the Oak Wilt Fungus in the Laboratory**. NA-FR-01-99. USDA Forest Service, Northeastern Area State and Private Forestry; St. Paul, MN: 12 p.

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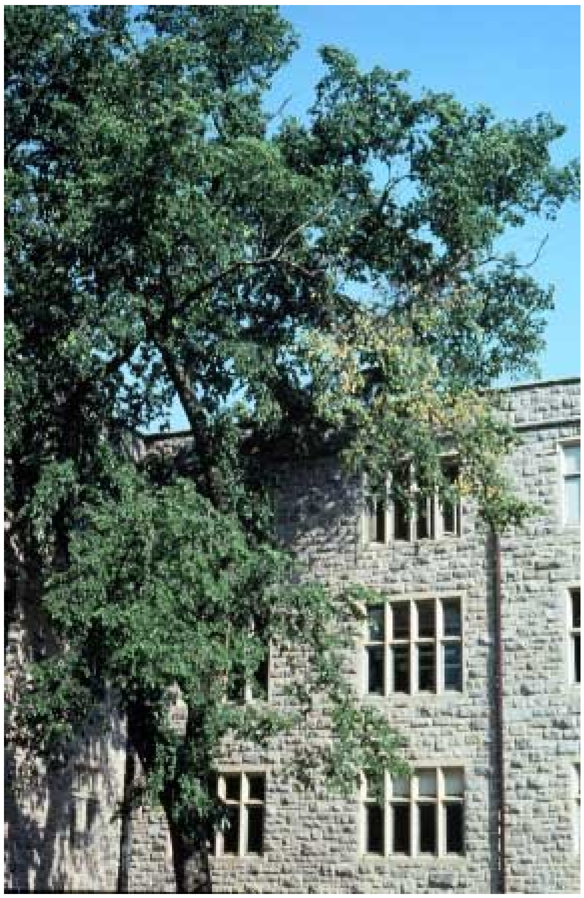
HOW to

Identify and Manage Dutch Elm Disease



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Cover photo: Branch flagging symptoms from a single point of Dutch elm disease infection in crown of elm. (*Photo courtesy of Dr. R. Jay Stipes*.)

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Contents

Introduction

At one time, the American elm was considered to be an ideal street tree because it was graceful, long-lived, fast growing, and tolerant of compacted soils and air pollution. Then Dutch elm disease (DED) was introduced and began devastating the elm population. Estimates of DED losses of elm in communities and woodlands across the U.S. are staggering (figure 1). Because elm is so well-suited to urban environments, it continues to be a valued component of the urban forest despite the losses from DED. The challenge before us is to reduce the loss of remaining elms and to choose suitable replacement trees for the ones we cannot save.

Figure 1. This photo is all too typical of the devastation caused by Dutch elm disease. Once a tree in a row is infected, the disease can move through connected root systems to kill the entire row. *(Photo courtesy of USDA Forest Service via Dr. R. Jay Stipes, Virginia Polytechnic Institute and State University)*

This guide provides an update for urban foresters and tree care specialists with the latest information and management options available for Dutch elm disease.

Symptoms

DED symptoms are the result of a fungus infecting the vascular (water conducting) system of the tree. Infection by the fungus results in clogging of vascular tissues, preventing water movement to the crown and causing visual symptoms as the tree wilts and dies.

Figure 2. Branch death, or Flagging, at multiple locations in the crown of a diseased elm. (*Photo courtesy of Dr. Steve Katovich,USDA Forest Service, St. Paul,MN.*)

Foliage symptoms: Symptoms of DED begin as wilting of leaves and proceed to yellowing and browning. The pattern of symptom progression within the crown varies depending on where the fungus is introduced to the tree. If the fungus enters the tree through roots grafted to infected trees (see disease cycle section), the symptoms may begin in the lower crown on the side nearest the graft and the entire crown may be affected very rapidly. If infection begins in the upper crown, symptoms often first appear at the end of an individual branch (called "flagging") and progress downward in the crown (cover photo).

Multiple branches may be individually infected, resulting in symptom development at several locations in the crown (figure 2). Symptoms begin in late spring or any time later during the growing season. However, if the tree was infected the previous year (and not detected), symptoms may first be observed in early spring. Symptoms may progress throughout the whole tree in a single season, or may take two or more years.

Vascular symptoms: Branches and stems of elms infected by the DED fungus typically develop dark streaks of discoloration. To detect discoloration, cut through and peel off the bark of a dying branch to expose the outer rings of wood. In newly infected branches, brown streaks characteristically appear in the sapwood of the current year (figure 3). It is important to cut deeply into the wood or look at the branch in cross section for two reasons: (1) As the season progresses, the staining may be overlaid by unstained wood, and (2) if infection occurred in the previous year, the current sapwood may not be discolored.

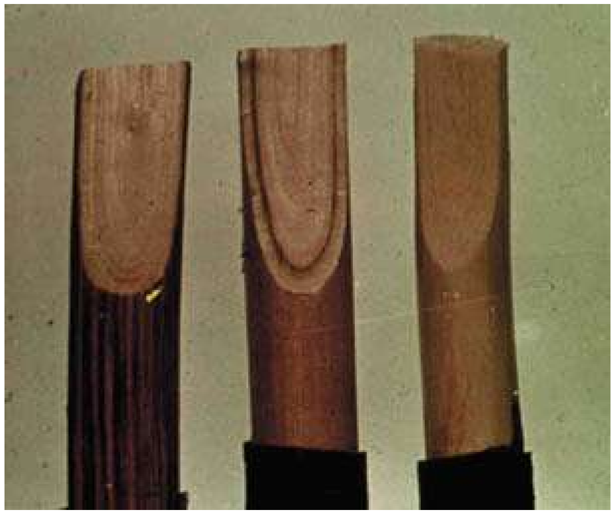

Figure 3. Brown streaking develops in sapwood of branches infected by Dutch elm disease fungus. Streaking is visible here (from left to right) in: (1) the newly formed sapwood, (2) spring sapwood overlaid by uninfected summer wood, and (3) is absent in an uninfected branch.
(*Photo courtesy of the America Phytopathological Society*.)

Distinguishing Dutch Elm Disease From Other Problems

Other pest problems commonly observed on elm include leaf spot diseases, which cause dark spots of dead tissue in the leaves, and elm leaf beetles, which eat holes in the leaves. These problems are easily distinguished from DED. Elm leaf beetles do not carry the Dutch elm disease fungus as elm bark beetles do.

Two other diseases, elm yellows and bacterial leaf scorch, are more easily confused with DED. The symptoms of these diseases are compared to DED in table 1.

Table 1. Comparison of symptoms of three elm diseases.

Dutch Elm Disease	Elm Yellows	Bacterial Leaf Scorch
Initially affects individual branches OR Affects lower crown nearest root graft.	Affects the entire crown.	Damage initially observed on single branches, and spreads to entire crown; oldest leaves affected first.

Leaves wilt and turn yellow, then brown.	Leaves turn yellow and may drop early.	Leaves brown along margin, with a yellow halo.
Symptoms often observed in early summer, but may be exhibited any time of the growing season.	Symptoms visible from July to September.	Symptoms appear in summer and early fall.
Brown streaking in sapwood.	No discoloration in sapwood.	No discoloration in sapwood.
No discoloration in inner bark.	Tan discoloration of inner bark.	No discoloration of inner bark.
No wintergreen odor.	Wintergreen odor in inner bark.	No wintergreen odor.

Elm yellows. This disease, which is also called elm phloem necrosis, is caused by a phytoplasma (microscopic bacteria-like organism) which systemically infects the phloem tissue (inner bark) of the tree. It is a serious disease that causes tree death. Symptoms of elm yellows differ from DED in that the leaves turn yellow (not brown and wilted) and drop prematurely, and the symptoms appear in the entire crown at the same time. The brown streaking which DED causes in the sapwood is absent, but the inner bark develops a tan discoloration and a characteristic wintergreen odor.

Bacterial leaf scorch. This disease is caused by the bacterium *Xylella fastidiosa*, which infects and clogs the water conducting tissues of the tree. Infection by this bacterium causes a slow decline over many years. Once a tree is infected, symptoms recur annually. Symptoms of scorch are irregular browning along the leaf margin with a yellow border between green and scorched leaf tissue. Older leaves on a branch are affected first.

Disease Cycle of Dutch Elm Disease

The biology, or "disease cycle," of DED depends upon the host, the fungus and the means by which the fungus moves into new host trees (figure 4).

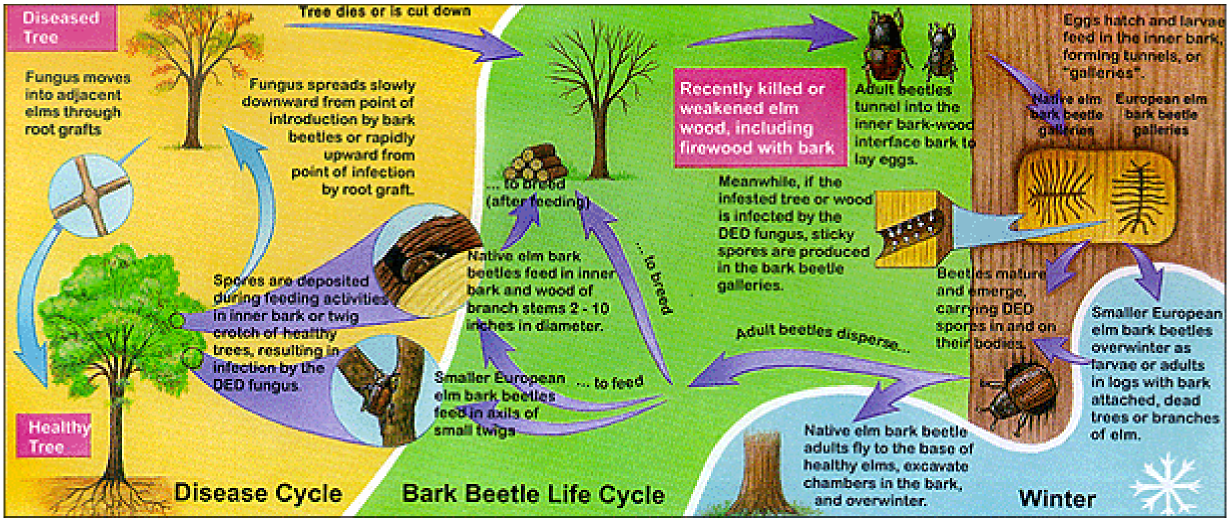

Figure 4. The disease cycle of Dutch elm disease is closely linked to the life cycle of elm bark beetles. *(Artwork by Julie Martinez, Scientific Illustrator, St. Paul, MN)*

Figure 4. Full-scale image

The elm host. Native species of North American elms vary in their susceptibility to DED, even within species. American elm (*Ulmus americana* L.) is generally highly susceptible. Winged elm (*U. alata* Michx.), September elm (*U. serotina* Sarg.), slippery elm (*U. rubra* Muhl.), rock elm (*U. thomasii* Sarg.), and cedar elm (*U. crassifolia* Nutt.) range from susceptible to somewhat resistant. No native elms are immune to DED, but some individuals or cultivars have a higher tolerance (and thus may recover from or survive with infection) or resistance to DED. Many European and Asiatic elms are less susceptible than American elm.

In addition to genetic factors present in some cultivars and species, physical factors affect tree susceptibility. These factors include time of year, climatic conditions (such as drought) and vitality of the tree. Water conducting elements are most susceptible to infection as they are being produced in the spring, thus elms are most susceptible to infection after earliest leafing out to midsummer. Trees are less susceptible under drought conditions. Vigorously growing trees are generally more susceptible than slower growing trees.

The Dutch elm disease fungus. DED can be caused by either of two closely related species of fungi: *Ophiostoma ulmi* (Buism.) Nannf. (formerly called *Ceratocystis ulmi*) and *Ophiostoma novo-ulmi* Brasier. The latter, which is more aggressive in causing disease, was recently recognized as being a separate species. The DED fungus was first introduced to the U.S. on diseased elm logs from Europe prior to 1930. It is unknown when the more aggressive species became established in the U.S.; however it was possibly present as early as the 1940's- 1950's, and most likely caused much of the devastating mortality through the 1970's. The less aggressive species is becoming increasingly rare in nature, and the aggressive species is thought to be responsible for most of the current mortality. Although some local resurgence of DED has been observed, there is no evidence that it is due to a change in the pathogen. Localized resurgence is more likely due to the following: (1) a decrease in vigilance in monitoring and sanitation, (2) a build-up in populations of the insect vectors, or (3) ingrowth of susceptible host trees in the wild.

Spread by elm bark beetles. Overland spread of DED is closely linked to the life cycles of the native elm bark beetle (*Hylurgopinus rufipes* Eich.) and the smaller European elm bark beetle (*Scolytus multistriatus* Marsh.) (figure 5). Both beetles are attracted to stressed, dying or dead elm wood to complete the breeding stage of their life cycle. The adult beetles tunnel into the bark and lay their eggs in tunnels (called galleries) in the inner bark. The eggs hatch and the larvae feed in the inner bark and sapwood.

The larvae mature into adults and emerge from the elm wood. If the DED fungus was present in the wood that the beetles infested, the fungus produces sticky spores in the beetle galleries. Spores of the DED fungus are eaten by or stick to the adult beetles as they emerge from diseased trees. Adult beetles then visit healthy trees, feed in twig crotches or branch inner bark, and introduce the fungus into or near severed wood vessels as they feed.

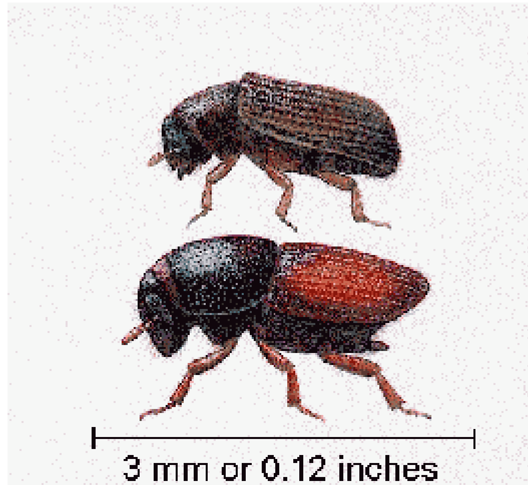

Figure 5. Overland spread of DED is closely tied to the life cycles of the Native elm bark beetle (top) and smaller European elm bark beetle (below). Note that the smaller European elm bark beetle is actually larger than the native elm bark beetle.
(Artwork by Julie Martinez, Scientific Illustrator, St. Paul, MN)

The importance of the two bark beetle species as vectors of DED varies across the range of elms. In northern areas (northern parts of Minnesota, Wisconsin, Maine, New York and New England and most of Canada, where winter temperatures below -6° F are common), the native elm bark beetle is the predominant vector. In other parts of North America, the smaller European elm bark beetle predominates. The life habits of the adults of the two species differ considerably, which has implications for management opportunities. These differences are described below.

Smaller European elm bark beetles overwinter as larvae or adults within the stem of the tree where they hatched. They emerge as adults in spring to feed in twig crotches of healthy trees, where they can introduce spores of the DED fungus to the crown. High numbers of beetles frequently will feed in a single tree, resulting in multiple points of infection. The cycle is repeated when beetles then seek out diseased and dying wood to breed in throughout the growing season, completing two or more generations per year. They have the potential to rapidly build up high populations.

Adult native elm bark beetles tunnel into the bark on the lower stems of healthy elms to overwinter. In spring they emerge to feed in the inner bark of elm branches and small stems before beginning their breeding cycle. They repeat their life cycle as previously described. They can transmit the DED fungus to healthy trees during the construction of overwintering sites in fall, or, more commonly, during feeding in spring.

Once the DED fungus is introduced into the upper crown of healthy elms by bark beetles, it slowly moves downward, killing the branch as it goes. Disease progression may occur rapidly, killing the tree by the end of the growing season, or may progress gradually over a period of two or more years. It is also possible that the tree may recover. The success and rate of progression within the tree depends on tree size, time and location of infection in the tree, climatic conditions, and response of the host tree.

Spread through grafted roots. Roots of the same or closely related tree species growing near each other often cross each other in the soil and eventually fuse (become grafted) to each other.

The DED fungus can move from infected trees to adjacent trees through these grafted roots. Infections that occur through root grafts can spread very rapidly throughout the tree, as the fungus is carried upward in the sapstream. Root graft spread of DED is a very significant cause of tree death in urban areas where elms are closely spaced (figure 6).

Figure 6. Where elms are closely spaced, the Dutch elm disease fungus may move down a row of trees through grafted roots. Removing trees without breaking root grafts may not keep the fungus from moving into adjacent trees. *(Photo courtesy of Dr. Joseph O'Brien, USDA Forest Service, St. Paul, MN)*

Managing Dutch Elm Disease

DED is managed by interrupting the disease cycle. The most effective means of breaking the cycle is early and thorough sanitation to limit the population of the insects that transmit the fungus from tree to tree. Other useful means of affecting the disease cycle include using insecticides to kill the insect vector, breaking root grafts between trees, injecting individual trees with fungicides to prevent or halt the fungus, pruning out early infections, and planting DED tolerant or resistant elm cultivars or other tree species.

Sanitation to reduce insect vectors. Many communities have been able to maintain a healthy population of mature elms through a vigilant program of identification and removal of diseased elms and systematic pruning of weakened, dying or dead branches. Sanitation by prompt removal of diseased trees or branches reduces breeding sites for elm bark beetles and eliminates the source of the DED fungus. To be completely effective in interrupting the spread of the disease by elm bark beetles, stems and branches of DED infected trees must be de-barked, destroyed, or utilized before the bark beetles emerge. During the growing season, removal should be completed within 2 to 3 weeks of detection. During the dormant season, removal should be completed before April, when overwintering beetles may begin to emerge.

Wood from infected trees can be destroyed by chipping, burning or burying. Wood may be retained for use as firewood or sawlogs if it is de-barked or covered from April 15th to October 15th with 4 to 6 mil plastic. The edges of the cover must be buried or sealed to the ground. If it is impossible to destroy all elm wood before the beetles emerge, the wood can be sprayed with a registered insecticide until disposal is possible. If insecticides are used, consider potential exposure to chemical residues when burning or handling the treated wood. Many communities have regulations on the removal of diseased elms and storage of elm firewood; make sure your activities comply with local regulations.

Insecticides to kill insect vectors. In areas where the native elm bark beetle is the principal vector, sanitation may be augmented by applying a registered insecticide to the lower stem of healthy elms in late summer to early fall (i.e., at the first sign of autumn leaf color change) to kill adult beetles as they prepare overwintering sites. In areas where the smaller European elm bark beetle are common, spring feeding in twig crotches can be prevented by spraying the crowns of elm trees with a registered insecticide. However, this may not be a preferred treatment method because of the difficulty in getting thorough coverage of all susceptible twig tissue, the risk of insecticide drift and exposure, and high expense.

Insecticide registrations and recommendations are frequently updated, and may vary considerably between states. Cooperative Extension Services at land grant colleges and certified arborists are able to provide current insecticide recommendations.

Disruption of root grafts. Large trees within 25 to 50 feet of each other are likely to have root grafts. Breaking root grafts between infected trees and adjacent healthy trees is an important means to prevent movement of the fungus into the healthy trees. Root grafts should also be disrupted between the healthy tree adjacent to a diseased tree and the next healthy tree. It may even be desirable to sever grafts between very valuable trees before DED is observed in the vicinity, as a proactive measure.

Root graft disruption should be completed before the infected trees are removed. Otherwise the transpirational pull from healthy trees will rapidly draw in the contents of diseased tree's root system when the vascular tension on the roots of the diseased tree is released by severing the stem. Root graft disruption can be accomplished by use of a vibratory plow or any trenching machine equipped with the longest blade available (preferably five-feet long, but at least three-feet long). Biocidal soil fumigants may also be used to kill root grafts if no other alternatives are available. However, these chemicals are generally restricted use pesticides and may only be applied by professional pesticide applicators. In addition, biocidal chemicals may not be effective if soil temperatures are below 50 °F.

Injecting elms with fungicide. Certain fungicides, when properly injected, are effective in protecting elm trees from infection via beetle transmission. This treatment is expensive and must be repeated every one to three seasons, thus it is appropriate only for high value or historically important trees. The treatment itself also may pose risks to the health of the tree.

Figure 7. Macroinjection of fungicide into the root flare of an elm tree.
(Photo courtesy of Mark Stennes, certified arborist, St. Paul, MN)

In order to be effective, the fungicide must be present at adequate concentration at all potential points of infection. Thus the dosage and means of application are critical to success. The injection of chemical into root flares in large volumes of water (macroinjection) provides thorough distribution of chemical in the crown (figure 7). Microinjection (injection of small volumes of concentrated chemical) is also an option, although it's efficacy compared to macroinjection has not been thoroughly researched. Preferably, injections should be done soon after the earliest leaves have fully expanded, but may be done from then to the end of the growing season. Label rates of concentration for chemical application are updated to reflect the most recent findings on effectiveness; always follow the current label.

Harmful effects of fungicide injection have sometimes been reported and include occasional leaf "scorching" or loss. Elms generally recover from this damage. Also, drilling injection holes results in wounding which, if repeated annually, may eventually result in significant discoloration and decay. Following fungicide injection with a flush of clean water can reduce damage to the cambium. Some chemicals are able to protect trees for up to three seasons, thus minimizing the frequency of treatments.

Several fungicides are registered for injection to prevent DED infection. These chemicals vary in duration of protective effects, means of application, risk of damage to the tree, documentation of effectiveness, and cost. Certified arborists or Cooperative Extension Services at land grant colleges are able to provide current recommendations on product availability and effectiveness.

Eradicating Dutch elm disease from newly infected trees. If a new crown infection of DED is detected early enough, there is opportunity to save a tree through pruning, fungicide injection, or both. Eradicative treatment is not possible on trees that have become infected via root graft transmission. Pruning, which can literally eradicate the fungus from the tree by removing it, has a high probability of "saving" a newly infected tree that has less than 5% of its crown affected. To be a candidate for eradicative pruning, the infection must be a new infection (not a residual infection from the previous season) and be present only in the upper crown (not yet present in the main stem). Since infection may be more advanced than symptoms indicate, it is important to peel off the bark of infected branches and locate the staining, which indicates the presence of the fungus. All infected branches should be removed at a branch fork at least 5 feet, and preferably 10 feet, below the last sign of streaking in the sapwood (figure 8). Whenever elm branches are pruned during the growing season, pruning paint specifically formulated for use on trees should be applied to prevent attraction of elm bark beetles to the wounded trees. (Painting tree wounds is generally not recommended, except to prevent disease transmission in oaks and elms.)

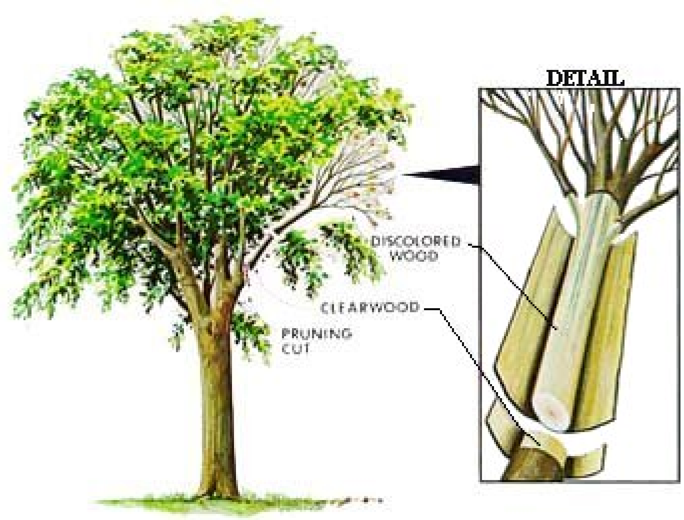

Figure 8. Eradicative pruning of branches infected with DED may be effective if there is adequate length (5 to 10 feet) of clearwood between the infected tissue and the remainder of the crown, or if the tree has been properly treated with fungicide. *(Artwork courtesy of Jim Lockyer, USDA Forest Service, Radnor, PA)*

Pruning is more likely to be effective if augmented by systemic injection of fungicides. Proper use of fungicides eliminates the need to eradicate all infected tissues from the tree, although all dead branches should eventually be removed. Whereas pruning alone is not effective against residual infections, fungicide injection may be. If fungicides are used, they should be injected prior to removal of diseased branches. The keys to successful eradicative treatment are early detection and prompt treatment

Planting Dutch Elm Disease resistant or tolerant trees. Planting trees with resistance or tolerance to DED is a valid management option. However, selecting only a few cultivars limits the genetic variability of the population. This could lead to increased risk of widespread losses if these cultivars are found to be susceptible to tree health problems such as poor adaptation to site, air pollution, other elm pests or pathogens (such as elm yellows or elm leaf beetle) or even other strains of DED which may eventually develop. Thus it is prudent to plant a mixture of suitable cultivars of as many elm genotypes as possible.

Santamour and Bentz (1995) recently published a checklist and brief description of elm cultivars in North America. The only true American elms on that list that are commercially available and have strong evidence of DED tolerance or resistance are the Princeton Elm, the American Liberty "multi-clone," and Independence, which is one of the cultivars in the American Liberty multi-clone. Two additional American elms, Valley Forge and New Harmony, were released by the USDA National Arboretum since the Santamour and Bentz listing was prepared. These two cultivars, which exhibit high tolerance to DED, should be available through retail nurseries by 2001.

Besides true American elms, there are many other hybrid elm crosses and species of elm that have high tolerance or resistance to DED. Several of these have attractive form, are well suited to urban environments, and are readily available (figure 9). Many of these are listed and described by Santamour and Bentz (1995) in the previously mentioned checklist.

Figure 9. Cultivars of elm selected for resistance to DED are available. This selection of *Ulmus japonica* demonstrates the potential these elms have as landscape trees.
(Photo courtesy of Dr. Eugene Smalley, University of Wisconsin--Madison)

In addition to careful selection of the tree species and cultivar, location and spacing are also important to reduce losses from DED. When selecting landscape trees and their locations, plant a mixture of tree species appropriate to the site. In addition to the species diversity, consider spacing of the trees. Future problems with root grafts can be avoided by carefully selecting planting location and maximizing tree species diversity.

Trees in Natural Stands or Wild Areas

Infected elms in wild areas and natural stands that are within or near urban areas often serve as a reservoir of elm bark beetles and DED fungus to infect high value landscape trees. Management is necessary in order to protect urban elms.

The most effective management option to reduce both the bark beetle vectors and the DED fungus is sanitation to promptly remove stressed, dead and dying elms as previously described. However, this intensity of treatment is often not feasible.

A "trap tree" method was developed in the 1980's to more cost effectively reduce populations of elm bark beetles. Under this method, DED infected elms which are still living are treated with an herbicide that kills the tree quickly and promotes rapid drying out of the bark. The bark beetles are attracted to the dying trees, but the rapidly drying bark is unsuitable for them to complete their lifecycle, and the bark beetle populations are reduced. However, treated trees may then become hazard trees with high risk of falling and causing personal injury or property damage.

Another option in wild areas or natural stands, other than accepting losses from DED, is to eliminate all elms and manage for alternative species. However, it is often desirable to retain elms for biodiversity, aesthetic, economic, or other reasons.

Deciding Which Management Practices to Use

Different management strategies will be applicable depending on whether you are working with a community program or trying to protect individual trees. In a community program, the objective will be to protect a population of elms. Individual landowners, however, may have no control over what neighbors do with their elms but may want to protect or save their own trees. The amount of money an individual or community is able to spend will also vary.

Where you have no control over the management of surrounding trees, the only options available are treatments to protect or save individual trees. Good sanitation practices and disruption of root grafts are necessary on individual properties, but these practices alone will not protect a tree from disease transmission by bark beetles from other properties. Preventive fungicide injection, eradicative pruning and fungicide injection, and insecticide treatment are generally the only options available for individual trees.

In a community program, resources to spend on individual trees may be low, but there is more opportunity to manage populations of elms. Where there are continuous elms, root graft disruption is essential to halt the spread. Sanitation is key to reducing beetle and DED populations, and is effective. Community ordinances can be established to encourage prompt removal of diseased trees and prevent the storage of elm wood with bark intact. Education will help citizens understand the importance and benefits of working together to manage DED. As resources allow, preventive treatment, eradicative treatment and insecticides can be used to augment a program. If you are working with a community with a significant elm resource, become familiar with the literature listed below and with what has worked well in other communities.

The impact of DED on our urban forests has been massive. Despite the losses, elms should and will continue to be a component of many urban forests. We have an opportunity to consider what trees will compose the future urban forest, and we can learn from the past. Landowners and communities can and should choose carefully what types of trees to plant and where to plant them.

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Pesticide Precautionary Statement:
Pesticides used improperly can be injurious to humans, animals, and plants. Follow label directions and heed all precautions on the labels. Store all pesticides in original containers, out of reach of children and foodstuffs. Apply pesticides selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. After handling a pesticide, do not eat, drink or smoke until you have washed. Dispose of empty pesticide containers properly. It is difficult to remove all traces of a herbicide (weed killer) from equipment. Therefore, to prevent injury to desirable plants do not use the same equipment for insecticides that you use for herbicides.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Great Trinity Forest Management Plan

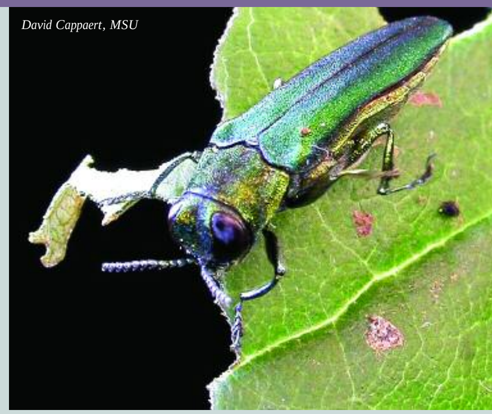
Insects and Disease

Emerald Ash Borer

Emerald Ash Borer and Your Woodland

Why should you be concerned about the emerald ash borer?

Emerald ash borer (*Agrilus planipennis* Fairmaire) has rapidly become the most important pest of ash trees (*Fraxinus* spp.) (Fig. 1) in North America. Emerald ash borer (EAB), a native of Asia, had never been found in North America or Europe until it was discovered in southeastern Michigan and Windsor, Ont., in June 2002. This exotic pest was probably introduced at least 10 years before it was discovered, in wood crating, pallets or similar packing material that was shipped into Michigan from Asia.



Emerald ash borer adult.

Fig. 1 – Healthy ash tree.

Damage to ash trees is caused by the EAB larvae, which feed in S-shaped tunnels on the inner bark of branches and tree trunks (Fig. 2). The inner bark, called phloem, transports nutrients and water within the tree. Galleries excavated by the flat, cream-colored larvae cause branches and eventually the entire tree to die. All true ashes such as green ash (*F. pennsylvanica*), white ash (*F. americana*) and black ash (*F. nigra*) are susceptible to EAB. Scientists believe that virtually all ash species in North America are at risk if EAB continues to spread. Emerald ash borer does not attack mountain ash (*Sorbus* sp.) and has not attacked other tree species in North America.

The EAB infestation has severely affected ash trees in southeastern Michigan. Estimates suggest more than 20 million ash trees in urban, suburban and forested areas have already been killed. In addition, localized populations of EAB, called outliers, have been found in nearly all counties in lower Michigan. These outliers are a result of infested ash firewood, nursery trees or logs that were transported out of southeastern Michigan before EAB was identified. Populations of EAB have also been found in several areas of Ohio, Indiana and Illinois, and more recently in Maryland and Pennsylvania. Detection and survey efforts will continue, and the chances are good that more EAB infestations will be discovered. Information about EAB regulations, symptoms of infested trees, insecticides for landscape trees and other topics can be found at **www.emeraldashborer.info**.

What does EAB mean for the *woodland owner* in Michigan? Should you try to harvest your ash as quickly as possible? How should you manage your forest? Should you just let nature take its course?

There are no simple answers to such questions. Much will depend on the condition of your woodland, your objectives for the property and the current status of the EAB situation. You will need to explore your options with a professional forester and stay up-to-date on the EAB regulations that affect your area.

Keep in mind, however, that EAB is not like a native forest insect – it is much more destructive and aggressive than its relatives such as bronze birch borer and two-

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MICHIGAN STATE UNIVERSITY EXTENSION

David Cappaert, MSU

Fig. 2. S-shaped galleries.

lined chestnut borer. North American ash trees have little resistance to this new pest, and even large, healthy ash trees will be killed within a few years of infestation. Prompt attention is needed to reduce the potentially negative economic and ecological impacts of EAB on your property. The following considerations can help you think about how you will manage your woodland property.

1. Consider reducing ash abundance.

Ideally, ash should make up no more than 10 to 25 percent of the basal area of your woodland. If ash exceeds that level and you believe that you have marketable ash trees on your property, you may wish to get estimates and consider selling the ash trees. The level of urgency will depend on how close your property is to sites known to be infested, your overall objectives for the property and the abundance of ash compared with other species on the site.

If you think you have marketable ash trees, work with a professional consulting forester – decisions about timber sales and stumpage values can be complicated. Consulting foresters can help you identify the markets that are available in your area. They may also know of portable or custom sawmills that can be hired to saw ash trees into boards for your own use or for sale.

You may also want to work with neighboring woodland owners. They are probably facing a situation similar to yours. Often the per-acre costs of setting up a timber sale decrease when larger areas are involved. Cooperating with neighbors may lead to lower costs and better timber prices for everyone.

Other tree species may be part of a harvest that removes ash. Many woodlands can benefit from a well-planned harvest in which ash reduction is only one of several landowner objectives. A mixed-species sale may be of interest to more buyers or result in higher profits for you. Again, it is important to work with a professional forester to ensure that the productivity and the health of your woodland are maintained or even enhanced by a harvest.

If you are considering a timber sale, know the current EAB situation in your area – does your property fall within a quarantined area?

If your woodland is in a quarantined county or township, contact the Michigan Department of Agriculture and learn about your options. The EAB situation is dynamic – regulations, quarantines and options can change rapidly as new information becomes available. The Michigan Department of Agriculture or the regulatory agency in your state will have the most up-to-date information available about quarantines, restrictions and options that apply to property in specific geographic areas. Generally, ash logs, wood or chips can move *within* quarantined areas but cannot be transported out of quarantined areas, into the Upper Peninsula or across state borders without compliance agreements and special permits from the state regulatory agency/agencies.

2. Non-timber Considerations

Many of the ash trees on your property may be too small for harvesting, or you may not want to get involved with harvesting and selling timber. You may still, however, want to consider cutting these trees to reduce the overall abundance of ash in the woodland and to reduce the density of EAB populations in your area.

Ash makes excellent firewood – it is easy to split and burns hot. *But PLEASE, remember that a single piece of infested ash firewood can start a new EAB infestation!* Many regulations apply to ash firewood. Also, most camp-grounds in the north central United States do not allow visitors to bring in firewood, particularly ash firewood, that originated in infested states or areas. It's best to avoid transporting ash firewood off your property altogether.

Ash trees can simply be cut and left on the ground. After cutting, the phloem and wood dry out, and after 6 to 12 months, even large pieces of ash will no longer be suitable for EAB egg laying or larval development. The decaying trees will provide habitat for many wildlife species. Ash trees can also be girdled with a chainsaw or drawknife and left standing. Ash snags are preferred habitat for a variety of wildlife, including cavity-dwelling birds, mammals and amphibians. Removing ash ahead of the EAB infestation may help slow the spread of this destructive pest or reduce the impacts of EAB in your region. The effectiveness of such actions, however, will depend on many factors, including the abundance of EAB and the overall number, size and distribution of ash on neighboring properties.

If you have only a few ash trees or if your woodland is not in or near a quarantined area or outlier, selling or cutting ash trees may be less urgent. Nevertheless, you may want to consider advancing a thinning schedule to remove ash sooner. Begin thinking now about how your woodlot will be affected as the EAB infestation spreads.

Black ash swamps are a special concern. Many times, nearly all the trees on such sites are black ash, and there are few, if any, alternative species to plant. Harvesting such sites with heavy equipment is often not practical because of the wet conditions. Members of several Native American tribes use black ash for baskets and may be interested in harvesting some black ash trees in some areas. The Department of Natural Resources, USDA Forest Service or MSU Extension office in your area may be able to help you contact basket makers interested in harvesting black ash trees.

3. Think about how EAB will affect your long-term objectives.

Think about what you want your woodlot to look like in the future. Determine what other tree species are present on your property. Can you encourage those species by selectively removing ash, using herbicides or planting?

Planting hardwood or conifer species, in combination with natural regeneration, can replace the ash component of your woodland, increase diversity and improve habitat for wildlife. Commercial nurseries and conservation districts sell tree seedlings each spring.

When choosing species to plant, consider the soil and weather, plus the risk of browse damage from deer, rodents and rabbits. A professional forester can advise you about the species that are most appropriate for planting on your property.

Be aware of other forest health issues that may be present in your woodland, such as beech bark disease, oak wilt and others. If other damaging pests present significant threats, be sure to consider them as you develop your forest management plan.

Also, remember that other insect and disease pests can affect ash trees. Signs of EAB infestation include characteristic D-shaped exit holes on branches or the trunk (Fig. 3) and S-shaped tunnels under the bark (Fig. 2). Adult beetles are metallic green and are most active from mid-June through early August. Unfortunately, it's possible to have an EAB infestation for several years before many people notice symptoms.

It is always best to work with a professional consulting forester to help you through the decision-making process for your property. Ash trees grow across a wide variety of habitats and site conditions. There are no standard prescriptions. Developing a written forest management plan for your woodland is a good idea for many reasons (records, taxes, memory, scheduling, etc.). Be wary of unsolicited offers to buy your trees. Take the time to consider all your options and make the decisions that best reflect your wishes.

Fig. 3. D-shaped exit holes.

Contact your county MSU Extension office for more information about ash trees and EAB. Several publications related to EAB are available, such as “Distinguishing Ash From Other Common Trees” (bulletin E-2892), “Ash Identification” (E-2942), “My Ash Tree is Dead – Now What Do I Do?” (E-2940), “Signs and Symptoms of the Emerald Ash Borer” (E-2938), “Native Borers and Emerald Ash Borer Look-Alikes” (E-2939) and “Don’t Be Fooled By Look-Alikes! (Emerald Ash Borer and Asian Longhorned Beetle)” (E-2944). You can download these bulletins online at **www.emdc.msue.msu.edu** or order a copy through your county MSU Extension office.

Infested ash tree and (inset) green ash leaf.

Learn more about how to recognize EAB and infested ash trees by visiting the Internet at:

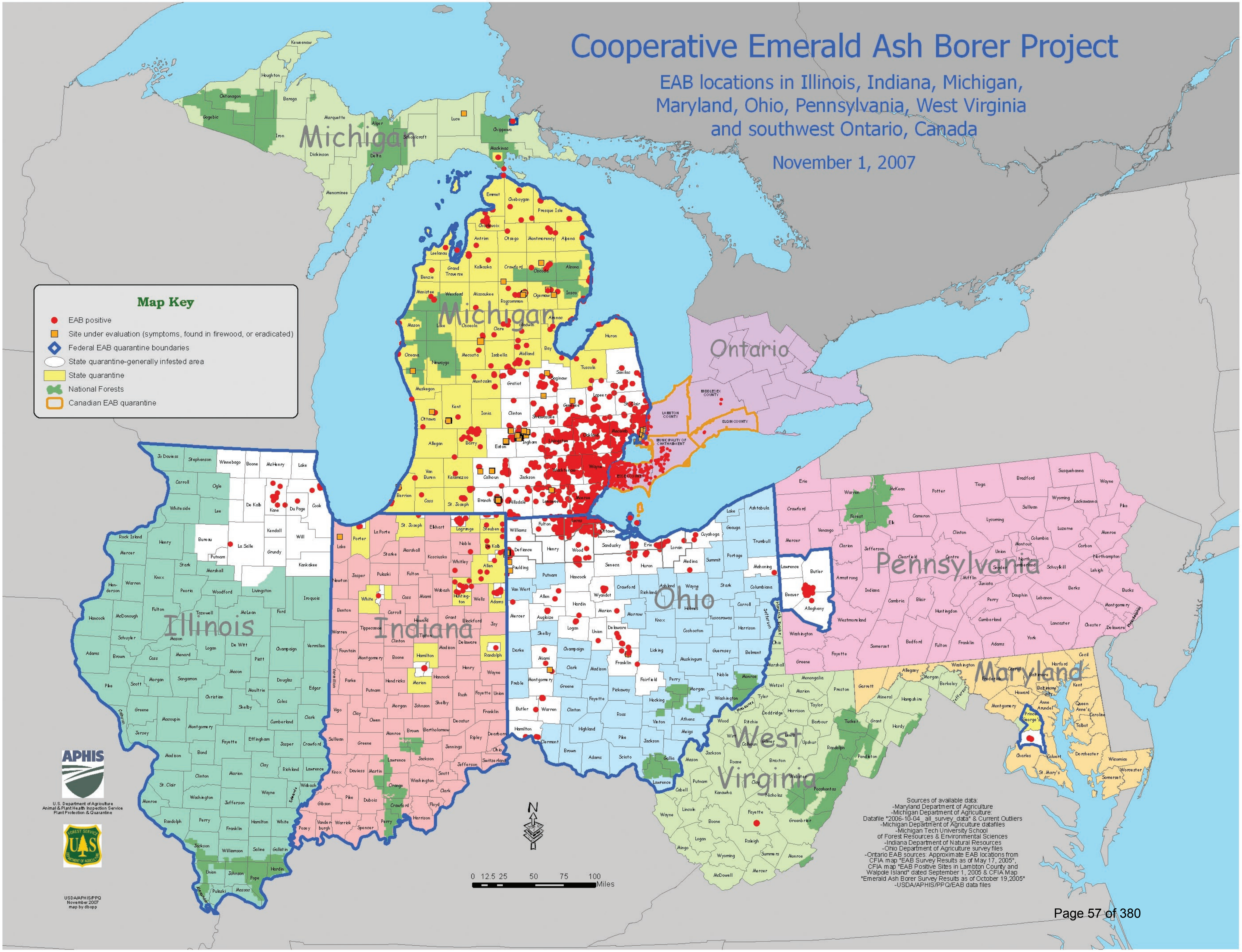
www.emeraldashborer.info

www.michigan.gov/mda, *then click on* **“emerald ash borer”**

www.na.fs.fed.us/fhp/eab

White ash trees killed by EAB are sawn into lumber near Midland, Mich.

Revised 9:07 – 10M, LB/KMF, Price 50¢.


Cooperative Emerald Ash Borer Project
EAB locations in Illinois, Indiana, Michigan, Maryland, Ohio, Pennsylvania, West Virginia and southwest Ontario, Canada
November 1, 2007
Map Key
EAB positive
Site under evaluation (symptoms, found in firewood, or eradicated)
Federal EAB quarantine boundaries
State quarantine-generally infested area
State quarantine
National Forests
Canadian EAB quarantine
Michigan
Ontario
Illinois
Indiana
Ohio
Pennsylvania
West Virginia
Maryland
LAMBTON COUNTY
MIDDLESEX COUNTY
ELGIN COUNTY
MUNICIPALITY OF CHATHAM-KENT
0 12.5 25 50 75 100 Miles
N
APHIS
U.S. Department of Agriculture
Animal & Plant Health Inspection Service
Plant Protection & Quarantine
USDA/APHIS/PPQ
November 2007
map by dbopp
Sources of available data:
-Maryland Department of Agriculture
-Michigan Department of Agriculture:
Datafile "2006-10-04_all_survey_data" & Current Outliers
-Michigan Department of Agriculture datafiles
-Michigan Tech University School
of Forest Resources & Environmental Sciences
-Indiana Department of Natural Resources
-Ohio Department of Agriculture survey files
-Ontario EAB sources: Approximate EAB locations from
CFIA map "EAB Survey Results as of May 17, 2005",
CFIA map "EAB Positive Sites in Lambton County and
Walpole Island" dated September 1, 2005 & CFIA Map
"Emerald Ash Borer Survey Results as of October 19,2005"
-USDA/APHIS/PPQ/EAB data files

Extension Bulletin E-2938 Reprinted December 2005

Signs and Symptoms of the Emerald Ash Borer

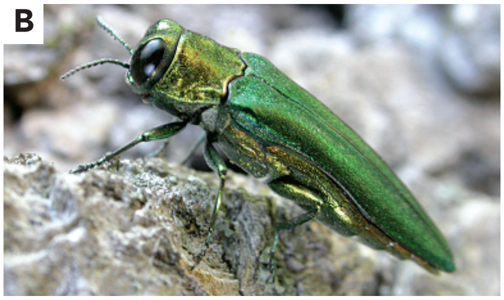
Mary Wilson, MSU Extension. Eric Rebek, Michigan State University Dept. of Entomology

Adult

A

Michigan State University

B

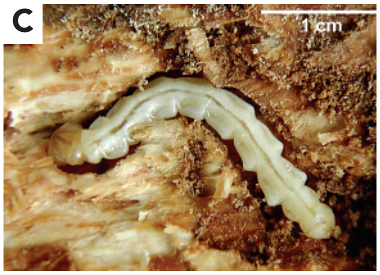


Michigan State University

- Bright, metallic green (Figs. A, B).
- 1/2 inch long, flattened back (Figs. A, B).
- Purple abdominal segments beneath wing covers.

Larva

C



D. Cappaert, MSU

- Creamy white, legless (Fig. C).
- Flattened, bell-shaped body segments (Fig. C).
- Terminal segment bears a pair of small appendages.

Canopy Dieback

D

E. Rebek, MSU

E

E. Rebek, MSU

- Begins in top one-third of canopy (Fig. D).
- Progresses until tree is bare (Fig. E).

Epicormic Shoots

F

J. Smith, USDA APHIS PPQ

- Sprouts grow from roots and trunk (Figs. F, G).
- Leaves often larger than normal.

G

J. Smith, USDA APHIS PPQ

Emerald Ash Borer

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Bark Splitting

H


J. Smith, USDA APHIS PPQ

I


A. Storer, Mich. Tech. Univ.

- Vertical fissures on bark (Fig. H) due to callous tissue formation (Fig. I).
- Galleries exposed under bark split.

Serpentine Galleries and D-shaped Exit Holes

J

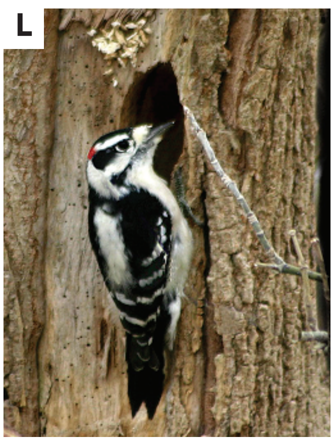

D. Cappaert, MSU

K


D. Cappaert, MSU

- Larval feeding galleries typically serpentine (Fig. J).
- Galleries weave back and forth across the woodgrain.
- Packed with frass (mix of sawdust and excrement).
- Adults form D-shaped holes upon emergence (Fig. K).

Increased Woodpecker Activity/Damage

L


D. Cappaert, MSU

M


Karen D'Angelo, MSUE

- Several woodpecker species (Fig. L) feed on EAB larvae/pupae.
- Peck outer bark while foraging (Fig. M).
- Create large holes when extracting insects (Fig. M).

Revised - 12:05 - 5M - KMF/LB

Extension Bulletin E-2939 New, February 2005

Native Borers and Emerald Ash Borer Look-alikes

Native Ash Borers


A


B

D.G. Nielsen, Ohio State University/OARDC


C

J. Solomon, USDA Forest Service www.forestryimages.com


D

D. Herms, Ohio State University/OARDC


E

D. Herms, Ohio State University/OARDC


F

D. Herms, Ohio State University/OARDC


G

D. Herms, Ohio State University/OARDC

Native ash borers are North American insects that tunnel under the bark of ash trees, sometimes causing enough damage to seriously weaken trees.

These two borers attack healthy ash trees:

Banded ash clearwing, *Podosesia aureocincta*; adult (Fig. A), larva (Fig. B).

Ash/lilac borer, *Podosesia syringae*; adult (Fig. C).

- Wasp-mimicking moths that feed on xylem of ash trees.
- Larvae are round with legs and expel frass from tree (Fig. D).
- Round exit hole (1/4 inch); pupal case exposed in exit hole upon emergence (Fig. E).

These three borers attack stressed or dying ash trees:

Redheaded ash borer, *Neoclytus acuminatus*; adult (Fig. F), larva (Fig. G).

Banded ash borer, *Neoclytus caprea*; adult (Fig. H).

- Longhorned beetles (roundheaded borers) that attack stressed ash trees, but also colonize elm, hickory, oak, linden and others.
- Larvae tunnel deep into xylem (Fig. I) and adults emerge from round-oval exit holes measuring 1/4 inch (Fig. J).


H

J. Solomon, USDA Forest Service www.forestryimages.com


I

Csoka, Hungary For Res Inst., www.forestryimages.com


J

J. Solomon, USDA Forest Service www.forestryimages.com

Emerald Ash Borer

MICHIGAN STATE UNIVERSITY EXTENSION

Native Borers (continued)

Eastern ash bark beetle, *Hylesinus aculeatus*; adult (Fig. K).

- Cylindrical bark beetle that forms galleries beneath the bark of ash trees (Fig. L).
- Infested trees peppered with tiny, round exit holes measuring approximately 1/16 inch (Fig. M).

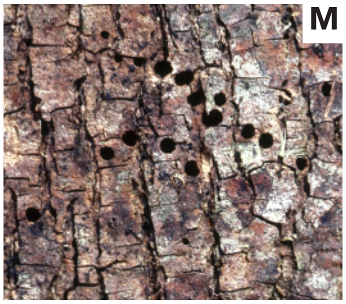
K

J. Solomon, USDA Forest Service
www.forestryimages.com

L

J. Solomon, USDA Forest Service
www.forestryimages.com

M



J. Solomon, USDA Forest Service
www.forestryimages.com

Emerald Ash Borer Look-alikes

The following insects are common to Michigan and could possibly be confused with emerald ash borer.

N

Michigan State University

O

University of Arkansas

P

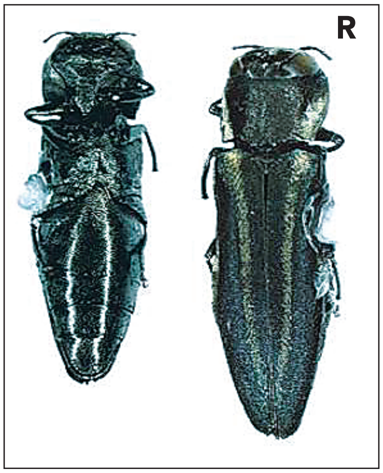
Michigan State University

- **Six-spotted tiger beetle**, *Cicindela sexguttata*; adult measures 1/2 inch long (Fig. N).
- **Caterpillar hunter**, *Calosoma scrutator*; adult measures 1 inch long (Fig. O).
- **Japanese beetle**, *Popillia japonica*; adult measures slightly less than 1/2 inch long (Fig. P).
- **Bronze birch borer**, *Agrilus anxius*; adult measures approximately 1/2 inch long (Fig. Q).
- **Two-lined chestnut borer**, *Agrilus bilineatus*; adult measures approximately 1/2 inch long (Fig. R).
- Several other uncommon metallic wood-boring beetles.

Q

J. Zablotny, USDA APHIS PPQ

R



J. Zablotny, USDA APHIS PPQ

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New - 2:05 - 5M - KMF/LB

Professional Guide to Emerald Ash Borer Treatments

David Smitley
Michigan State University, Department of Entomology
June 20, 2005

Several insecticide products have worked well in our research tests for control of emerald ash borer (EAB). At this time treatments are needed **every year** in order to protect ash trees from EAB and they are recommended only in the quarantined area; it is not necessary to treat ash trees outside of this area. At this time the quarantined area includes all of Monroe, Wayne, Macomb, St.Clair, Lenawee, Washtenaw, Oakland, Lapeer, Hillsdale, Jackson, Livingston, Genesee, Ingham, Shiawassee, Saginaw, Branch, Calhoun, Eaton, Clinton and Gratiot counties. Tests have shown that we can protect healthy trees from emerald ash borer with insecticides, but we may not be able to save severely compromised trees. By the time you see dead branches, thinning of the canopy, and woodpecker activity, the tree is already severely damaged, and it may be too late to save it with insecticides. For most of the ash trees within an area defined by the following points; Downtown Detroit, Rockwood (near the mouth of the Detroit river), Milan (south of Ann Arbor), Ann Arbor, Brighton, Pontiac, and Sterling Heights, it is too late to save them unless they have already been treated in previous years.

The products listed below will protect trees from emerald ash borer if treatments begin when trees are still healthy. For more information on how well each of these products work, see reports of our research tests at emeraldashborer.info . At the website you will see a list of topics on the left side of your screen. Just click on *research* and the results from 5 different EAB insecticide tests by Michigan State University will pop-up.

Table 1. Products For Landscapers and Arborists to Use for Protecting Ash Trees From Attack by Emerald Ash Borer.

Active ingredient	Product name	Timing	Type of Application
Imidacloprid	Imicide (Mauget) Pointer (Wedgle) IMA-jet (Arborjet)	Late May to early July	Trunk injection (once per year)
Bidrin	Injectacide-B	Late May to early September	Trunk injection (once per year)
Imidacloprid	Merit	Mid to late April	High pressure soil injection (once)
Cyfluthrin	Tempo	Early June and again in late June	Trunk and foliage spray (twice)
Bifenthrin	Onyx	" "	Trunk spray (twice)
Beauveria fungus	BotaniGard	" "	Trunk and foliage Spray (twice)

Note: This information is for educational purposes only. Reference to commercial products or trade names does not imply endorsement by MSU Extension or bias against those not mentioned.

Extension Bulletin E-2940 Revised, March 2007

My Ash Tree is Dead… Now What Do I Do?

Emerald Ash Borer

MICHIGAN STATE UNIVERSITY EXTENSION

More than 20 million ash trees have been killed by the emerald ash borer so far in southeastern Michigan. Consequently, many homeowners are left wondering what to do with the dead and dying trees in their yards. Though the Michigan Department of Agriculture (MDA) has implemented quarantine restrictions on the movement of ash wood in many areas throughout Michigan, many value-added options are available to homeowners who wish to utilize the wood from their trees. As you continue to care for your landscape in the future, remember that the utilization tips outlined below are also applicable to a variety of other tree species.

First, realize that the quarantine does not require you to remove your dead or dying ash tree.

If your dead tree is located in a yard or along a street, it will likely pose a hazard over time and should be removed immediately. However, if one of your dead trees is within a woodlot, it is much less likely to pose a danger to you or your family. If left standing, these trees can provide valuable habitat for wildlife. Standing dead trees are an integral component of a healthy ecosystem, creating nesting sites for birds, sheltered cavities for mammals and structure for a variety of other organisms. Safety, however, should be your top priority — if you think that the tree could be a hazard for you or others, be safe and remove it.

If you plan to remove your tree, hire a reliable, insured, licensed arborist/tree service company.

The state has created a program to help reduce ash tree removal costs for communities and homeowners in the EAB-quarantined area. If your municipality is participating, this system will allow you to access the same tree removal services chosen by your city or township at state-contracted rates. Please note that all wood removed in this program will become the property of the local government. Contact your local city or township office for more information.

As another option, you may wish to hire a tree removal company on your own. Joining with your neighbors to hire a single company for a large group of local tree removals may also allow you to benefit from bulk purchasing prices.

Before hiring a company, be sure to obtain:

- Estimates from multiple companies.
- Proof of insurance.
- Written estimates of cost.
- Written agreement on disposal/site cleanup requirements.
- References.

For a list of local arborists or for tips on how to select a tree service company, please contact your county Michigan State University Extension office.

More information can also be found at:
http://www.emeraldashborer.info/files/arborist.pdf

If you choose to remove your tree, the wood does not have to go to waste. There are several ways that you can recover some of the value in this resource and put the wood to good use around your home.

If you plan to use the wood from your tree, you should consider a few things first:

- Do you have a specific need for this wood?
- Does your tree have a valuable sawlog worth milling into lumber?
  - Is the tree at least 12 inches in diameter?
  - Is the base of the trunk at least 6 feet long and clear of branches, cracks, rot or other defects?
  - Has the tree been dead for only one year?
- Do you have the room to store this material and the ability to handle the product appropriately (by drying lumber, etc.)?
- Have you communicated your plans to your tree removal company? A tree must be cut down carefully to preserve its value. Also, many tree services may charge less if they do not have to dispose of your tree.

By utilizing wood from trees that need to be removed instead of buying other wood products, you can reduce waste and help to conserve forest resources. Here are examples of some of the ways homeowners can use their landscape trees:

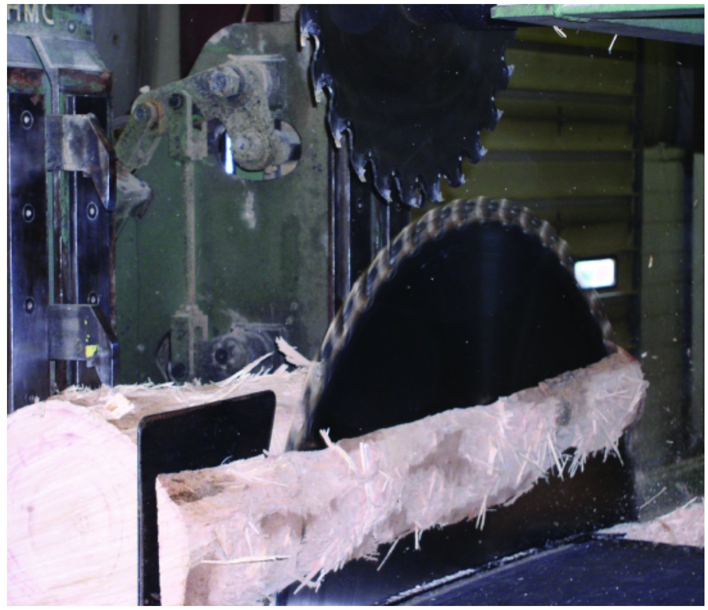
- **Lumber:** Many local mill operators can bring a portable sawmill directly to your home, allowing your removed trees to be converted into lumber that you can use for a variety of projects. Milling is especially suited to trees killed by the emerald ash borer because the insect does not damage the interior portion of the wood when it kills the tree. Ash wood has many redeeming qualities and often makes a good substitute for oak. It can be made into many beautiful and durable products, including furniture, flooring, paneling and molding.

  Portable sawmill operations generally charge by the hour or by the total board feet of lumber produced. Lists of local sawmill operations can be obtained at your county MSU Extension office or from your county's Conservation District forester.

- **Landscaping materials:** Dead landscape trees can still bring beauty and structure to your yard. You can easily have them milled to become landscape timbers or chip them to create mulch or compost for gardening and home landscaping projects.
- **Art and furniture:** If the tree has special significance for your family, you may want to consider hiring a woodworker or chainsaw carver to create a piece of art or furniture from the wood. Many people, devastated by the death of a beloved landscape tree, have managed to create treasured family heirlooms in this way. Organizations such as the Michigan Association of Woodturners, the United Chainsaw Carvers Guild or the Michigan Woodworkers' Guild can be good resources for finding a suitable craftsperson.
- **Firewood:** Wood from trees killed by the emerald ash borer can still be used for firewood at the location where the trees were removed. However, this firewood should not be transported to other locations. For more information about the laws and quarantine regarding firewood movement, please contact your county MSU Extension office.

If you do not need the wood at your home, here are some ways that you can economically dispose of the materials without contributing to the spread of the emerald ash borer:

- Sell your ash wood to a reputable industry. If you (and your neighbors) have a significant number of trees, you may be able to sell the logs to a sawmill or other industry. Be sure to get a signed statement from the buyer that all wood will be handled in a way consistent with the MDA quarantine regulations.
- Dispose of your tree at a local wood disposal site. Many communities have publicly or privately run wood collection yards available. Wood dropped at these yards is generally recycled into mulch, fuel or firewood; in some cases, it is even milled into lumber. Fees for wood disposal vary by site and by the condition of the wood (chips vs. logs, etc.). A list of some available yards can be found at: **www.michigan.gov/eab**. Click on "I think I have a tree...," and follow the links.



- Provide materials to local woodworkers. Many craftspeople enjoy using removed street and yard trees for their specialty projects. Again, if you find someone interested in buying your wood, be sure that he/she will respect quarantine regulations.
- Donate the wood. Your wood could make a difference in your own community. You may want to ask your local schools, parks or community organizations (Habitat for Humanity, scouting groups, nature centers, etc.) if they have need for raw materials for picnic tables, park benches, renovation or construction programs, or other projects.

Whatever you choose to do with your dead ash trees, be sure that NO ASH WOOD LEAVES THE QUARANTINE AREA!

You have the power to be a major player in the emerald ash borer eradication efforts. By not allowing any infested wood to leave the quarantined region, you are helping the state with the most difficult part of the battle.

"Under the quarantine, it is illegal to move ash trees, branches, lumber with bark attached, wood chips larger than 1 inch, and any deciduous firewood from designated areas. Additionally, the movement of all ash nursery stock

is prohibited within, into and from the entire Lower Peninsula," says the Michigan Department of Agriculture. More information about current quarantined areas and regulations can be found at the MDA Web site (**www.michigan.gov/mda** — click on "Emerald Ash Borer" in the "Quick Links" section) or obtained by calling your county MSU Extension office.

For more information about successful urban wood recycling and utilization programs, please see the following resources:

The Southeast Michigan Resource Conservation and Development Council's Ash Utilization Options Project Web site: **www.semircd.org/ash**.

Bratkovich, Stephen M. 2001. *Utilizing Municipal Trees: Ideas From Across the Country*. NA-TP-06-01. Newtown Square, Pa.: U.S. Dept. of Agriculture, Forest Service, Northern Area State and Private Forestry. Online at: **http://www.treesearch.fs.fed.us/pubs/viewpub.jsp?index=11059**.

Cesa, Edward T.; Lempicki, Edward A.; and Knotts, Howard. 2003. *Recycling Municipal Trees: A Guide for Marketing Sawlogs from Street Tree Removals in Municipalities*. NA-TP-02-94. Morgantown, W. Va.: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. Online at: **http://www.fs.fed.us/na/morgantown/frm/cesa/rmt/rmt_index.html**.

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In cooperation with:

Southeast Michigan Resource Conservation & Development Council

DEPARTMENT OF NATURAL RESOURCES DNR MICHIGAN

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http://www.semircd.org

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http://www.michigan.gov/dnr

UT Extension

SP657

Impacts of Air Pollution on the Urban Forest

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An average human breathes around 3,400 gallons of air each day. Included in each breath can be numerous noxious chemicals as well as suspended particles. Consequently, human lungs must cope with this pollution. It is well known that air pollution is hazardous to human health and of enormous concern today. However, the “lungs” of our urban areas, trees growing in and around our cities, must also contend with air pollution. Just as air pollution impacts humans, air pollution affects trees in a variety of ways.

Pollution has long been identified as harmful to trees. Historically, impacts of air pollution were primarily local in scale (trees impacted by a nearby industrial area).Yet today, trees are being affected on both the local and regional scale. Entire urban areas and even rural area trees are experiencing adverse impacts of air pollution.

Trees help cleanse the air by reducing levels of carbon dioxide (CO_2) and removing pollutants, while releasing oxygen through **photosynthesis**. Air pollution directly injures trees by damaging living tissue, primarily foliage, and impairs photosynthesis and the ability to respirate. Air pollutants also weaken trees, predisposing them to further damage by insects and disease. Some air pollutants can also indirectly impact tree health by altering ecosystem processes such as soil chemistry and nutrient cycling. The result is decreased tree vigor and growth that can culminate in tree death.

Robert Anderson

Ozone damage to maple.

Tim Tigner

Ozone damage to black cherry.

Identifying Air Pollution Injury

Air pollution may cause short-term damage, which can be immediately visible, and long-term damage, which can lead to gradual tree decline. Signs of tree injury from air pollution generally appear first in the foliage. Leaves or needles may begin to appear discolored, spots may occur between the veins or the tips may appear burned. Air pollution injury is often difficult to identify because symptoms are similar to other injuries such as nutritional deficiencies and drought. Additionally, long-term damage generally

Trees that are known to be relatively tolerant of air pollution	Trees that are known to be relatively intolerant of or sensitive to air pollution
• Arborvitae	• American elm
• Boxelder	• Lombardy poplar
• Douglas-fir	• Willow
• Flowering dogwood	• White pine
• Northern red oak	• Virginia pine
• Willow oak	

predisposes a tree to other environmental stresses, making diagnosis difficult due to the masking effects of the additional stress. Some tree species are more susceptible to air pollution than are others.

The Causes

Some of the major air pollutants and their primary sources are:

- Carbon dioxide: Burning oil, coal or natural gas for energy.
- Sulfur dioxide: Burning coal to generate electricity.
- Hydrogen fluoride and silicon tetrafluoride: Aluminum and phosphate fertilizer production, oil refineries and steel manufacturing.
- Nitrogen oxides (NOx): Burning fossil fuels and automobile exhausts.
- Ozone: Chemical reactions of sunlight, NOx and volatile organic compounds (occurs naturally and found in products such as paints, solvents, gasoline, adhesive and others)
- Methane: Burning fossil fuels, livestock waste or landfills.
- Chloroflorocarbons: Air conditioners, refrigerators or industrial foam.
- Particulates: Dust, ash, pollen and smoke.

The major phytotoxic (detrimental to plants) air pollutants are ozone, sulfur dioxide and nitrogen oxides.

Ozone

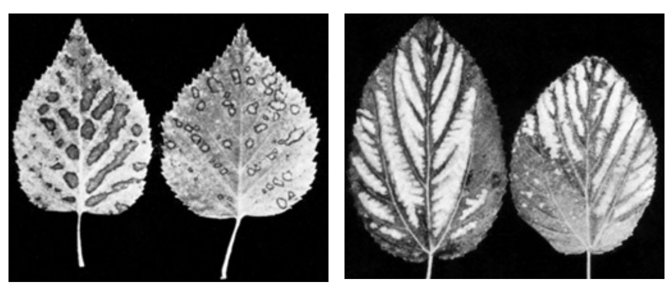
Ozone is not generally emitted directly into the air; instead, ozone (O_3) is formed through a chemical reaction in the Earth's lower atmosphere, the troposphere. Volatile organic compounds (VOCs) react with nitrogen oxides (NOx) in the presence of heat and sunlight to create ground-level ozone. Ground-level ozone is damaging to human and plant health and is the major component of smog. A few major sources of NOx and VOCs are motor vehicle exhaust, industrial emissions, gasoline vapors and chemical solvents.

Ozone enters the tree through stomatal openings on the leaf. Ozone then reacts with leaf tissues to inhibit photosynthetic processes. The amount of ozone entering the tree will depend on the ozone concentrations in the area. Unfortunately, metropolitan areas and the mountains of East Tennessee experience some of the highest concentrations of ground-level ozone. On deciduous trees, a common symptom of ozone stress is purple speckling on upper surfaces of leaves. On coniferous trees, symptoms include yellow mottling on needles, shorter needles and loss of needles. Other general visible symptoms on both hardwoods and pines include chlorosis (yellowing) and premature leaf-drop. While damage from high concentrations of ozone does not commonly kill trees (although it can), it is an additional stress on the health of trees. Ozone also disrupts carbohydrate transport to the leaves. This increases the concentration of sugars in the leaves and makes the foliage more susceptible to insect attack.

Sulfur Dioxide and Nitrogen Oxides

In addition to being a component of ground-level ozone, nitrogen oxides, along with sulfur dioxide, are the primary causes of acid deposition or "acid rain." Sulfur dioxides are produced primarily by the burning of coal and oil to generate electricity, from smelting ore that contains sulfur and in the manufacturing of sulfur-based products.

Much like ozone, acid rain rarely kills a tree. Instead, acid rain weakens the tree by damaging leaves and limiting the uptake of nutrients. At lower pH levels (more acid soil) the majority of macronutrients become unavailable for tree growth. Acid rain facilitates the leaching of beneficial nutrients from the soil and at the same time increases the release of substances such as aluminum that are more toxic to trees and plants. (Refer to UT Extension publication SP 534 on *Nutrient Deficiencies in Trees* for more information.) Therefore, the effect is a "one-two punch" that can severely impact the ability of trees to grow.



Katz, Ledingham and McCallum

Sulphur dioxide injury on birch and dogwood.

You Can Help

The most serious forms of air pollution are difficult to prevent without a community effort. Minimize the air pollution you produce by keeping your automobiles tuned, limiting your use of internal combustion engines and obeying local open-burning ordinances. Planting more trees can

Trees with a range of ozone tolerance and sensitivity.

Tolerant	Intermediate	Sensitive
Abies balsamea - Fir, balsam	*Acer negundo* - Boxelder	*Catalpa* spp. - Catalpa
Abies concolor - Fir, white	*Cercis canadensis* - Redbud, eastern	*Fraxinus americana* - Ash, white
Acer saccharum - Maple, sugar	*Liquidambar styraciflua* - Gum, sweet	*Fraxinus pennsylvanica* - Ash, green
Betula pendula - Birch, European white	*Pinus echinata* - Pine, shortleaf	*Gleditsia triacanthos* - Honeylocust
Cornus florida - Dogwood, white	*Pinus sylvestris* - Pine, Scotch	*Juglans regia* - Walnut, English
Ginkgo biloba - Ginkgo	*Quercus coccinea* - Oak, scarlet	*Liriodendron tulipifera* - Poplar, tulip or yellow-poplar
Ilex spp. - Holly	*Quercus velutina* - Oak, black	*Malus* spp. - Crabapple
Juglans nigra - Walnut, black	*Syringa* spp. - Lilac	*Pinus nigra* - Pine, Austrian
Nyssa sylvatica - Gum, black	*Ulmus parvifolia* - Elm, lacebark	*Pinus strobus* - Pine, eastern white
Picea abies - Spruce, Norway		*Pinus taeda* - Pine, loblolly
Picea pungens - Spruce, blue		*Pinus virginiana* - Pine, Virginia
Pinus resinosa - Pine, red		*Platanus occidentalis* - Sycamore, American
Pseudotsuga menziesii - Fir, Douglas		*Quercus alba* - Oak, white
Quercus robur - Oak, English		*Quercus palustris* - Oak, pin
Quercus rubra - Oak, red		*Salix babylonica* - Willow, weeping
Taxus spp. - Yew		*Sorbus aucuparia* - Mountain ash, European
Thuja spp. - Arborvitae		
Tilia americana - Linden or Basswood, American		
Tilia cordata - Linden, little-leaf		

Adapted from: Appleton and others, 2000.

Trees with a range of sulfur dioxide tolerance and sensitivity.

Tolerant	Intermediate	Sensitive
Acer saccharinum - Maple, silver	*Acer negundo* - Boxelder	*Amelanchier* spp. - Serviceberry
Acer saccharum - Maple, sugar	*Acer rubrum* - Maple, red	*Betula* spp. - Birch
Ginkgo biloba - Ginkgo	*Pinus nigra* - Pine, Austrian	*Fraxinus pennsylvanica* - Ash, green
Juniperus spp. - Juniper	*Populus deltoids* - Cottonwood	*Pinus strobus* - Pine, eastern white
Picea pungens - Spruce, blue	*Quercus alba* - Oak, white	*Populus nigra* 'Italica' - Poplar, lombardy
Quercus palustris - Oak, pin	*Sorbus aucuparia* - Mountain ash, European	*Salix nigra* - Willow, black
Quercus rubra - Oak, red	*Syringa* spp. - Lilac	*Ulmus parvifolia* - Elm, lacebark
Thuja spp. - Arborvitae	*Tilia americana* - Linden or Basswood, American	
Tilia cordata - Linden, littleleaf	*Ulmus americana* - Elm, American	

Adapted from: Appleton and others, 2000.

also help. When planting new trees, assess your landscape before planting. If planting near streets, highways and roads, consider planting trees that are more tolerant of common air pollutants. In addition, the USDA Forest Service (Nowak citation) suggests the following for managing your urban forest landscape:

- Increase the number of healthy trees (increases pollution removal).
- Sustain existing tree cover (maintains pollution removal levels).
- Sustain large, healthy trees (large trees have greatest per-tree effects).
- Use long-lived trees (reduces long-term pollutant emissions from planting and removal).
- Use low-maintenance trees (reduces pollutant emissions from maintenance activities).
- Reduce fossil fuel use in maintaining or controlling vegetation on property (reduces pollutant emissions).
- Plant trees in energy-conserving locations (reduces pollutant emissions from power plants).
- Plant trees to shade parked cars (reduces vehicular VOC emissions).
- Supply ample water to vegetation (enhances pollution removal and temperature reduction).
- Plant trees in polluted areas or heavily populated areas (maximizes tree air quality benefits).
- Avoid pollutant-sensitive species (increases tree health).
- Use evergreen trees for particulate matter reduction (year-round removal of particles).

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John Skelly

Ozone damage to yellow-poplar.

Canadian Forest Service

Foliar necrosis on ash caused by sulfur dioxide.

Andrew J. Boone

Ozone damage to white pine.

SP657-15M-9/05 R12-4910-051-002-06 06-0067

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SP 534

Nutrient Deficiencies in Trees

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Assistant Professor
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Our knowledge of the nutrition of ornamental trees is sparse. Most research has been conducted on juvenile plants or seedlings that are grown for a few weeks or months in greenhouses, growth chambers or even in nurseries where the controlled conditions are quite different than the environmental conditions encountered in nature and those found in larger, developing trees. Furthermore, most of the literature on nutrient deficiencies is from crop science or horticultural plants, not trees. The information available for trees is at best fragmentary. This fact sheet provides information on some of the nutritional deficiencies found in urban trees in Tennessee and the responses of trees to those deficiencies.

Most of our native soils in Tennessee do not have nutrient deficiencies. Total elemental analysis of 13 soil profiles representing six of the eight major land resource areas in Tennessee established that elemental concentrations were well within the normal ranges for plant growth (Ammons et al. 1997). However, deficiencies do occur in highly altered soils of urban landscapes where topsoil has been removed, soil has been compacted, drainage altered or unconsolidated soil fill material has been added. Deficiencies can also occur in many unaltered soils.

Sixteen essential elements are required for plant growth. An element is considered essential if plants cannot complete their life cycle without it, and if the element is directly involved in the metabolism of the plant. Three elements, carbon, hydrogen and oxygen, are readily available from air and water. The remaining 13 elements are obtained from the

Alan S. Windham

Iron chlorosis of pin oak (*Quercus palustris*) leaves.

Tennessee Valley Authority

Healthy and manganese deficient leaves of cottonwood (*Populus deltoides*).

Macronutrients

Mineral Element	Plant Process	Visual Symptoms of Deficiency
Nitrogen (N)	Production of amino acids and protein. Synthesis of chlorophyll. Growth regulator. Nucleic acids.	Chlorosis of older leaves progressing from pale green to yellow. Colors may mottle. Occasionally, scorching of leaf tips and margins.
Phosphorus (P)	High-energy bonds (ATP - adenosine triphosphate) associated with energy transfer. Nucleic acids.	Accumulates anthrocyanins, a leaf color pigment causing a blue-green or a red-purple coloration. Flowering and fruiting reduced. Lower leaves tend to turn yellow.
Potassium (K)	Opening and closing of stomata, enzyme activity, protein synthesis, photosynthesis and cell growth.	Leaf margins become scorched, turn brown or mottled and curl downward. Chlorosis first begins at the tips and margins of leaves and progresses toward the base.
Calcium (Ca)	Meristematic tissues of the root tips, bud elongation and development of fruits. Pectin synthesis and cell wall elasticity.	Chlorosis and necrosis of leaves, distorts growth of root tips and shoots.
Magnesium (Mg)	Enzyme systems and chlorophyll synthesis.	Chlorosis of leaves followed by a brilliant yellow color between the leaf veins.
Sulfur (S)	Plant hormones. Three amino acids in synthesis of proteins.	Similar to N deficiencies. Yellowing and necrosis of young leaves resulting from inhibition of protein synthesis. Some stunting of shoot and root tips.

Micronutrients

Mineral Element	Plant Process	Visual Symptoms of Deficiency
Iron (Fe)	Synthesis of chloroplast proteins and various enzymes.	Veins of leaves remain dark green while the interveinal tissues become chlorotic turning light green to yellow. Dieback of shoots is also common. Easily confused with Mn and Mg deficiencies because chlorosis symptoms are similar.
Manganese (Mn)	Photosynthesis, respiration, enzyme reactions	Similar to iron symptoms. Older leaves develop pale, brownish or purple spots.
Boron (B)	Sugar translocation, nucleic acid synthesis and pollen formation.	Death or rosetting (witches broom) of apical shoots. Leaves are dwarfed and discolored, becoming chlorotic or necrotic. Terminal and lateral buds and root tips eventually die.
Zinc (Zn)	Plant growth regulators, particularly auxin and indoleacetic acid (IAA). Enzyme reactions.	Chlorosis, bronzing, or mottling of younger leaves. Abscission of older leaves. Terminal nodes have dwarfed or rossette leaves that are closely spaced (short internodes), small and discolored.
Copper (Cu)	Enzymes	Permanent wilting of leaves. Cu deficiencies difficult to visually detect.
Molybdenum (Mo)	Enzymes in nitrogen fixation.	Few symptoms. Pale color with some scorch on margins of lower leaves. Interveinal chlorosis similar to symptoms of N deficiencies.
Chlorine (Cl)	Photosynthesis	No visual symptoms.

Table 1. Sources of fertilizer amendments and application methods to control nutrient deficiencies.

Mineral	Source	Application
N	Ammonium, urea, nitrates	Ground
P	Superphosphate, rock phosphate	Ground
K	Potassium salts (KCl) and sulfate	Ground
Ca	Lime	Ground
Mg	Dolomitic limestone, epsom salts	Foliar spray (salts) or ground
S	Various sulfates, soil organic matter	Ground
Fe	Iron sulfate	Foliar spray (sulfate) or ground
Mn	Sulfates	Ground
B	Borax or boric acid	Ground or foliar spray
Mo	Sodium molybate	Ground or foliar spray
Zn, Cu	Sulfate	Ground or foliar spray

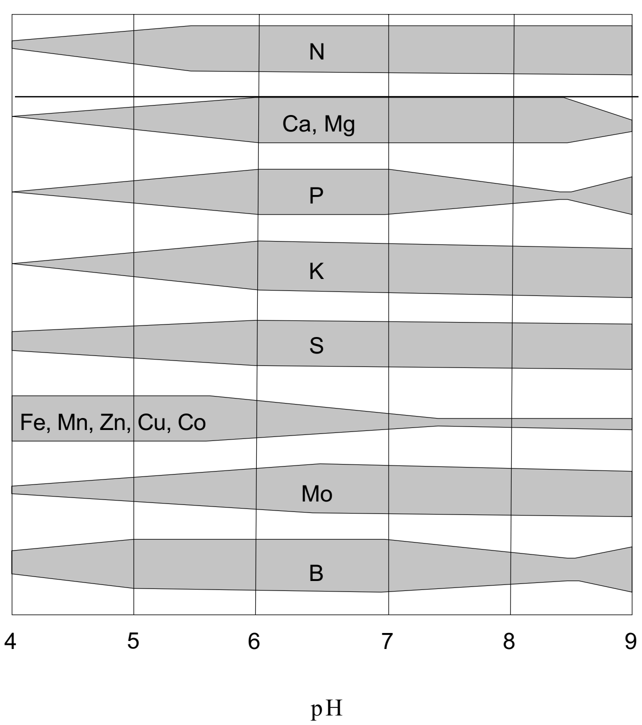

Figure 1. The relationship between soil pH and the availability of plant macro- and micronutrients. Modified from Barnes et al. 1998.

soil complex. Six of these elements, called macronutrients, are required in fairly large quantities in plants, usually in excess of 1,000 parts per million (ppm). These are nitrogen, phosphorous, potassium, sulfur, calcium and magnesium. The other mineral nutrients, including iron, boron, manganese, zinc, copper, chlorine and molybdenum, are known as micronutrients and are required in smaller quantities of usually <200 ppm.

Damage by insects and disease can mimic nutrient problems resulting from **chlorosis**, an abnormal yellowing of plant tissues that results from inadequate chlorophyll synthesis, or **necrosis**, death of plant tissue. Herbicide toxicity can also mimic nutrient deficiency. Your local county Agricultural Extension office can assist you with problem identification.

A few common visual symptoms of nutrient deficiencies are small chlorotic leaves, dead areas of leaf tips and margins or between veins, dieback of stem tips and twigs, bark lesions and excessive gum formation.

If you suspect a nutrient deficiency, the first step is to have your soil tested. Soil tests will give you baseline information on the probability of response to fertilizer and the amount of fertilizer to add. Even though nutrients may be present in sufficient elemental quantities, they may be in a form that is unavailable to plants. In general, pH affects the solubility of several elements (Figure 1). For example, iron and manganese precipitate in high pH, alkaline soils, decreasing their solubility, and thus their availability to plants.

Tennessee Valley Authority

Healthy (left) and magnesium deficient foliage of *Quercus* spp.

Mark Halcomb

Nutrient deficiency in river birch (*Betula nigra*) due to an acidic pH level.

Phosphorus also becomes more unavailable in alkaline conditions, because it forms complexes with calcium to form insoluble calcium phosphates. Alternatively, calcium and magnesium are frequently deficient in acidic, lower pH soils. Nutrients such as sulfur tend to be deficient in soils with low organic matter.

Once the soil test results are obtained, they should be interpreted professionally at the Extension office or by other knowledgeable professionals to prescribe treatments that rectify the nutrient deficiency. Most prescriptions will be to modify the pH of the soil to make certain nutrients more available (such as adding lime to increase alkalinity or acidifying agents to lower pH) or to add fertilizers by ground applications or foliar sprays (Table 1). With more than 2,000 different formulations of fertilizers available, these professionals can recommend the formulation and amount that will best satisfy your specific soil situation. Generally, the addition of fertilizer as nutrient amendments is a temporary rather than a permanent cure for nutrient deficiencies and should be re-applied periodically.

The role of each of these nutrients in plants and the visual symptoms if that nutrient is deficient are reviewed in the accompanying table.

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Great Trinity Forest Management Plan

Insects and Disease

How to Evaluate and Manage Storm-Damaged Forest Areas

How to Evaluate and Manage Storm-Damaged Forest Areas

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[3] USDA Forest Service. Southern Region. Forest Health. Atlanta. GA.

Introduction

Hurricanes, tornadoes, and ice storms strike somewhere in the South almost every year. They cause extensive forest damage by uprooting, wounding, bending, and breaking trees. Standing water, which often accompanies hurricanes, can cause additional stress and mortality. When one of these natural disasters occurs, it is important to have a plan for managing damaged timber.

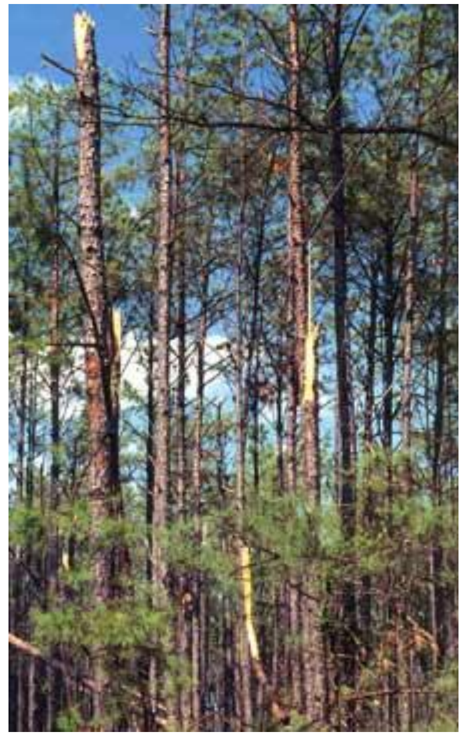
Development of a storm damage management plan involves several systematic steps. As soon as possible, the area should be sketch mapped or aerial photographed. The next step is to ground check the damage to determine the need for salvage. Priorities for salvage will depend on location, amount and type of damage, and management objectives. This guide presents methods managing storm-damaged trees to reduce growth loss, product degrade, and mortality. In the process, other factors such as threatened and endangered species must be considered. The information presented here will assist in setting priorities

Survey the Damage

Two types of surveys, general and intensive, are needed to determine the extent of forest damage from a storm.

General surveys are designed to determine geographical area affected by storms. These are very quickly and easily done from the air. Using aerial survey techniques, damaged areas may be sketched on preexisting maps or photographs, or damaged areas may be aerially photographed. A planimeter or other device is then used to determine acres affected.

Intensive surveys are designed to collect information on volumes of timber damaged and on conditions of surviving trees. Volumes of storm-damaged timber are difficult to estimate with aerial survey techniques because damaged trees are broken and twisted together. It is also difficult to determine tree condition from the air. Consequently, intensive surveys usually require ground-based plots for acceptable accuracy. The number and size of plots are determined by desired accuracy, and by time and personnel constraints.



Tornado damage surveys are unique because the storm tracks are usually long and narrow with few surviving trees. Volumes of tornado damaged timber may be estimated by taking systematic plots on a transect parallel to the storm track but just outside the damage area.

Note Types of Damage and Take Action Breakage

Breakage

Breakage is the most common type of storm damage. Its impact depends on the degree and pattern of damage as well as the tree species involved.

Breakage inevitably lowers timber values. Breaks are uneven by their nature and occur randomly along the tree bole. The random pattern lowers value since products are normally cut in specified lengths. Breakage also lowers value because difficulty in logging in broken timber slows productivity. Patterns are important when assessing breakage impact. When ice or strong gale-force winds break trees, break patterns are simple and limited to the area adjacent to the breakpoint. Hardwood trees are seldom killed by breakage. Even when tops are completely gone, new branches will sprout and the tree will recover. In hardwoods, the major problem is that breaks in the trunk or large branches (over 3 in. diameter) permit entry of stain and decay fungi. Stain will move vertically from the injury at a rate of 6 to 18 inches per year, and decay will follow the stain in 8 to 10 months.

Hurricane-damaged stand.

Pine tree with broken main stem.

Internal stain on a previously damaged tree.

Most species of pine will die if tops are completely broken and no live limbs remain. If three or more live limbs are left in the tops of loblolly or slash pines, the chance of survival is excellent (above 75 percent). One of the lateral branches in these trees will become the terminal, and in 8 to 10 years the only sign of breakage will be a sharp crook in the bole at the point where the break occurred. These trees will experience growth losses, however.

Recommendations

For hardwoods, trees with broken tops or branches over 3 inches in diameter should be salvaged during the next scheduled harvest. High-value trees such as those in recreation areas and in yards should be properly pruned to promote rapid healing. For pines, if three live limbs or less remain, the trees should be harvested as quickly as practical.

Twisted Trunks

The cyclonic winds that are typical of tornadoes, and often accompany hurricanes, cause twisting and separation of wood fibers in the main stein. Logs from trees that have experienced this treatment may fall apart when sawn for lumber products. Trees twisted by cyclonic winds may appear normal, except that pines often have pitch flow along the trunk.

Recommendations

Trees with evidence of twist injury should be removed, since the problem will not disappear with time and considerable losses may be incurred during a later harvest.

Root Damage

If they are not salvaged promptly, uprooted trees probably will be degraded quickly by stains, decays, and secondary insects, such as *Ips* bark beetles, borers, powderpost beetles, and ambrosia beetles. The longer salvage is delayed, the greater the amount of degrade and weight loss from rapid drying. Degrade translates into a stumpage value loss. The amount of degrade that is acceptable to industry depends on the tree species and local markets. Table I shows the probable sequence of invasion by damaging organisms in storm-damaged timber.

Table 1- Sequence of invasion of damaging organisms in storm-damaged timber

Species	Year 1	Year 2
Pine	Bark beetles, ambrosia beetles, sawyers, blue stain fungi, soft rot fungi	Decay fungi

Oak and hickory	Wood borers, ambrosia beetle, stains, soft rot fungi	Sapwood fungi
Other hardwoods	Wood borers, ambrosia beetles, stains, soft rot fungi	Sap and heartwood decay fungi

Root-sprung trees will not die immediately, but will show decline symptoms over a period of several years. These trees may be invaded by root rot organisms and subjected to drought stress and insect attack. Root-sprung pines may be invaded by bark beetles and blue stain fungi. These pines can serve as prime habitat for the southern pine beetle and, if conditions become favorable, an outbreak could occur. They can also harbor high populations of turpentine beetles.

Recommendations

Trees with major root damage should be salvaged as 500fl as possible to avoid growth loss, product degrade, bark beetle attacks, and mortality.

Major Wounds

During storms, many trees sustain wounds caused by falling tops, adjacent uprooted trees, and major branch breakage. In hardwoods, wounds that do not penetrate more than 2 inches into the sapwood and have less than 144 square inches of surface area will have only localized stain, but little decay. Wounds that exceed these limits will have stains and decay that move at the rates described for broken branches. Pine trees with major wounds to the lower bole and larger roots may be attacked by bark beetles.

Wounds associated with storm damage.

Recommendations

Trees with major wounds should be considered for removal during the next scheduled harvest, or they should be included in the salvage operation.

Bent Trees

Bent hardwoods usually are not attacked by insects or diseases because they are not in a stressed condition. Pine trees that are bent to the extent that cracks and resin flow occur may be invaded by bark beetles and disease-causing organisms.

Trees bent during a hurricane.

Recommendations

Small trees (under 15 feet in height) usually straighten even after severe bending. Taller severely bent hardwoods should be removed during the salvage operation or the next scheduled harvest. Be sure to inspect large pine timber for pitch flow. Many large, green, standing trees may not be usable for veneer, poles. or lumber because of internal ring shake, splintering and separation of the wood fibers. Often, the only external evidence of such damage is pitch or sap flow where the injury has broken the bark. These characteristics are often overlooked, and considerable losses are incurred during a later harvest.

Trees killed by standing water.

Standing Water

In standing water, the dissolved oxygen is quickly depleted, so trees of most species are injured by prolonged flooding, particularly during the growing season. The loss of soil oxygen leads to root mortality and tree death. Trees weakened by standing water are often attacked by insects or affected by diseases.

Recommendations

Forest managers may wish to favor flood-tolerant trees and shrubs in areas subject to intermittent flooding.

Tree species that can tolerate prolonged or intermittent flooding are noted in table 2. Flood-tolerant shrubs include: buttonbush, sand plum, deciduous holly, and swamp-ironwood.

Manage to Reduce Pest-Caused Losses

Storm damage often increases the risk of pest outbreak by weakening the defenses of host trees. Pest infestations will not develop unless suitable host trees are available, so every effort should be made to remove concentrations of susceptible host trees. A well-planned and executed salvage operation can greatly increase a stand's resistance to pest attacks. To ensure effective salvage, we recommend the following approach:

1. Act quickly. Prompt salvage will help avoid losses from degrade and subsequent pest- caused mortality.

2. Measure carefully the extent of the damage before deciding on a salvage operation. A number of factors such as stand age, species, stocking, and management objectives will need to be considered.

3. Salvage the most severely damaged timber first. Concentrate on the pine stands, because they are more susceptible than hardwoods to pest outbreaks. On deep sandy soils where a stand will be left, the stumps should be treated for annosus root rot control. During salvage avoid damage to residual trees.

4. Complete salvage promptly and in one continuous operation. Bark beetle populations are more likely to build up in the slash and move into healthy trees if logging operations are prolonged or interrupted for periods of a month or more. (When salvage is delayed, a helpful guide is available for utilization of beetle-killed pine trees based on tree appearance. See table 2.)

Bark beetles often kill weakened

trees

5. Follow the practices listed below to ensure that the residual material (slash) will dry quickly. Bark beetle infestations will not build up in dry material.

- Cut all logs from seriously damaged trees to the minimum merchantable size and remove them from the area.
- Lop and scatter all harvesting slash and tops into open areas when possible.
- Scatter large accumulations of slash away from the bases of residual trees, and into direct sunlight if possible.
- Sever downed trees from roots that could keep them alive.

6. Inspect large pines for pitch flow. Many large, green, standing pines may be unusable for veneer, poles, or lumber because of internal splintering and separation of the wood fibers. Often, the only external evidence of storm damage is pitch flow where the bark has been broken.

7. Follow the ratings of species resistance to insects and diseases in table 3 when planning the salvage of timber, especially hardwoods.

8. Consider deducting storm-damage losses on income-tax returns. Landowners can secure advice from local foresters, accountants, attorneys, or Internal Revenue Service agents concerning deductible losses.

9. Check for pest activity after salvage operations are finished. Make periodic surveys, either aerial or ground, of the residual stands to check for pest activity. These surveys may be required for up to 2 years. Trees that are turning yellow, have pitch tubes on the bark, or red boring dust around the base, are probably affected by insects, diseases, or both. These trees should be considered for control activities.

Table 2-Utilization guidelines for beetle-killed pine trees[1]

Product	Class A Trees with needles or no needles, but twigs attached	Class B Trees with no needles, most twigs and branches lost, and some broken tops	Comments
Appearance lumber2	Not recommended	Not recommended	Blue stain prohibits use
Dimension lumber2 (structural)	Can be used with caution	Not recommended	Should be kiln dried to prevent emergence of secondary insects. Low moisture content may dull saws and chipper knives faster than with sound wood and may require milder kiln schedule. Do not use where toughness is important.
Decorative lumber boards and paneling	Can be used	Can be used	Should be kiln dried
Posts, poles, piling	Not recommended	Not recommended	Toughness and preservative treatability may be highly variable
Plywood	Can be used	Not recommended	Adhesives and gluing practices may have to be adjusted
Hardboard, particle-board, medium density fiberboard	Can be used	Can be used	Low moisture content may affect some production schedules. Should be mixed with sound wood.
Pulp	Can be used	Can be used	Blue stain and low moisture content may affect pulping process and chemical or energy requirements. Should be mixed with sound wood, particularly where strength is important.

Fuelwood	Can be used	Can be used	Low moisture content increases heat value

[1]For more information on utilization of beetle-killed trees, see "A Guide for Using Beetle-Killed Southern Pine Based on Tree Appearance", by Michael P. Levi, USDA Agriculture Handbook 572.

[2]For more information on economics of producing lumber from beetle-killed pines, see "A Mill Operator's Guide to Profit on Beetle-Killed Southern Pine", by S. A. Sinclair, USDA Agriculture Handbook 555.

Manage to Reduce Hurricane Damage

Tree species vary in their ability to withstand hurricane winds and salt damage. Wind resistance depends on the interaction of five factors: strength of the wood, shape and size of the crown, extent and depth of the root system, previous moisture conditions, and shape of the bole.

Salt-damagedpines

No tree species has perfect wind resistance, but live oak, palm, pondcypress, and baldcypress are among the best, as shown in table 3. These trees combine deep root systems with buttressed trunks (low center of gravity). The wood of live oak is exceedingly strong and resilient. The crown is usually widespread, but this does not seem to negate its strong points. Cypress has relatively weak wood, but its crown s so sparse and its foliage so limber that it is also extremely windfirm.

Shallow-rooted trees are easily uprooted, especially after the soil is saturated by heavy rains.

Common shallow-rooted trees along the coast are dogwood, water oak, pecan, sweetbay, and red maple. Common deep- rooted trees are live oak, longleaf pine, and pondcypress and baldcypress.

Trees growing in sandy soils are more deeply rooted than trees crowing in soils with an inhibiting clay layer or a high water table. Although rooting habits vary according to the soil profile, each species has a characteristic pattern. Another factor to be considered is the height of the tree. The taller the tree, the greater is its chance of breaking, especially if the bole has little taper. For this reason, tall, slim slash and longleaf pines are extremely vulnerable. Open-crowned and lacy-foliaged trees, such as cypress and mimosa, offer less resistance to the wind, and thus are better able to survive. On the other hand, magnolia trees with their heavy, wind-catching foliage are windthrown more than their root system and bole structure would indicate. Palm trees offer little surface to the wind because they have almost no laterally extended crown and branches. This characteristic makes them fairly windfirm, despite their limited root systems.

Table 3-Resistance of tree species to hurricane-related damage (In descending order of resistance)

Flood tolerant	Breakage	Uprooting	Salt	Deterioration by insect and disease
baldcypress	live oak	live oak	live oak	live oak
pondcypress	palm	palm	palm	palm
tupelo-gum	baldcypress	baldcypress	slash pine	sweetgum
sweetbay	pondcypress	pondcypress	longleaf pine	water oak
willow	sweetgum	tupelo-gum	pondcypress	sycamore
sweetgum	tupelo-gum	redcedar	loblolly pine	baldcypress
sycamore	mimosa	sweetgum	redcedar	pondcypress
river birch	dogwood	sycamore	tupeolo-gum	southern red oak
cottonwood	magnolia	longleaf pine	baldcypress	magnolia
green ash	sweetbay	mimosa	sweetgum	tupelo-gum

red maple	southern red oak	southern red oak	water oak	sweetbay
pecan	water oak	magnolia	sycamore	hickory
mulberry	sycamore	slash pine	sweetbay	pecan
American elm	longleaf pine	loblolly pine	southern red oak	redcedar
persimmon	slash pine	sweetbay	hickory	red maple
silver maple	loblolly pine	water oak	mimosa	mimosa
water oak	redcedar	red maple	pecan	dogwood
swamp chestnut oak	hickory	dogwood	magnolia	longleaf pine
magnolia	red maple	hickory	red maple	slash pine
hickory	pecan	pecan	dogwood	loblolly pine

Based on these observations, the following preventive measures are recommended to forest managers in hurricane-risk areas:

1. Keep a balanced mixture of size and ace classes to prevent a complete loss. Young trees are rarely damaged, because they tend to bend with the wind: old trees tend to break or uproot.

2. Where feasible, stagger thinnings to limit exposure of the recently thinned areas.

(During Hurricane Camille. recently thinned stands of pine with little taper were severely broken. while open stands and stands thinned several years earlier suffered less damage.)

3. Manage for well-spaced, thrifty trees and, as much as possible, develop a spread of age classes to distribute the risk of wind damage.

4. Consider planting longleaf pine in deep sandy soils, because long leaf has a deep taproot.

5. When planting slash and loblolly, use an 8-by 8-foot or wider spacing.

Winds often carry saltwater inland for a considerable distance. The leaves on trees saturated with saltwater turn brown and give tile appearance of being burned. Most of these trees will not die and should not be cut. See table 2 for resistance among tree species. The trees may lose their leaves and Sonic growth, but most of them will grow new leaves and recover. Check trees closely in the spring after salt damage for adequate recovery or possible bark beetle attack. Trees should be harvested if they have been attacked by bark beetles or if they have not put on new growth in the first full growing season after the damage occurred.

EXTENSION NOTES

Ontario

CARING FOR ICE-DAMAGED WOODLOTS AND PLANTATIONS

Ice storms are common in southern Ontario and play an important role in the natural cycle of forest succession. Depending on the level of damage, trees can recover from ice damage within a few years. Severe ice storms accompanied by high winds can damage large areas of forests, creating gaps in the forest canopy where species of trees that need direct sunlight can grow.

This Extension Note provides information on how to assess ice damage and what to do to make the most of an ice-damaged woodlot or plantation. For more specific information on caring for ice-damaged sugar bushes, refer to the *Interim Guidelines for the Tapping and Restoration of Sugar Bushes Affected by the Ice Storm of January 1988,* which is available at offices of the Ontario Ministry of Agriculture, Food and Rural Affairs.

DO YOU NEED PROFESSIONAL EXPERTISE?

Before you begin to assess the ice damage in your forest, consider your knowledge of forest management principles and practices. Do you have the general and technical knowledge you need to assess the damage or to carry out the required work? Depending on your training, experience and circumstances, you may need professional help. For information on finding forestry expertise, see Extension Note: *Caring for Ice-Damaged Trees.*

SAFETY FIRST

Before taking any action, even an assessment, consider your safety. Be careful when approaching any damaged trees. Branches that appear to be well

wedged in the crown of a tree can fall without warning at any time and cause severe injuries. Wear a hard hat at all times. Don't go near any trees that are close to power lines. When it comes time to care for your trees, don't cut any large branches or prune unless you have been trained to do so. In recognition of the dangers of these activities, anyone who operates a chain saw for commercial purposes in Ontario must be trained and certified.

CONSIDER YOUR GOALS

Whether or not you have a management plan for your woodlot or plantation, it's important to consider your long-term goals before you begin your assessment. For example, if you want to provide habitat for wildlife or places for recreation, you may only want to clear access points and walking trails — even in severely damaged stands. But if you're managing a stand for timber products, you may want to harvest trees over the next few years before they lose their commercial value. You may also want to prune and take other steps to avoid future losses. The options available to you will depend on the site conditions, age of trees, species of trees and the extent of ice damage in your forest. Combined, these and other considerations will determine whether your long-term goals need to be modified, whether investment in work on your property will generate financial returns and, ultimately, what your plan of action should be to meet your goals.

ASSESS THE DAMAGE

In most cases, it's wise to wait one growing season before assessing your forest. Waiting this length of time will enable you to see the full effect of the storm without incurring any long-term financial losses. Red pine plantations are an exception, however. Assess them and take any required action as soon as possible.

Follow these steps to assess the damage in each stand on your property.

1. **DEFINE STANDS**
   Determine what kind of stands you have. Look for areas with different kinds of species or ages of trees. You may find that you have some of the following kinds of stands.

DEFINE YOUR STAND

Look at your stand, what are the majority of the trees, hardwoods or conifers?

Hardwood

Most trees are hardwoods	**Immature** — most trees are less than 10 cm dbh
	Mature — most trees are greater than 10 cm dbh

Conifer

Most trees are conifers	**Young** — most trees are less than 3 m tall
	Maturing — most trees are less than 15 cm dbh
	Mature — most trees are greater than 15 cm dbh

2. GATHER TOOLS

You'll need the following:

- flagging tape or tree-marking paint
- clipboard
- pencil
- calipers or a yardstick and a string
- one tally sheet for every stand

3. SELECT SAMPLE PLOTS

Choose three sample "plots" or spots to assess in each stand. The damage in the plots should be typical of the damage in the stand.

4. MARK SAMPLE TREES

Mark 10 trees in each sample plot with flagging tape or tree-marking paint. Choose trees that are representative of all the different species and sizes of trees in the woodlot. In plantations, choose five trees in two adjacent rows. Use the tally sheet (Table 1) to record the information for each plot.

5. RECORD SPECIES

Record the species name for sample trees.

6. RECORD SIZE

Estimate the diameter at approximately 1.3 metres above the ground (dbh) of sample trees in hardwood stands. Using the table of "Hardwood Size Classification" on the tally sheet, determine a tree's size class. Mark an "X" in the appropriate column under "Size Classification." In plantations, record the approximate age of the stand and tree height.

7. ASSESS DAMAGE OF EACH TREE IN THE SAMPLE PLOT

The procedure for assessing damage varies according to the main kind of damage a stand has endured. Bending is the most common kind of damage in young hardwood stands. In these stands, assess the level of bending damage as shown in Figure 1. Broken branches and stems are the most common kinds of damage in older stands. This kind of damage is called "crown damage," and it is assessed differently in hardwood and conifer stands. Assess crown damage as shown in Figure 2 and 3. Record the appropriate damage code for each tree on your tally sheet.

8. SUMMARIZE RESULTS

Bending Damage

For stands of bent saplings and trees tally the number of trees in each "Bending Damage" category. Then calculate the percentage of trees in each category. If more than 75 per cent of the trees are in bending-category 1, consider the damage to be minimal. If more than 50 per cent are in category 3, consider the damage as severe. Consider all other conditions as moderate.

Crown Damage in Hardwood Stands

Total the number of trees in each "Crown Damage" category. If more than 50 per cent of the trees are in category 4, consider the damage to the stand to be severe. If more than 75 per cent of the trees are in category 1, consider the damage to be minimal. Consider all other conditions to be moderate.

For example, if you sampled three plots in a mature hardwood stand and 25 of the 30 trees sampled (75 per cent) were in damage class 1 (0 to 25 per cent crown damage), damage to this stand is minimal. If 10 of the 30 trees were in crown damage category 1 (no damage) and 15 were in damage class 2, damage in this stand is minimal as well. However, if 15 of the 30 trees sampled were in damage category 3, damage is moderate.

Crown Damage in Conifer Plantations

Total the number of trees in each "Crown Damage" category. If more than 50 per cent of trees are in category 4, consider the damage to be severe. If more than 75 per cent of the trees are in categories 1 and 2, consider the damage to be minimal. Consider all other conditions as moderate.

Assess General Stand Condition

In natural hardwood woodlots, record your observations about smaller trees on the tally sheet. What species are present? Are they bent or broken? Are there many smaller trees (a sign of successful natural regeneration)? Also look for signs of insects or diseases. In oak stands, record whether there are large numbers of gypsy moth egg masses. Gypsy moth feeding can damage foliage, possibly killing trees that are already under stress. To learn how to identify gypsy moth egg masses, see Agriculture and Agri-food Canada's publication *No Gypsy Moth Riders.*

In plantations, record observations about any other trees that are growing around the planted trees. What species are present? Are they bent or broken? Are there many? Look for signs of insects or diseases. Pay attention to white pines, which are susceptible to white pine blister rust.

TABLE 1 — WOODLOT & PLANTATION STAND TALLY SHEET

Stand Number: Date:
Stand Type: Landowner name:

Tree #	Species	Size Class (hardwoods only)				Damage Classification				Bent		
		A	B	C	D	1	2	3	4	1	2	3
Plot 1 1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Plot 2 1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Plot 3 1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Total												
%												

Hardwood Size Classification
A 10 to 25 cm (4–9 in.)
B 26 to 40 cm (10–16 in.)
C 41 to 48 cm (17–19 in.)
D over 50 cm (20 in.)

Plantation Crown Damage
1 no damage
2 up to two year's growth broken
3 broken crown
4 < three live branches

Hardwood Crown Damage
1 0–25 degree crown loss
2 26–50 degree crown loss
3 51–75 degree crown loss
4 > 75 degree crown loss

Bent Classifications
1 < 20 degrees
2 20–60 degrees
3 > 60 degrees

Comments ....

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FIGURE 1: BENDING DAMAGE

When bending is the most significant kind of damage in a stand, estimate the degree of bending in each sample tree according to the following categories and mark an "X" in the "Bending Damage" column on the tally sheet.

Category	Degree of Bending
1	less than 20 %
2	between 20 and 60%
3	over 60 degrees%

FIGURE 2: CROWN DAMAGE IN HARDWOOD STANDS

Estimate the degree of damage to each sample tree's crown. Look at the places where branches have broken and try to estimate how big these branches were before the storm and how big the entire crown was. Then estimate the percentage of the crown that remains and subtract that number from 100 to get the percentage of the tree's crown that was lost. Don't worry about being precise. Instead, place the tree in one of the following categories and mark an "X" in the "Crown Damage" column on the tally sheet.

Category	Percentage Crown Lost
1	0 to 25%
2	26 to 50%
3	51 to 75%
4	greater than 75%

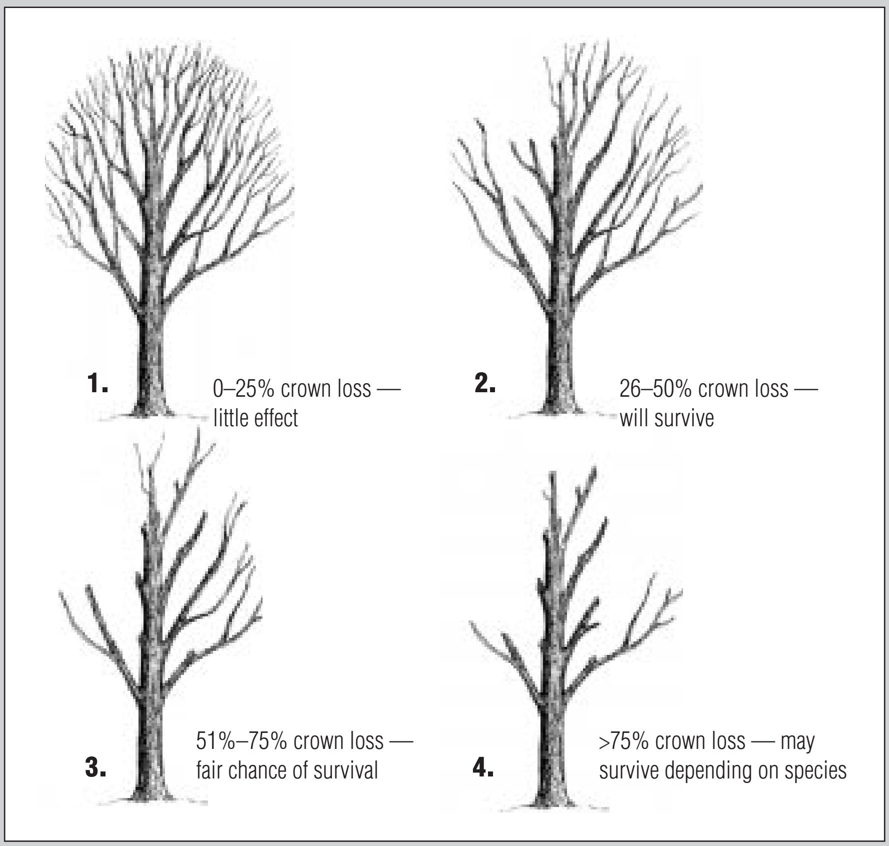
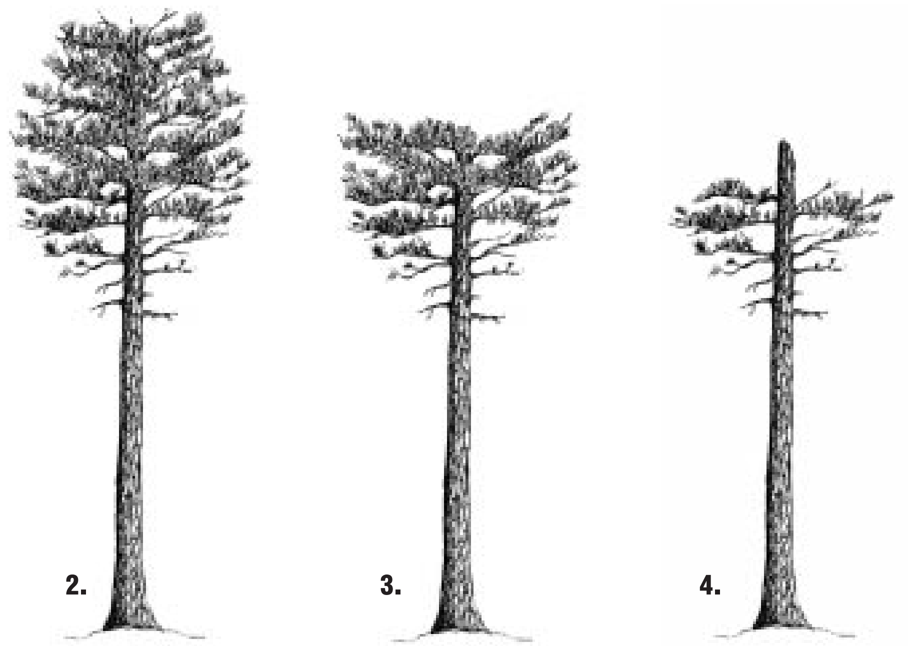


FIGURE 3: CROWN DAMAGE IN CONIFER PLANTATIONS

The procedure for assessing damage in plantations is the same for stands of all ages and species (conifer and hardwood). Look for damage to a tree's crown and determine which of the following categories best describes a sample tree's condition. Then mark an "X" in the "Crown Damage" column on the tally sheet.

Category	Crown Condition
1	no damage
2	leader and up to 2 years growth broken
3	broken in the middle of the crown
4	less than 3 live branches remaining



Broken leader — will recover

broken mid-crown — good chance of recovery

>75% broken below crown — low chance of recovery

DETERMINE WHAT TO DO

After you have assessed the damage, consider the general recommendations below and the specific instructions in Table 2 to determine how to care for each stand.

STRAIGHTENING BENT TREES

Don't pull trees to an upright position when they are still frozen. If you do, you could harm the tree. Gentle straightening or pulling in the spring when the trees are more flexible can be successful with smaller trees. Staking a tree to straighten it is not economically viable in most cases.

Scattered bent trees in mature forests are not a major concern. Almost all trees that are bent less than 20 degrees will straighten on their own. Most trees that are bent between 20 and 60 degrees will likely straighten. Few trees bent more than 60 degrees will straighten. If a tree has not straightened on its own by June, it most likely will not do so.

Bent trees that have straightened may have internal damage that can affect their future commercial value.

HARVESTING TREES

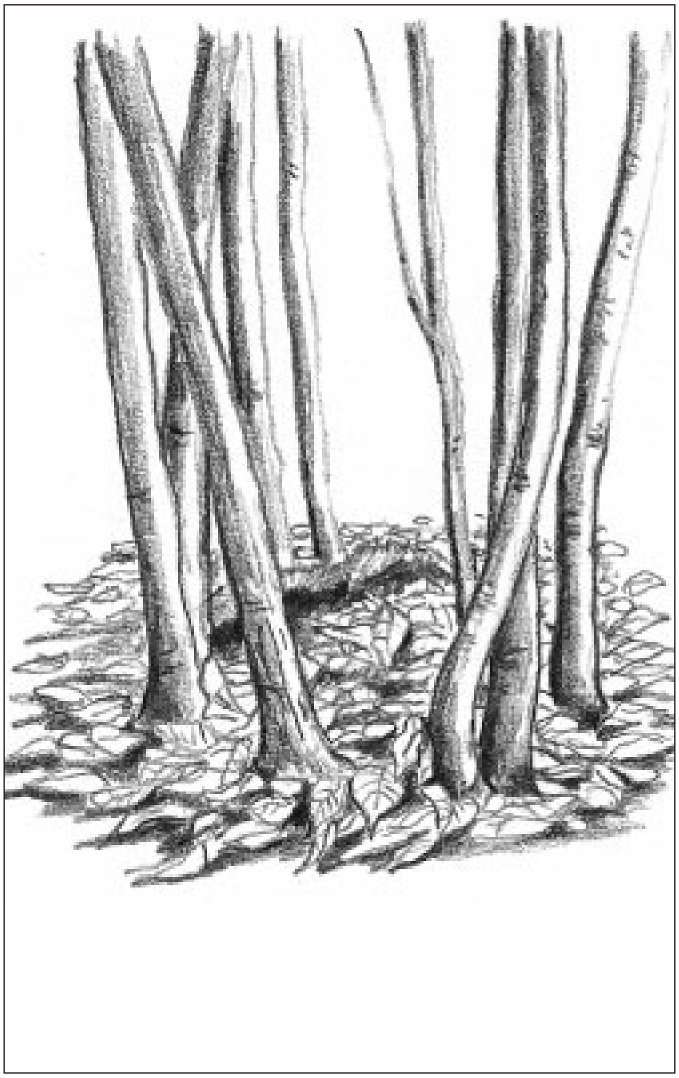
When damage to a stand is minimal, little action is required. In moderate to severely damaged stands, consider harvesting individual trees or groups of trees that have category 4 crown damage. This level of damage can eliminate species or age groups from the stand. You may need expert advice to help you assess the implications of severe damage for the long-term health and value of your stand. An expert can also help you determine if there are markets for the kinds of wood products you have. For more information on marketing wood products, consult the Landowner Timber Marketing Package, which is available through the LandOwner Resource Centre.

CONSIDER THE VALUE OF CONIFERS TO WILDLIFE

Living conifers, no matter how severely damaged, provide habitat for wildlife. If damaged conifers are not safety hazards, you may want to leave them alone. You can also leave some conifers standing for wildlife habitat and cut others to the ground to encourage faster decomposition. To prevent fires, remove large piles of broken trees and branches that are within 150 metres of buildings and 30 metres of public roads.

ENCOURAGE SPROUTING

Many damaged trees will produce ground-level sprouts that can regenerate the forest. Species that sprout readily are red maple, silver maple, cherry, basswood, willow, oaks and poplars. To encourage sprouting, cut the tree down close to the ground before the leaves come out in the spring.



KEEP AN EYE ON THE FOREST — MONITOR

It will take a few years before you will be able to determine the extent of the damage caused by a major ice storm. During this time, keep a close eye on the forest. Many different stresses can combine to cause serious damage. Check to see whether there are insect infestations or diseases. Look at leaf size, shape and color. Watch for resin or gum on the bark and signs of insect feeding, egg masses, conks and other fruiting bodies.

Look at the trees you marked during the assessment for signs of change. This is best done in mid- to late summer before the leaves change color.

If you don't already have one, consider developing a management plan. Forests are complex ecosystems that contain many interdependent forms of life. If you want to take wood from the forest over the long term or to develop a haven for wildlife and recreation, a management plan will help you achieve your goals and revitalize your woodlot. To find out more about developing a plan, see the following publications:

- *A Woodlot Management Plan*
- *Making Your Woodland Pay*
- Extension Note: *A Business Approach to Owning Rural Property*

TABLE 2 — EXPECTATIONS AND RECOMMENDED ACTIONS

MATURE HARDWOOD STANDS
Minimal Damage

- most trees will survive and grow a new crown within 10 years
- harvest only those trees that have severely damaged stems or, if economic value is important, damaged or deteriorating trees that could lose their future potential for wood products
- leave some damaged or deteriorating trees to provide snags and cavity trees for wildlife
- monitor stand's health over several years

MATURE HARDWOOD STANDS
Moderate Damage

- most trees with 26% to 75% crown damage will survive but their growth rate may be reduced
- most trees with more than 75% crown damage will not survive, except for basswood, beech, ash, poplar and willow
- wait until the end of the first growing season to decide which trees to harvest
- consider getting expert advice to determine which trees should be harvested to improve the long-term health of the forest
- retain uncommon species, even if severely damaged, to maintain the diversity of species in the stand

MATURE HARDWOOD STANDS
Severe Damage

- up to one quarter of the trees with more than 75% crown loss will survive
- it may take several years for severely damaged trees to decline and die
- extensive crown damage could open up the forest canopy allowing more sunlight to reach the forest floor, which will encourage the growth of species that need sunlight to become established and change the species composition of the future forest
- wait until the end of the first growing season to decide which trees to harvest
- harvest trees in damage category 4
- leave some severely damaged trees to provide snags and cavity trees for wildlife
- retain uncommon species, even if severely damaged, to maintain the diversity of species in the stand
- consider getting expert advice on the potential and necessity of a commercial harvest, the implications of future changes in species composition and the best courses of action

IMMATURE HARDWOOD STANDS
Minimal Damage

- most trees will recover
- trees bent less than 20 degrees will straighten
- most trees bent 20 to 60 degrees will likely straighten
- trees bent more than 60 degrees are not likely to straighten
- allow bent trees until mid-summer to recover before taking action
- cut broken trees to the ground before they get their leaves in the spring to encourage sprouting from the stumps

IMMATURE HARDWOOD STANDS
Moderate Damage

- cut broken trees to the ground before they get their leaves in the spring to encourage sprouting from the stumps
- allow bent trees until mid-summer to recover before taking action
- consider regenerating areas of the stand that do not recover by mid-summer by cutting all trees to the ground before the leaves come out the following spring

IMMATURE HARDWOOD STANDS
Severe Damage

- bent trees are likely to survive but will remain bent
- cut broken trees and trees that are bending more than 60 degrees to the ground before they get their leaves in the spring to encourage sprouting from the stumps
- consider regenerating areas of the stand that do not recover by mid-summer by cutting all trees to the ground before the leaves come out the following spring

YOUNG HARDWOOD PLANTATION
Minimal Damage

- trees will survive and crowns are likely to recover
- allow bent trees until mid-summer to recover before taking action
- if future timber value is important, apply corrective pruning to trees in damage categories 1 and 2

TABLE 2 — EXPECTATIONS AND RECOMMENDED ACTIONS *CONTINUED*

YOUNG HARDWOOD PLANTATION
Moderate Damage
- broken trees will probably produce sprouts
- allow bent trees until mid-summer to recover before taking action
- if future timber value is important, apply corrective pruning to trees in damage categories 1 and 2
- if the planted species sprouts easily, consider cutting stems in damage category 3 to the ground to encourage new growth from the stumps

YOUNG HARDWOOD PLANTATION
Severe Damage
- trees broken mid-stem may sprout
- if the species sprouts easily, cut all stems to the ground to regenerate the stand

HYBRID POPLAR PLANTATIONS
Minimal Damage
- allow bent trees until mid-summer to recover before taking action
- consider cutting to the ground trees that do not recover by mid-summer to encourage regeneration through sprouting
- leave some trees as potential cavity trees for wildlife

HYBRID POPLAR PLANTATIONS
Moderate Damage
- allow bent trees until mid-summer to recover before taking action
- cut to the ground trees that have broken stems and no living crown to encourage regeneration through sprouting
- consider planting coniferous species under trees in heavily damaged areas
- trees with broken branches but intact stem may regrow a crown
- monitor trees over the growing season

HYBRID POPLAR PLANTATIONS
Severe Damage
- allow bent trees until mid-summer to recover before taking action
- if trees are more than 15 centimetres dbh, get expert advice about the potential of a commercial harvest
- leave damaged trees alone if they have conifers growing under them
- monitor to see if trees are sprouting from the stems and remaining branches
- assess the stand frequently in coming years

MATURE AND MATURING CONIFER PLANTATIONS
Minimal Damage
- there is little that can be done to protect the commercial value of trees that are damaged above the height of 5 metres
- consider harvesting dead trees to decrease risk of insect infestation

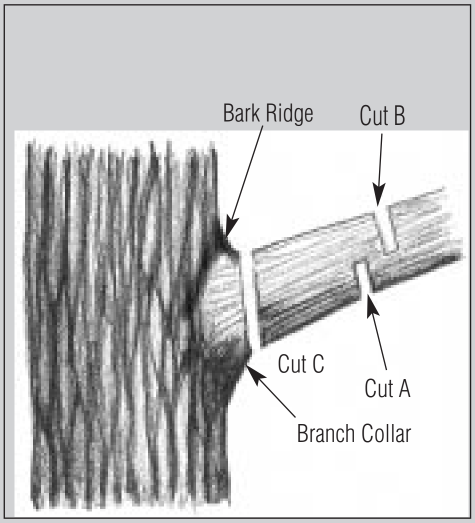
FIGURE 4: CORRECTIVE PRUNING IN HARDWOODS

DAMAGE TO LARGE BRANCHES

Cut A
Make your first cut two feet from the trunk. Cut half way through the branch, moving from the bottom up.

Cut B
The second cut is one-third to half the diameter of the limb away from the first cut. Cut half way through the branch. At this point, the limb should fall from its own weight.

Cut C
The final cut is next to the trunk. Cut outside the branch collar with the lower edge being further away from the trunk of the tree.



DAMAGE AT THE TOP OF THE TREE

A clean, 45 degree cut at the top of the tree will prevent water from pooling and rotting the trunk. Make the cut below the break and above the next live branch that is at least one-third the size of the stem.

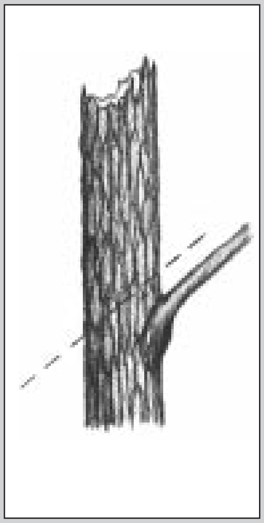
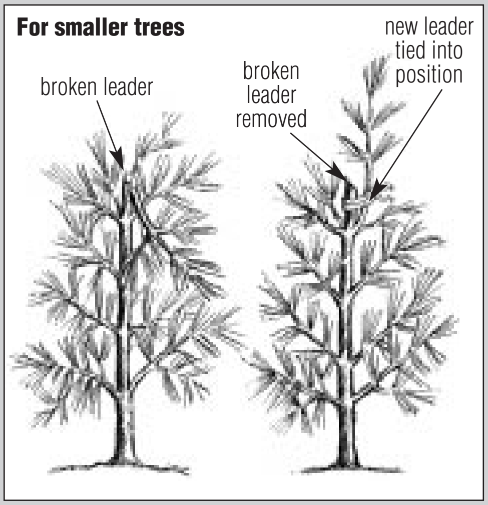


FIGURE 5: CORRECTIVE PRUNING IN CONIFERS

Choose the strongest branch in the highest whorl as a future leader. Prune back the broken leader until it's about 10 centimetres long. Use tape or other biodegradable material to tie the new leader into position. With larger trees where it is not possible to tie up a branch, choose a new leader and prune back the remaining branches to one-third the length of the chosen leader.



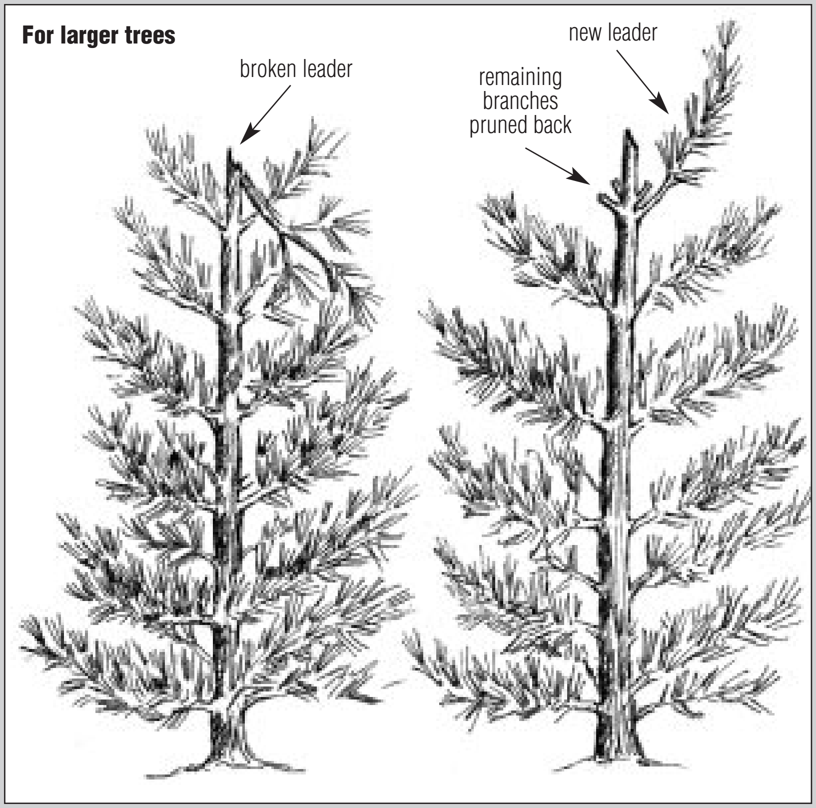


TABLE 2 — EXPECTATIONS AND RECOMMENDED ACTIONS *CONTINUED*

MATURE AND MATURING CONIFER PLANTATIONS
Moderate Damage

- there is little that can be done to protect the commercial value of trees that are damaged above the height of 5 metres
- harvest as few trees as possible to retain the density of trees in the stand and to encourage damaged trees to grow new leaders
- harvest red pine and white pine trees with commercial value (generally larger than 15 centimetres dbh) that are in damage categories 3 and 4 before June to reduce risk of blue stain fungus
- cut to the ground the remaining trees that are in damage category 4, as well as severely bent trees, to encourage decomposition
- leave a few damaged trees as potential cavity trees for wildlife

MATURE AND MATURING CONIFER PLANTATIONS
Severe Damage

- trees in damage category 4 are likely to die
- harvest red pine and white pine with commercial value (generally larger than 15 centimetres dbh) that are in damage categories 3 and 4 before June to reduce risk of blue stain fungus
- cut to the ground the remaining trees that are in damage category 4, as well as severely bent trees, to encourage decomposition
- leave a few damaged trees as potential cavity trees for wildlife
- consider restoring the site to a hardwood forest if hardwood regeneration is present (see Extension Note: *Managing Regeneration in Conifer Plantations to Restore a Mixed Hardwood Forest*

YOUNG WHITE PINE AND RED PINE PLANTATIONS
Minimal Damage

- trees with broken tops will survive and a new leader will take over
- allow bent trees until mid-summer to recover before taking action
- consider applying corrective pruning to trees with damaged leaders

YOUNG WHITE PINE AND RED PINE PLANTATIONS
Moderate Damage

- consider corrective pruning of crop trees to maintain their commercial value
- if you have not chosen crop trees, select up to 500 evenly spaced trees per hectare (200/acre) as crop trees, including as many undamaged trees as possible

TABLE 2 — EXPECTATIONS AND RECOMMENDED ACTIONS *CONTINUED*

- do not choose as crop trees those in damage class 3 or those that are infected with white pine blister rust
- harvest as few trees as possible to retain the density of trees in the stand and to encourage damaged trees to grow new leaders

YOUNG WHITE PINE AND RED PINE PLANTATIONS
Severe Damage
- trees in category 3 and 4 are likely to respond to corrective pruning
- cut dead trees to the ground to encourage decomposition
- harvest as few trees as possible to retain the density of trees in the stand and to encourage damaged trees to grow new leaders
- consider harvesting and replanting heavily damaged areas (see Extension Note: *Planning for Tree Planting)*

YOUNG WHITE SPRUCE, NORWAY SPRUCE AND TAMARACK PLANTATIONS
Minimal Damage
- trees that have lost their leaders will likely recover because these species have many lateral buds that can form new leaders

YOUNG WHITE SPRUCE, NORWAY SPRUCE AND TAMARACK PLANTATIONS
Moderate Damage
- trees that have lost their leaders will likely recover because these species have many lateral buds that can form new leaders
- harvest as few trees as possible to retain the density of trees in the stand and to encourage damaged trees to grow new leaders
- cut dead trees to the ground to encourage decomposition

YOUNG WHITE SPRUCE, NORWAY SPRUCE AND TAMARACK PLANTATIONS
Severe Damage
- harvest as few trees as possible to protect the plantation's density and encourage trees to grow new leaders
- cut dead trees to the ground to encourage decomposition
- consider harvesting and replanting heavily damaged areas (see Extension Note: *Planning for Tree Planting)*

YOUNG JACK PINE STANDS
Minimal Damage
- damaged trees will enrich the soil, protect soil from erosion and provide habitat for wildlife and a cover crop for hardwood regeneration
- no action required

YOUNG JACK PINE STANDS
Moderate Damage
- consider corrective pruning of damaged trees if timber value is important
- cut trees in damage category 4 and severely bent trees to the ground to reduce the risk of forest fires
- retain some damaged trees as potential cavity trees for wildlife

YOUNG JACK PINE STANDS
Severe Damage
- cut trees in damage category 4 and severely bent trees to the ground to reduce the risk of forest fires
- consider restoring the site to a hardwood forest if hardwood regeneration is present (see Extension Note: *Managing Regeneration in Conifer Plantations to Restore a Mixed, Hardwood Forest)*
- consider harvesting and replanting heavily damaged areas (see Extension Note: *Planning for Tree Planting)*

CEDAR STANDS
Minimal Damage
- most cedars will grow new crowns
- consider harvesting severely damaged trees

CEDAR STANDS
Moderate Damage
- some cedars will grow new crowns
- consider harvesting patches of severely damaged trees
- cut dead trees to the ground to encourage decomposition

CEDAR STANDS
Severe Damage
- consider harvesting patches of severely damaged trees
- cut dead trees to the ground to encourage decomposition
- if the cedar stand is part of a deer yarding area remove fallen branches and debris from deer trails

FOR MORE INFORMATION

For more information on caring for ice-damaged trees, contact your nearest office of the Ministry of Natural Resources. For specific information on sugar bushes or nut trees, contact the Ministry of Agriculture, Food and Rural Affairs.

The following Extension Notes will help you care for your woodlot or plantation:
- *Cavity Trees are Refuges for Wildlife*
- *Managing Regeneration in Conifer Plantations to Restore a Mixed, Hardwood Forest*
- *Managing Young Hardwood Stands for Sawlog Production*
- *Planning for Tree Planting*
- *Selling Standing Timber*

Further reading:
- *A True Picture Taking Inventory of Your Woodlot,* Eastern Ontario Model Forest, 1997
- *Diagnosing Injury to Eastern Forest Trees: A Manual for Identifying Damage Caused by Air Pollution, Pathogens, Insects, and Abiotic stresses.* Penn State College of Agriculture, Penn State University, 1987
- *Field Guide to Tree Diseases of Ontario,* C. Davis and T. Meyers, NODA/NFP Tech Report TR-46, 1997
- *Interim Guidelines for the Tapping and Restoration of Sugar Bushes Affected by the Ice Storm of January 1998.* MNR and OMAFRA, 1998
- *Landowners Timber Marketing Package,* Resource Stewardship of S.D. & G, 1997
- *Making Cents out of Forest Inventories: A Guide for Small Woodlot Owners,* 1998
- *No Gypsy Moth Riders,* Agriculture and Agri-Food Canada pamphlet, publication number 1516B

DEFINITIONS

DBH (diameter at breast height)
Diameter of a tree trunk measured 1.3 metres above the ground.

Leader
Shoot growing at the top of a tree's stem or principal branch.

Regeneration
Young trees and the process of establishing young trees.

Succession
Succession is the natural process of change that occurs in a forest over time as one community of living organisms replaces another. In southern Ontario, the cycle of succession usually begins when an ice storm, high wind or fire creates gaps in the forest cover. This event launches a cycle of succession which may include several different kinds of ecosystems. The cycle can take hundreds or thousands of years.

Whorl
Ring of branches around the stem of a plant.

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Insects and Diseases of Trees in the South

June 1989

Protection Report R8-PR 16

INTRODUCTION

This publication has been prepared to assist forest managers and home-owners in identifying pests of southern trees. The insects and diseases discussed are the more common ones attacking forest and ornamental trees. Prompt identification and treatment of these pests may mean the difference between losing or saving a valuable shade tree. Underlying all successful forest and ornamental pest control efforts, however, is the necessity to keep trees in a healthy, vigorous condition. Chemical supression recommendations are not included in this publication. For pesticide information contact the local State or Federal extension specialist, forester, entomologist, or pathologist.

Credit for some of the pictures in this guide goes to the Southern and Southeastern Forest Experiment Stations and universities. We acknowledge the help of the Forest Pest Management field personnel who assisted in compiling this booklet. To all involved — thank you.

USDA Forest Service
Southern Region
1720 Peachtree Street, NW
Atlanta, GA 30367-9102

Cover Pictures. Spiny oakworm (see page 14) and black knot disease on cherry (see page 57).

This publication supersedes General Report R8-GR 5, June 1985.

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INSECTS

DISEASES

COTTONWOOD LEAF BEETLE, *Chrysomela scripta F.*

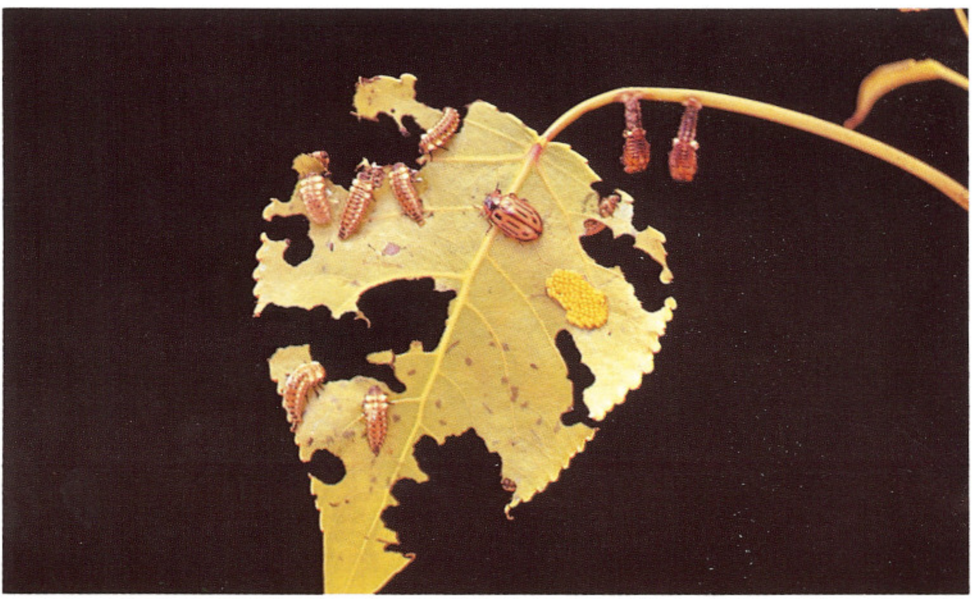
Importance.—Willows, poplars, aspens, and alders are attacked in the eastern half of the United States. Stunting and multiple-forked tops have been especially severe in intensively managed cottonwood plantations. Damage is most critical during the first 3 years after planting and may cause mortality.

Identifying the Insect.—Adults are about ¼ inches (6 mm) long. The head and thorax are black, and the margins of the thorax are yellow or red. The wing covers are usually yellowish with broken black stripes, but are sometimes almost pure golden to black. Young larvae are black, but become light to dark brown with prominent white scent gland spots along their sides. Mature larvae reach about ½ inch (12 mm) in length. The larvae emit a pungent odor when disturbed.

Identifying the Injury.—The young larvae are gregarious and skeletonize the leaves. Later, they feed separately and consume the entire leaf, except the larger veins. Adults chew holes in the leaves, may attack tender shoots, sometimes killing the terminals, causing reduced growth, stem deformity, or even tree mortality.

Biology.—The adults hibernate under bark, litter, and forest debris. Beetles may be collected in large numbers under or near cottonwood or willow trees in the winter. In the spring, after leaf growth begins, they fly to host trees to feed on the leaves and twigs. In a few days, the female beetles begin to lay their lemon-yellow eggs in clusters of 25 or more on the undersides of leaves. The larvae reach full size and pupate in less than 2 weeks. The pupae attach to leaf surfaces, the bark, or to weeds and grass beneath the trees. The adult beetles emerge after 5 to 10 days. There are six to eight generations per year in the South.

Control.—Under forest conditions, they are often held in check by lady beetle predators which feed on the eggs and pupae. Control may be needed in plantations during the first 3 years. Chemical sprays have been successful in nurseries and young plantations.



Typical damage and life stages adults, larvae and pupae.

LINDEN LOOPER,
Erannis Tiliaria (Harris)
and
EASTERN OAK LOOPER,
Phigalia titea (Cramer)

Importance.—The linden looper and eastern oak looper cause defoliation in the spring. Host species attacked include the red and white oak groups, maples, elms, hickories, ash, and cherry. Heavy defoliation usually occurs in May and June and can cause growth loss and mast reduction. If coupled with other stresses, this defoliation may cause mortality. The greatest impact of these insects is often felt in public use areas where defoliation reduces the aesthetic value, and larvae and their droppings create a nuisance.

Identifying the Insect.—Male moth wings are light gray to tan, with wavy lines, and a span of 1 to 1½ inches (25 to 37 mm). Linden looper females are wingless, and the eastern oak looper female has wing pads, but cannot fly.

Mature larvae of these loopers are about 1½ inches (37 mm) long. The eastern oak looper has a tan head and body, with many lengthwise, black, wavy lines. The larval segments have small, hairy tubercles. The linden looper has a rusty brown head, a tan back with numerous wavy black lines, and yellow sides. Coloring of both loopers varies with population densities.

Identifying the Injury.—Early evidences of feeding are small holes in the leaf produced by young larvae feeding on the expanding foliage. Older larvae consume the entire leaf, except the midribs and major veins.

Biology.—Adults emerge and lay their eggs in early spring. Eggs hatch at about the time of bud break, and the young larvae begin feeding on the expanding foliage. Feeding continues for approximately 6 weeks, then the mature larvae enter the soil and pupate.

Control.—The eggs and larvae are attacked by insect parasites and predators. Other natural enemies also help in control. Sticky bands placed around the trunks of high value trees can trap the females as they climb the tree to lay eggs. In high use or high value areas, chemical control may be needed.

Linden looper larva.

Eastern Oak looper larva.

EASTERN TENT CATERPILLAR, *Malscosoma americanum* (F.)

Importance.—The eastern tent caterpillar is primarily an aesthetic problem and has little adverse effect on the host trees. Species of the genus *Prunus* are preferred hosts, with black cherry being the primary, uncultivated host.

Identifying the Insect.—Full-grown larvae are between 2 to 2½ inches (50 to 65 mm) in length. Caterpillars have black heads, with long, light brown body hairs. The back has a light stripe, bordered on each side with yellowish-brown and black wavy lines. The sides are marked with blue and black spots. Moths have a wingspread of about 2 to 2½ inches (50 to 65 mm) and are yellowish-brown, with two narrow, light lines across the front wings.

Identifying the Injury.—The larvae construct a white web or tent in the crotch of a small branch. They consume the entire leaf, except the midrib.

Biology.—Overwintering eggs hatch about the time black cherry buds open in the spring. Young larvae begin to construct a tent and enlarge the structure as they grow. Full-grown larvae construct tough, silken cocoons. Moths emerge in early summer and lay eggs in shiny, dark brown masses around small twigs or branches of host trees.

Control.—Control is not normally necessary. Defoliated trees usually refoliate after being attacked. Chemicals can be used to protect fruit trees, or tents containing the caterpillars may be picked off and destroyed.

Typical tent on cherry.

Larva.

ELM LEAF BEETLE,
Pyrrhalta luteola (Mueller)

Importance.—The elm leaf beetle attacks all species of elm. However, in most of its range, the beetle prefers the Siberian elm. When defoliation is severe for several consecutive years, limbs and sometimes the tree may be killed. The beetles may become a nuisance in the fall when they move into homes searching for overwintering sites. The adults may be a problem in the spring when they congregate in windows as temperatures increase.

Identifying the Insect.—The larvae are green to yellow, with a black head and two black stripes on the back. Pupae are about ¼ inch (6 mm) long and bright orange-yellow. The adults are approximately ¼ inch (6 mm) long and yellowish to green with a black stripe on each wing margin.

Identifying the Injury.—Adults chew holes in the leaves, particularly on new growth. The larvae feed on the under surfaces of leaves, leaving upper surfaces and the veins intact. Leaves shrivel and turn brown when damage is severe.

Biology.—In the spring the adults fly to elms and eat small holes in the newly developing leaves. Eggs are laid in a cluster on the undersides of leaves. The eggs hatch and the larvae feed for 2 to 4 weeks. The larvae crawl to sheltered places on the tree or ground to pupate. In one to two weeks new adults emerge and again feed and lay eggs. There are two to four generations per year, depending on the geographical location.

Control.—No chemical controls are recommended in forest stands. Homeowners may use recommended insecticides to protect valuable shade trees. Sprays should be directed at the undersides of the leaves, beginning in the early spring.

Typical damage and life stages—adults, larvae, and eggs.

ELM SPANWORM,
Ennomos subsignarius (Hubner)

Importance.—The preferred hosts of elm spanworm are red and white oaks and a few other hardwood species, especially hickory, pecan, and related trees. This is a destructive forest pest, particularly in the southern Appalachians, where widespread, severe outbreaks have occured. Repeated defoliation can cause growth loss, dieback, reduction in mast crops, and even mortality.

Identifying the Insect.—Larvae are slate gray to brownish black, with yellowish body markings (yellow or green at low population densities), and 1½ to 2 inches (40 to 50 mm) long. The adults are snow-white moths. The small, barrel-shaped, olive-green eggs are laid in masses on the underside of small branches in the Southeast. To the north, they are found more commonly on the bole.

Identifying the Injury.—Young larvae feed on the edge and undersides of leaves, causing a shothole appearance at low population levels. When populations are high, they consume the entire leaf, except the main veins, giving a feathered appearance to the tree.

Biology.—Overwintering eggs hatch in early spring when the buds break, usually in late April in the South. The larvae feed for 4 to 6 weeks and then pupate in net-like cocoons on the host tree or understory. Six to 10 days later, in late June or mid-July, the moths emerge and deposit their eggs. There is one generation per year.

Control.—Insect parasites attack the eggs of the elm spanworm. Other natural enemies are also important in keeping infestations in check. Chemical controls may be needed to protect high value trees.

Larva.

Feeding damage on leaves.

FALL CANKERWORM, *Alsophila pometaria* (Harris) and SPRING CANKERWORM, *Paleacrita vernata* (Peck)

Importance.—The fall and spring cankerworms defoliate a variety of hardwood species in the spring. Hosts include the red and white oak groups, maples, elms, hickories, ash, and cherry. Heavy defoliation usually occurs in May and June, and can cause growth loss, mast reduction, and, if coupled with other stresses, may result in mortality. Their greatest impact is often felt in high public use areas where defoliation reduces the aesthetic value, and larvae and their droppings create a nuisance.

Identifying the Insect.—The wings of male moths are light gray to tan, with wavy lines, and span about 1 to 1½ inches (25 to 37 mm). Females are wingless.

Mature larvae of the fall cankerworm are about 1 inch (25 mm) long and vary from light green to black, with light yellow lines on the sides and a dark dorsal stripe. Mature larvae of the spring cankerworm are 4/5 to 1 5/10 inches (18 to 30 mm) long and range in color from reddish to yellowish brown, yellowish green, or black. The head is light and mottled with a yellow stripe along each side of the body. Coloring of both loopers varies with population density.

Identifying the Injury.—Small holes in the leaves are early evidence of young larvae feeding on expanding foliage. Older larvae consume the entire leaf, except the midribs and major veins.

Biology.—Fall cankerworm adults emerge in the fall following a hard freeze. They overwinter in the egg stage. The spring cankerworm adults emerge in February and March to lay their eggs. For both species, the eggs hatch at about the time of bud break, and the young larvae begin feeding on the new foliage. Feeding continues for approximately 6 weeks, after which the mature larvae enter the soil and pupate.

Control.—The eggs and larvae are attacked by insect parasites and predators. Other natural enemies also help in control. Sticky bands placed around the trunks of high value trees can trap the females as they climb the tree to lay their eggs. In high use or high value areas, chemical control may be needed.

Female moth laying eggs.

Fall cankerworm larva.

FALL WEBWORM,
Hyphantria cunea (Drury)

Importance.—The fall webworm is not considered an important forest pest. However, ugly webs can seriously detract from aesthetic values. The preferred hosts in the South are persimmon, pecan, and sourwood.

Identifying the Insect.—The adult moth has a wingspan of 1 (25 mm) to 1¼ (31 mm) inches and is snowy white, usually with dark spots on the wings. The larvae are 1 (25 mm) to 1¼ (31 mm) inches long and covered with silky hairs. The color varies from pale yellow to green, with a black stripe on the back and a yellow stripe on each side.

The pupae are found inside a gray cocoon constructed of silk, frass, and debris. The eggs are small, yellow, or light green, and turn gray before hatching.

Identifying the Injury.—Usually the first signs of attack are the large, silken web and skeletonized leaves. The silken web usually contains large numbers of caterpillars.

Biology.—The moths emerge in the spring. After mating, females lay eggs in masses (400 to 500) on the undersides of host leaves. The eggs hatch in approximately 2 weeks, and the larvae immediately begin to feed and construct webs. They enlarge the web as they continue to feed for 4 to 8 weeks. Then they spin a pupal cocoon in a sheltered place or in the duff or soil. There are at least two generations per year in the South.

Control.—Biotic agents, and unfavorable weather take their toll of these insects. Occasionally, chemical control may be necessary.

Typical damage showing large tents.

Larva.

FOREST TENT CATERPILLAR, *Malacosoma disstria* Hbn.

Importance.—Outbreaks occur periodically on oaks, tupelo gum, and other hardwoods over wide areas of the eastern half of North America. Growth loss and dieback occur, but trees are seldom killed unless they sustain 3 or more successive years of complete defoliation.

Identifying the Insect.—The larvae have pale bluish lines along the sides of a brownish body, and a row of keyhole-shaped white spots down the middle of the back. They are sparsely covered with whitish hairs, and reach 2 inches (50 mm) at maturity. Adult moths are buff-brown, with darker oblique bands on the wings. Egg masses of 100 to 350 eggs encircle the twigs and are covered with frothy, dark brown cement.

Identifying the Injury.—The first noticeable signs of attack are sparse crowns and falling frass. Caterpillars often cluster on the lower trunks of infested trees. Single trees or complete stands may be completely defoliated during the spring.

Biology.—Eggs hatch in early spring. Caterpillars feed for 4 to 6 weeks on the opening buds, foliage, and flowers. Despite its name, this species does not form tents. Pupation occurs in yellowish cocoons and lasts 10 to 14 days. Moths emerge from late May to July, mate, and deposit their eggs. There is one generation per year.

Control.—Natural control agents include insect parasites of eggs, larvae, and pupae. Predators and viruses and fungus diseases, as well as high and low temperatures, also kill forest tent caterpillars. Starvation is common when populations exceed the food supply. Several chemicals and a microbial insecticide are registered for control.

Larvae - note keyhole shapes on back.

Large areas are often defoliated.

GYPSY MOTH,
Lymantria dispar (Linnaeus)

Importance.—The gypsy moth, which came from France, is considered one of the most important pests of red and white oaks in the Northeast. It has spread southward into Virginia and is continuing to move south. Favored host species are oak, apple, alder, basswood, birch, poplar, sweetgum, willow, and hawthorn. Less favored are hickory, maple, cherry, cottonwood, elm, blackgum, larch, sassafras, and hornbean. Some mortality even occurs in white pine. It causes widespread defoliation, resulting in reduced growth, loss of vigor, mortality, and reduces aesthetic, recreational, and wildlife values. Gypsy moth larvae can be a serious nuisance in urban and recreation areas.

Identifying the Insect.—Older larvae are brownish-gray, with tufts of hair on each segment and a double row of five pairs of blue spots, followed by six pairs of red spots, on the back. Mature larvae are from 1½ to 2½ inches (40 to 60 mm) long. Adult male moths are dark brown, with wavy dark bands across the forewings. Females are white and cannot fly.

Identifying the Injury.—Young larvae chew small holes in leaves. Older larvae feed on leaf edges, consuming entire leaves except for the larger veins and the midribs. The entire tree is often defoliated.

Biology.—Larvae emerge in late April or early May from overwintering eggs and feed through June and into early July. Pupation occurs in sheltered places and lasts 2 weeks. Adults emerge in July and August. Females deposit egg masses (100 to 800 eggs) covered with buff-colored hairs, under rocks and on tree trunks, limbs, houses, picnic tables, trailers, campers, mobile homes, cars, and other sheltered places.

Control.—Natural controls, including introduced insect parasites and predators, virus diseases, and adverse weather conditions, help control the gypsy moth. Chemical and microbial insecticides have been used, primarily in urban and recreation areas, to prevent defoliation and the nuisance effects of the pest.

Larva.

Heavy defoliation in the middle of summer.

LOCUST LEAFMINER,
Odontata dorsalis (Thunb.)

Importance.—Outbreaks of the locust leafminer are generally more spectacular than destructive. In combination with other stress factors, infestations can contribute to growth loss and even mortality. The major hosts are black locust and honeylocust. Other tree species (apple, beech, birch, cherry, elm, oak, and hawthorn) are occasionally attacked.

Identifying the Insect.—The adult is a small, elongated, flattish beetle, about ¼ inch (5 to 6 mm) in length. The head is black, and the thorax and most of the wing covers are orange. The full-grown larvae are yellowish, flat, and slightly larger than adults.

Identifying the Injury.—Adults skeletonize and eat holes in the leaves, whereas larvae mine the leaves (the latter damage is more destructive). Under outbreak conditions, whole hillsides turn gray or brown, often suggesting fall color change.

Biology.—Adults overwinter in bark crevices or in leaf litter and emerge about the time leaves begin to unfold in the spring.

Eggs are deposited on the undersides of locust leaflets. They overlap like shingles in groups of three to five and are cemented together by excrement. Upon hatching, the larvae first feed collectively in a common, blisterlike mine. Then, the larvae disperse, excavating their own individual mines. Pupation occurs within the translucent blisters in July. There are two generations annually.

Control.—Control of the locust leafminer is generally not necessary. When aesthetics are involved (such as in park, shade tree, or recreation situations), control might be justifiable.

Typical damage caused by larval mining.

ORANGESTRIPED OAKWORM,
Anisota senatoria (J. E. Smith)
and
PINKSTRIPED OAKWORM,
Anisota virginiensis (Drury)
and
SPINY OAKWORM,
Anisota stigma (Fabricus)

Importance. —These oakworms occur throughout the eastern United States. They are voracious feeders, and where abundant, quickly strip the trees of their foliage. Since defoliation takes place in late summer to fall, however, forest stands of white and red oak are generally able to survive with only minimal growth loss or crown dieback. The greatest damage is the aesthetic impact and nuisance the caterpillars create in urban areas.

Identifying the Insect. — The larvae of the orangestriped oakworm are black with eight narrow yellow stripes, the pinkstriped oakworm larvae are greenish brown with four pink stripes, and the spiny oakworm larvae are tawny and pinkish with short spines. Larvae are about 2 inches (50 mm) long and have a pair of long, curved "horns". The adult moths are a similar yellowish red, with a single white dot on each of the forewings.

Identifying the Injury. — Young larvae feed in groups, skeltonizing the leaf. Later they consume all but the main veins and usually defoliate one branch before moving onto another. Older larvae are less gregarious and can be found crawling on lawns and the sides of houses.

Biology. — Adult moths appear in June and July and deposit clusters of several hundred eggs on the underside of leaves. The eggs hatch within a week, and the larvae feed during July to September for 5 to 6 weeks. The pupae overwinter in the soil. The orangestriped and spiny oakworms have only one generation per year, while the pinkstriped oakworm has two generations.

Control. — Natural enemies generally prevent widespread defoliation. Chemical control may be needed for high value trees.

Orangestriped oakworm larva.

Pinkstriped oakworm larva.

Spiny oakworm larva.

POPLAR TENTMAKER, *Clostera inclusa* (Hubner)

Importance. — The poplar tentmaker occurs in southern Canada and from New England to Georgia and Colorado. Endemic populations may defoliate small groups of poplar and willow, especially trees growing in the open. Epidemic populations may completely defoliate large cottonwood plantations. Complete defoliation twice during the same growing season will result in growth loss, crown dieback, and in some cases, tree mortality.

Identifying the Insect. — Full grown larvae are light brown to nearly black and up to $1^3/_5$ inches (42 mm) long. They have four light yellow lines on the back, and a bright yellow and several indistinct lines on each side. Adults are brownish gray, with three whitish lines crossing each forewing. The hindwings are crossed by a wavy band.

Identifying the Injury. — Newly hatched larvae skeletonize the leaf; older larvae devour all except the leaf stalk. Severe defoliation occurs during summer and early fall. Many one or two-leaf webbed tents hang from the branches.

Biology. — Moths appear from March through September and lay cream to pink colored eggs in clusters of 150 to 300 on the leaves. The larvae are gregarious and live in tents or webs constructed by pulling together the edges of one or more leaves and lining them with silk. They feed from May to October and pupate in loose cocoons. There are four generations per year in the South.

Control. — Natural controls include parasites of the pest's eggs and larvae. Predators and virus and fungus diseases also kill the poplar tentmaker. Two chemical insecticides are registered for control.

Larvae in tent.

Typical webbed leaf tents.

SLUG OAK SAWFLY,
Caliroa quercuscoccinae (Dyar)

Importance.—The slug oak sawfly is usually an endemic pest of red and white oaks. From 1974 to 1976, however, it was epidemic in Kentucky, Virginia, and Tennessee. This pest has been reported from Massachusetts through North Carolina, Kentucky, and Tennessee. Repeated defoliations reduce growth, vigor, mast crops, and kill some trees.

Identifying the Insect.—Larvae are sluglike, yellowish green, and shiny, with black heads and thoracic legs. They are ½ inch (12 mm) long, and feed in groups. The adult is a typical sawfly, about ¼ inch (6 mm) long and light brown.

Identifying the Injury.—Leaves are skeletonized. Larvae consume the lower surfaces of the leaves, making the leaf transparent and revealing a fine network of veins. Defoliation starts in the upper crown in early summer and progresses downward. By late summer, heavily infested trees may be completely defoliated or have a light-reddish appearance.

Biology.—Larvae overwinter in cocoons and pupate in the spring. Adults and larvae are present throughout the summer. Eggs are deposited in single rows of slits on the lower leaf surface along main veins. There are two to three generations per year.

Control.—Microbial diseases, parasites, and other natural enemies generally keep the slug oak sawfly in check. Insecticides may be needed on high value shade and ornamental trees.

Larva beginning to skeletonize leaf.

VARIABLE OAKLEAF CATERPILLAR,
Heterocampa manteo (Doubleday)

Importance.—This defoliator is common throughout eastern North America. It attacks a wide variety of hardwoods, including all species of oaks, but prefers the white oaks. Some infestations have covered millions of acres, retarding tree growth and reducing vigor. Outbreaks occur periodically and usually subside after 2 to 3 years, before serious tree mortality occurs.

Identifying the Insect.—The larval color is variable, but is generally yellowish green, with a narrow white stripe down the center of the back, and one or two yellowish stripes on the sides. The head is amber, with one dark and one light band on each side of the head. Mature larvae may reach 1 ½ inches (37 mm) long. The adult moth is ashy gray, with three dark wavy lines across each forewing. The wingspan is approximately 1 ½ inches (37 mm).

Identifying the Injury.—Young larvae skeltonize the leaf, while older larvae devour the entire leaf except the leaf stalks and main veins. There are two periods of defoliation—early May to late June and mid-August to late September.

Biology.—There are two generations in the South and one generation in the North. In the South, the larvae feed from early May until late June and pupate in the soil. Second generation larvae feed from mid-August until late September, then move to the ground to spin cocoons and over winter. Adult moths emerge from cocoons by early spring.

Control.—Insect parasites and predators destroy eggs, larvae, and pupae. Winter mortality also helps keep most infestations in check. Chemical control is occasionally needed to protect high value trees.

Larva and feeding damage.

WALKINGSTICK,
Diapheromera femorata (Say)

Importance.—The walkingstick attacks oaks and other hardwoods. In the South, severe outbreaks have only occurred in the Ouachita Mountains of Arkansas and Oklahoma. Branches are killed or die back in heavily defoliated stands, but continuous defoliation for several years can result in mortality. The insects create a nuisance in high use areas such as parks and recreation sites.

Identifying the Insect.—Nymphs and adults are slender and have long thin legs and antennae. While motionless, they closely resemble their host. Adults are about 2½ to 3 inches (62 to 76 mm) long, and their body color varies from brown to green to multicolors of gray, green, and red.

Identifying the Injury.—The entire leaf blade, except the base of the stout veins, is eaten. During heavy outbreaks, large stands are often completely denuded. Trees may be defoliated twice during the same season. Because the walkingstick does not fly, infestations are often localized and spread only a few hundred yards during the season.

Biology.—Overwintering eggs in leaf litter hatch in May and June. Nymphs become adults during the summer and fall. Females deposit up to 150 eggs, which are randomly dropped to the forest floor. There is one generation per year in the South, while 2 years are required farther North.

Control.—Natural enemies, particularly birds, are often effective. Chemical control is occasionally warranted in high use areas.

Patches of heavy defoliation.

Adult walkingstick - note how it blends with foliage.

WALNUT CATERPILLAR,
Datana integerrima,
Grote and Robinson

Importance.—The walnut caterpillar feeds only on black walnut, pecan, hickory, and butternut. Defoliation may weaken the tree and make it susceptible to damage by wood borers. Tree mortality is rare, but may occur after 2 years of heavy defoliation.

Identifying the Insect.—Eggs are spherical and pale green with white caps. They are laid in clusters of 120 to 800 on the underside of leaves. All larvae have black heads. Newly hatched larvae are light green and change to reddish brown with white stripes. Fully grown larvae are nearly black with white hairs. They are 1 to 2 inches (25 to 50 mm) long.

Pupae are ¾ inch (20 mm) long and shiny, dark, reddish brown. The wing-span of moths is about 1¾ inches (45 mm). The front wings are dark tan with four rust colored lines. The hind wings are light tan.

Identifying the Injury.—Young larvae skeletonize the upper leaf surface. As they grow, they feed on the entire leaf except the petiole. Individual branches, entire trees, or groups of trees may be completely defoliated.

Biology.—Moths emerge in May and lay eggs. Eggs hatch in 8 to 10 days, and larvae feed until mature and pupate in the soil. Adults emerge in July and begin the second generation, which is the largest and most destructive. Larvae cluster together on tree branches or trunks and molt simultaneously, leaving a large mass of hairy cast skins adhering to the bark.

Control.—Parasites, predators, and diseases are major factors influencing population levels. Cultural controls are: clipping foliage to destroy egg masses and larvae, removing clustered larvae as they gather to molt, and destroying pupae by shallowly disking the soil after larvae have pupated. Chemical control is usually not necessary because tree mortality is rare.

Larva.

WHITEMARKED TUSSOCK MOTH,
Hemerocampa leucostigma (J. E. Smith)

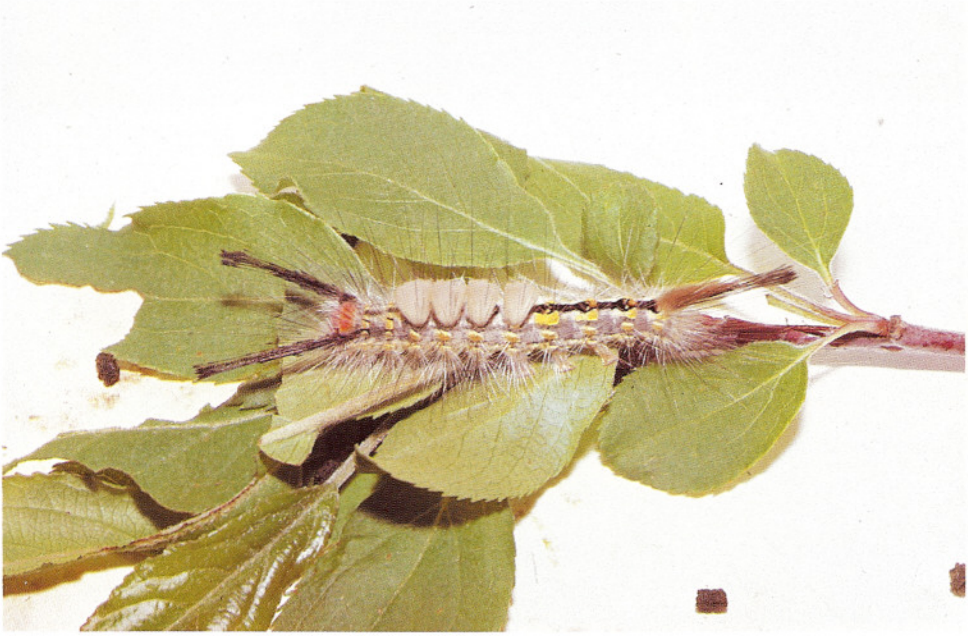
Importance.—In the South, the whitemarked tussock moth occasionally occurs in epidemic numbers and heavily defoliates several species of hardwood, primarily live oak, water oak, red oak, and white oak. It is not considered a serious forest pest; however, it causes considerable damage to shade and ornamental trees. Trees are seldom killed, but growth loss does occur. Larvae often create a nuisance in urban and recreation areas due to dropping frass, their allergenic hairs, and their migratory habits.

Identifying the Insect.—The larva is 1 to 1½ inches (25 to 38 mm) long. It has a bright red head with a yellowish body, a pair of upright pencil tufts of black hairs on the prothorax, and four white to yellowish brushlike tufts of hairs on the back toward the head. The adult male moth is gray brown, with darker wavy bands and a white spot. The female is wingless and whitish gray.

Identifying the Injury.—Young larvae chew small holes in leaves. Older larvae feed on leaf edges, consuming entire leaves, except for larger veins and midribs. Entire trees may be defoliated.

Biology.—Overwintering occurs in the egg stage. Eggs are laid in small, white masses and hatch in the early spring. Larvae feed until they pupate in May or June. Pupation occurs in a cocoon, and adults emerge in about 2 weeks. Adults live 2 to 4 weeks. In the South there may be as many as three generations per year. The female adult emerges from a beige cocoon and mates, laying her eggs in a mass on her cocoon.

Control.—Parasites, predators, microbial diseases, starvation, and unfavorable weather normally bring epidemics under control. Control is not necessary under forest conditions. In urban and recreation areas, insecticides may be desirable to avoid defoliation, the nuisance effect of this pest, and the allergenic effect of the larval hairs.



Larva.

YELLOWNECKED CATERPILLAR, *Datana ministra* (Drury)

Importance.—This caterpillar is a defoliator of oaks and many other hardwoods throughout the United States. Infestations have been most common in the Appalachian and Ozark Mountains and their foothills. Damage is more severe among shade and ornamental trees than forest stands.

Identifying the Insect.—The larvae are yellowish and black striped, and moderately covered with fine, white hairs. The head is jet black. The segment behind the head is bright orange-yellow—hence, its name, yellownecked caterpillar. Full-grown larvae are about 2 inches (50 mm) long. When disturbed, the larvae lift their heads and tails in a distinctive U-shape. This is a defensive measure to prevent parasitism by various wasps and flies.

Identifying the Injury.—Newly hatched larvae skeltonize the leaf; older larvae devour all except the leaf stalk. Individual trees, or even stands, may be defoliated during late summer and early fall. Since defoliation is confined to the late part of the growing season, little damage is caused to the tree.

Biology.—Moths appear during June and July and deposit white eggs in masses of 50 to 100 on the undersides of the leaves. Larvae feed in groups, maturing in August and September. Mature larvae drop to the soil and pupate at depths of 2 to 4 inches (50 to 100 mm), where they spend the winter. There is one generation per year.

Control.—Natural enemies generally keep infestations in check. Chemical controls are occasionally needed.

Larva.

CARPENTERWORM, *Prionoxystus robiniae* (Peck)

Importance.—In eastern and southern states, oaks—particularly red oaks—are the most heavily damaged. Other hosts are green ash, black locust, elm, maple, willow, cottonwood, and sometimes fruit trees and ornamental shrubs. The damage—wormholes—causes unsightly scars on ornamental trees and degrade, estimated at 15 percent of the value of rough sawn lumber.

Identifying the Insect.—Newly hatched larvae are ¼ inch (6 mm) long and reddish pink. They gradually become greenish white and are 2 to 3 inches (50 to 75 mm) long at maturity. Brown pupal skins protruding from entrance holes are common in early summer. Adults are grayish, stout-bodied moths. The hindwing in the male has an orange spot.

Identifying the Injury—Earliest signs of attack are sap spots on the trunk. Later, frass is ejected from entrance holes. Burrows 2 inches (50 mm) in diameter under the bark, and galleries ½ inch (12 mm) in diameter and 5 to 8 inches (12 to 22 cm) long in the wood are typical. Galleries are open or loosely plugged with frass. Holes in lumber are dark stained.

Biology.—Adult moths appear in April to June and deposit 400 to 800 eggs in bark crevices. Eggs hatch in 10 to 12 days, and young larvae tunnel into the bark and wood. Pupation occurs within the gallery during spring and lasts 3 weeks. A life cycle requires 1 to 2 years in the South, and 2 to 4 years in the North.

Control.—Management practices such as maintaining high tree vigor, removing brood trees, preventing bark injuries, and spraying the trunk or fumigating the galleries with insecticides help to minimize damage.

Attacks on the trunk.

Larva in a typical gallery in the wood.

COLUMBIAN TIMBER BEETLE, *Corthylus columbianus* (Hopkins)

Importance.—This beetle occurs over much of the East and south to Georgia and Arkansas. It attacks oaks (particularly red oaks), maples, birch, basswood, sycamore, yellow poplar, and elm, damaging the trunks of live trees of all sizes. Damaged wood cannot be used for veneer, cooperage, and furniture.

Identifying the Insect.—Adults are black to reddish-brown cylindrical beetles about 1/5 inch (4 mm) long. The larvae are white, legless and C-shaped.

Identifying the Injury.—Holes less than 1/10 inch (2 mm) in diameter are bored straight into the sapwood until the tunnel nears the heartwood, turning right or left. Damage is conspicuous in log ends. Streaks of stain originating from the tunnels are called flagworm defects.

Biology.—Adult beetles construct galleries. Eggs are laid in chambers along the main tunnel where the larvae live and develop. Larval food is a white fungus that grows on the gallery walls. There are two to three generations per year.

Control.—There is no apparent relationship between tree vigor and susceptiblity. No natural enemies have been found. Protection of veneer-quality trees with insecticides should be considered.

Pupae and adult.

Staining on bark at point of attack.

COTTONWOOD BORER, *Plectrodera scalator* (Fab.)

Importance.—The cottonwood borer ranges throughout the eastern Unites States, but highest populations and greatest damage occur in the South. It attacks cottonwood and willow. Trees weakened by severe infestations may be broken off by wind. Damage is sometime serious in cottonwood nurseries, natural stands, and plantations, particularly those planted offsite.

Identifying the Insect.—Adult beetles are 1 to 1$^{1}/_{5}$ inches (25 to 38 mm) long and about ½ inch (12 mm) wide. They are black with lines of cream-colored hair forming irregular black patches. Larvae are seldom seen.

Identifying the Injury.—The adults may cause serious damage in cottonwood nurseries by feeding on the tender shoots of young trees, causing them to shrivel and break off. The larvae bore into the inner bark and wood at the root collar and tunnel downward into the roots. Light brown, fibrous frass is sometimes ejected from bark openings at or slightly above the ground line, accumulating in piles at the base of the tree. The root collar and roots of infested trees may be riddled by larval tunnels.

Biology.—The adults appear in midsummer. After feeding briefly, they descend to the bases of host trees where the famale deposits her eggs in small pits gnawed in the bark. Eggs hatch in 16 to 18 days. The larvae bore downward in the inner bark, entering a large root by autumn. Pupation occurs in the gallery from April to June and lasts about 3 weeks. The new adults chew exit holes through the sides of the pupal chambers and emerge through the soil. Some larvae complete development in 1 year, while others require 2 years.

Control.—Management practices—such as locating new nurseries away from infested trees, planting uninfested cuttings, and removing and destroying infested rootstock—help to minimize damage. Three weekly applications of insecticide, timed to begin soon after emergence, have given good control of adult beetles in nurseries.

Adult.

Larvae in a root.

COTTONWOOD TWIG BORER, *Gypsonoma haimbachiana* (Kft.)

Importance.—The cottonwood twig borer is widely distributed throughout the eastern United States, from Canada to the Gulf states and west to Missouri. It is one of the most destructive insects of young cottonwood. Other poplars are also hosts. Terminal shoot injuries cause serious stunting, forks, crooks, and other malformations. This leads to reduction in the quality and quantity of merchantable pulpwood, sawlogs, or veneer.

Identifying the Insect.—The adult is ash gray and has wingspread of ½ to 7/10 inch (13 to 17 mm). The basal portion of the forewing is darker than the apical. Full-grown larvae are pale, with a brown-yellow head. They are from 2/5 to ½ inch (10 to 13 mm long).

Identifying the Injury.—Larvae bore into the terminals and branch ends of the host. They frequently kill the bud and up to 10 inches (25 cm) of the terminal. Often the old dead terminal remains intact on the tree for several months after the larvae have emerged. A stunted, deformed, limby tree is a good indication of cottonwood twig borer damage.

Biology.—The female moth lays eggs on the upper surface of leaves along the midrib, alone or in groups of two to eight. Hatching occurs in about 5 days. The young larvae cover themselves with silk mixed with trash, then bore into the midrib. After about 3 days the larvae abandons their midrib galleries and move to tender shoots where they tunnel in and complete their larval development. Larvae reach maturity in about 21 to 23 days and move down the trunk, where they spin cocoons in sheltered bark crevices or litter or between leaf folds. Adult moths emerge in 8 or 9 days. It takes from 40 to 45 days to complete the life cycle in midsummer. There are four or more generations per year in the South.

Damage on cottonwood.

Control.—The most effective natural control is a potter wasp, which tears open tender cottonwood shoots and removes twig borer larvae from their galleries. Other wasps also parasitize twig borer larvae. Direct control can be obtained through the use of soil-applied systemic insecticdes.

HICKORY BARK BEETLE,
Scolytus quadrispinosus Say

Importance.—The hickory bark beetle is reported to be the most serious insect pest of hickory in the United States. Several states have reported instances where thousands of trees were killed. Pecan and butternut are also hosts.

Identifying the Insect.—The adult is short, stout, black, almost hairless, and $^1/_5$ inch (5 mm) long. The underside of the posterior is concave and has spines. The larvae are typically white or cream-colored, legless grubs, about the same size as the adults.

Identifying the Injury.—Dying leaves and twigs and trees with red foliage are the first eveidence of attack. Short, vertical egg galleries with radiating larval galleries etched in the sapwood are good indicators of damage.

Biology.—Adults appear in early summer and feed for a short time at the bases of leaf petioles and on twigs before attacking the trunks.

Twenty to 60 eggs are deposited in egg galleries in the phloem. When nearly full-grown, the larvae gradually angle away from the adult gallery. Before reaching maturity, they leave the phloem to pupate in the bark. Winter is spent in the larval stage and pupation occurs in the spring. There are usually two generations each year in the southern United States.

Control.—Control practices include felling infested trees over large areas and destroying the bark during winter months or storing infested logs in ponds. Insecticides can also be used.

Egg gallery and larval mines.

LOCUST BORER,
Megacyllene robiniae (Forster)

Importance.—This is the most serious insect pest of black locust. It provides infection courts for the fungus, *Fomes rimosus,* which causes substantial defect, growth loss, and some mortality. The only host is black locust.

Identifying the Insect.—The adult is an attractive longhorned beetle, often seen feeding on goldenrod in late summer and early fall. It has bright yellow bands expanding across a jet black thorax and wing covers, and the third band on the wings forms a "W" design. Legs are yellow-orange and long. Full-grown larvae are full-bodied, pale, and about 1 inch (25 mm) long.

Identifying the Injury.—The first sign of attack occurs in the spring, around the time of bud burst. Oozing sap at the point where the larva bores into the tree causes a wet spot on the bark. Eventually, the larva begins to tunnel into the wood, pushing granular frass out of the entry hole.

Wood infested by locust borers can be virtually "honeycombed" by the larvae. Sometimes stems are so weakened that they become windbroken.

Biology.—Eggs are deposited in rough bark surfaces and around wounds of living trees. Newly-hatched larvae excavate a small hibernating cell in the inner bark and overwinter. In the spring, they bore into the wood, enlarging the tunnel to the exterior. About mid-July, they emerge at the original attack point. There is one generation annually.

Control.—Since the heaviest attacks occur in stressed trees, most preventive recommendations are designed to encourage or maintain health and vigor. This includes planting superior trees, avoiding pure locust stands, and removing low vigor and overmature trees. Excluding damaging livestock from black locust stands can also reduce beetle attacks.

Damage caused by borers and wind.

Adult.

RED OAK BORER, *Enaphalodes rufulus* (Haldeman)

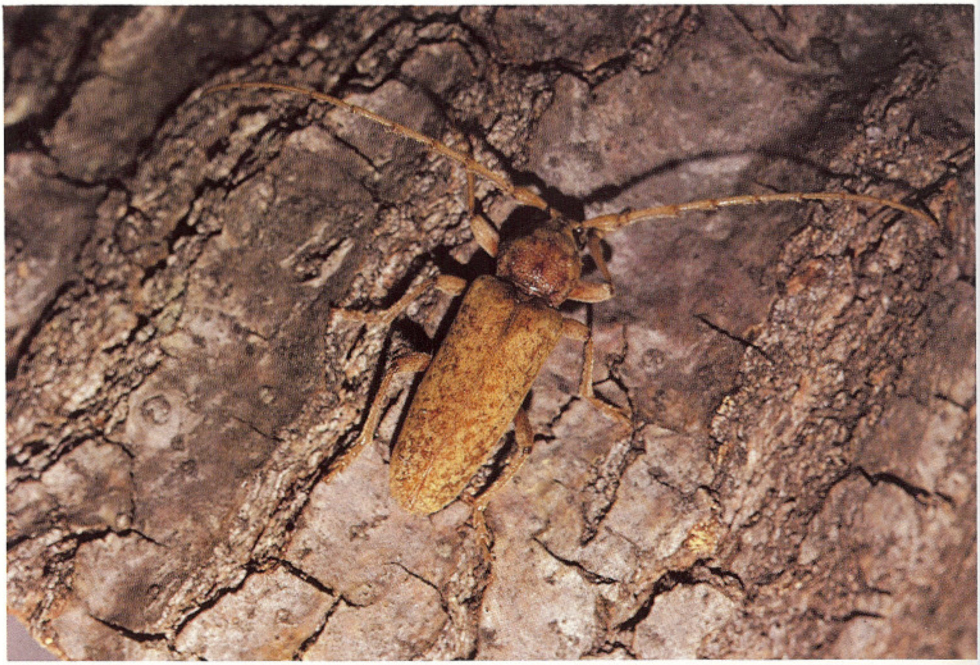
Importance.—This is a major pest of red oaks, accounting for millions of dollars in losses from defects and degrade in lumber. Valuable shade trees in parks and cities are sometimes attacked, but are rarely killed.

Identifying the Insect.—Adult borers are longhorned beetles. Their antennae are very long, almost doubling their 1-inch (25 mm) body length. Their rust brown color blends well with the bark surface, and they are rarely seen. The pale, robust larvae have very small legs on the thorax.

Identifying the Injury.—The first signs of attack resemble the fine frass produced by ambrosia beetles. As the larvae bore into the tree, sap begins to extrude from the attack points. Within the tree, tunnel diameters gradually increase from pinhole size to about ½ inch (12 mm) in diameter as larvae grow. Tunnels are 6 to 10 inches (15 to 25 cm) long and are often accompanied by discolored and decaying wood. They are usually within 6 inches (15 cm) of the pith.

Biology.—The red oak borer has a 2-year life cycle. Eggs are laid in midsummer in roughened areas or near wounds, and larvae tunnel under the bark for the first year. In the second year, the more damaging wood tunneling commences. Prior to pupation, the larvae chew round exit holes through which they later emerge as adults.

Control.—Removal of brood trees significantly reduces the pest population. Measures aimed at encouraging stand vigor will discourage attack. Infested, high value shade trees may be treated with insecticides.



Adult.

SMALLER EUROPEAN ELM BARK BEETLE,
Scolytus multistriatus (Marsham)

Importance.—This beetle is the prime vector of the Dutch elm disease fungus which has destroyed millions of American elms since its introduction into the United States. The beetle attacks all native and introduced species of elms.

Identifying the Insect.—Adults are reddish-brown beetles about ¼ inch (3 mm) long. The underside of the posterior is concave and armed with a prominent projection or spine on the undersurface of the abdomen. The larvae are typical, white or cream-colored, legless grubs, about the same size as adults.

Identifying the Injury.—Beetles excavate a 1 to 2 inch (25 to 50 mm) straight egg gallery parallel with the wood grain. Larval mines are roughly perpendicular to the egg gallery. The result is a design resembling a long-legged centipede on the inner bark and wood surface.

Symptoms of the disease are described under "Dutch Elm Disease" in this booklet.

Biology.—Smaller European elm bark beetles overwinter as larvae under the bark and develop into adults in the spring, emerging after the leaves expand. Adults feed at twig crotches of healthy elms, infecting the tree with Dutch elm disease. Then they fly on to other elms for breeding. These attacked trees have usually been weakened by drought, disease, or other stress factors.

After boring through the bark, the beetles excavate their egg galleries, grooving the inner bark and wood surface in the process. When larvae are full-grown, they construct pupal cells at the end of their larval mines. New adults emerge by boring directly through the bark, leaving it peppered with tiny "shot holes." There are two generations annually.

Control.—The most effective method of reducing losses is probably through removal of dead and dying elms and the pruning of dead and dying limbs. Several chemical insecticides may be applied as preventative sprays or to kill beetles before they spread to uninfested trees.

Beetle feeding at twig crotch

TWOLINED CHESTNUT BORER, *Agrilus bilineatus* (Weber)

Importance.—This borer attacks red and white oaks throughout the East. Trees weakened by drought, insect defoliation, or other factors are most susceptible. Larvae mine the cambium, resulting in girdled trees. Mortality can be extensive in weakened stands.

Identifying the Insect.—Adult beetles are about 1/5 to ½ inch (6 to 12 mm) long, slender, and black, with a light yellowish stripe on each wing cover. Larvae are white, slender, flattened, and about 1 inch (25 mm) long, with two spines at the rear end.

Identifying the Injury.—Larvae excavate winding mines in the inner bark and outer sapwood of the main trunk and large branches, frequently girdling the tree. Attacks usually begin in the upper tree canopy and extend downward as the tree continues to weaken. D-shaped adult emergence holes are evidence of infestation.

Biology.—Adults emerge during spring and early summer and deposit eggs in bark crevices. Eggs hatch in 10 to 14 days. The larvae burrow through the bark and cambium. They overwinter in cells in the bark and pupate the follwing spring. There is one generation per year.

Control.—Control is mainly a matter of preventing attacks through cultural practices that promote tree vigor. Spraying to protect foliage from insect defoliators is recommended in some areas.

Larvae in galleries.

WHITE OAK BORER,
Goes tigrinus (DeGeer)

Importance.—This is one of the most destructive borers of the white oak group in the South. Its importance is compounded by the increasingly higher prices of veneer-quality lumber.

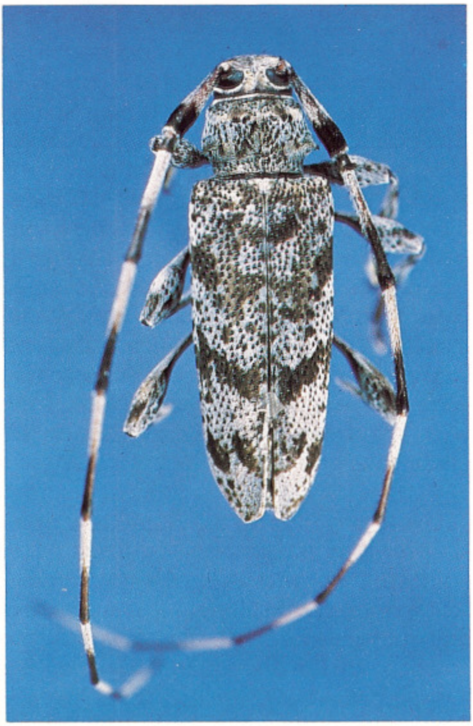
Identifying the Insect.—The adult long-horned beetles are rarely seen. They are mottled brown and white, about 1 inch (25 mm) long, with a spine on each side of the thorax and antennae about as long as the body. Larvae are grub-like, pale yellow, robust, and up to 1½ inches (37 mm) long.

Identifying the Injury.—Oozing of sap and frass production on trunks are the most prominent indications of infestations. The sap often attracts flies, bees, wasps, butterflies, and other insects. Internal damage consists of extensive larval mining, often accompanied by discoloration and subsequent decay of the wood.

Biology.—Adults emerge in mid-spring and deposit eggs in roughened bark or near wounds. About 3 weeks later, eggs hatch, and larvae tunnel directly into the wood. New adults develop within the tunnels and emerge through a new, circular exit hole. The life cycle requires 3 to 5 years for completion.

Control.—Removal of heavily infested brood trees, combined with measures designed to encourage tree vigor, are the most practical controls. Woodpeckers and sap ooze are the most important natural controls.

Removing vines, which are good egg laying sites, may be cost effective when the wood is used for veneer. Vine removal operations should not damage bark, since this can actually encourage infestations.



Adult

Typical attack on white oak.

APHIDS

Importance.—Aphids infest hardwoods and conifers throughout the United States. They can be found almost anywhere on a tree, particularly on new growth. Heavy infestations distort foliage, cause terminal dieback, reduce tree vitality, weaken the tree, and cause branch and crown dieback. In young trees and seedlings, mortality can occur from heavy infestations. Aphids are usually of greatest concern in nurseries, seed orchards, and shade and ornamental trees. Honeydew and sooty mold, associated with aphids, usually mar the beauty of ornamentals.

Identifying the Insect.—Aphids vary in bodycovering and range in size from 1/50 to ¼ inch (½ to 6 mm) long. However, they are all soft-bodied insects. Most aphids are pear-shaped, with a pair of cornicles at the posterior of the abdomen. They may be transparent, yellow, green, pink, brown, almost black, or spotted. Some may be covered with a white woolly wax. Some are winged, while others are not.

Identifying the Injury.—Aphids feed on various parts of a tree. Some feed on the undersides of leaves, causing stunting, curls, and folds in the leaves. Other symptoms to look for are: leaf discoloration; dieback or "flagging" of newly formed terminals, branch ends, and new leaves; early leaf drop; and ringlike swellings or knots at nodes and buds. Trees with poor vigor or with branch and crown dieback should be examined closely for aphids. Sooty mold and ants frequenting a tree are good indicators of an active or recent aphid attack.

Biology.—Overwintering can occur in any life stage, but the most common is the adult or egg. Eggs hatch and live births usually occur in the spring, and nymphs begin feeding on selected parts of the plant. Some aphids migrate as nymphs; others spend their life in one place. Some aphids have only one generation per year; other have several. Some aphids require alternate hosts in alternate generations.

Control.—Parasites and predators are effective in controlling aphid outbreaks and maintaining low populations. However, insecticides are often used to protect high value trees and are most effective against the nymphs.

Typical soft-bodied aphid on pine.

LACE BUGS,
Corythucha spp.

Importance.—Adults and nymphs of lace bugs feed on the leaves of many species of hardwoods throughout the South. Some of the more common species affected are sycamore, oak, elm, hackberry, and basswood. By the end of August, leaves attacked by these insects may be discolored and perform little photosynthesis, and may even fall from the tree.

Identifying the Insect.—Nymphs are usually dark colored and covered with spines. Adults have broad, transparent, lacelike wingcovers. They are flattened, and about ¼ inch (6 mm) long. Some species are beautifully colored.

Identifying the Injury.—Infested leaves have chlorotic flecks or tiny chlorotic spots on the upper side. Heavily infested trees may be partially or full defoliated, especially during dry weather.

Biology.—Adults overwinter in bark crevices and similar protected areas of their host. The adults become active during the spring and lay eggs on the underside of leaves. After the eggs hatch, the nymphs begin feeding on the underside leaves. They feed by inserting their mouth parts into leaf tissue and sucking the plant juices. A complete life cycle, from egg to adult, may take in 30 to 45 days; several generations may occur each year. In late summer, both adults and nymphs will be feeding at the same time.

Control.—Natural enemies are usually effective in maintaining populations at a low level and bringing outbreaks under control. Chemical controls are usually only used on shade and ornamental trees.

Adults on sycamore.

BLACKHEADED PINE SAWFLY,
Neodiprion excitans Rohwer

Importance.—This sawfly, which ranges from Virginia to Texas, prefers loblolly and shortleaf pines but also feeds on slash, longleaf, and pond pines. Because heaviest defoliation occurs during late summer and fall, trees may go through the winter stripped of their needles. The resulting loss in vigor may predispose slow-growing pines to bark beetle attack.

Identifying the Insect.—Older larvae are about 1 inch (25 mm) long and olive green with a glossy black head. Two longitudinal black stripes run along the top of the body, and a conspicuous row of black spots occurs on each side. The adult female is about ½ inch (12 mm) long with a light brown body. She lays her eggs singly at the bases of needles on the tips of shoots.

Identifying the Injury.—Defoliation during spring and summer is not serious because larvae tend to feed on the older foliage. In the fall, however, defoliation may exceed 90 percent of the total crown and result in a considerable growth reduction during the following season. Heavily defoliated trees, especially overmature sawtimber, may be killed following secondary attacks by bark beetles.

Biology.—The larvae overwinter in light brown cocoons spun principally in duff, topsoil, and bark crevices at the base of the trees. Pupation is completed in the spring, and both adults and larvae are sometimes present throughout the summer and fall. There are 3 to 4 generations per year in the Gulf coastal region.

Control.—Outbreaks of the blackheaded pine sawfly occur periodically and usually subside rapidly. Natural enemies are usually helpful in preventing or ending outbreaks. Insecticides may be warranted on high value trees.

Larvae.

INTRODUCED PINE SAWFLY, *Diprion similis* (Hartig)

Importance.—The introduced pine sawfly occurs from Canada to North Carolina, and in the central and lake states. Eastern white pine is its favored host, but it also attacks Scotch, red, jack, and Swiss mountain pines. Infestations of this insect can be very serious in young plantations of white pine grown for timber products or Christmas trees.

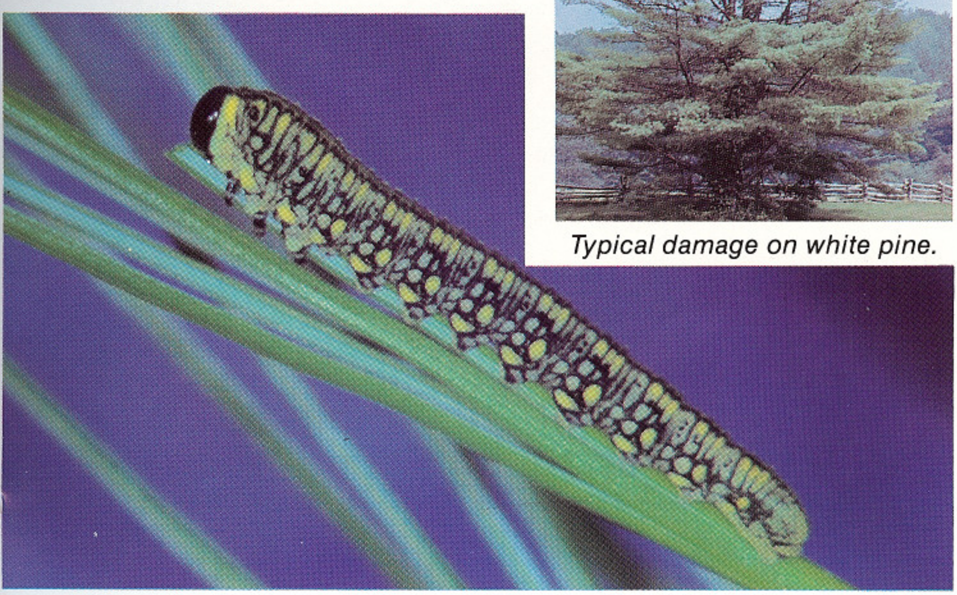
Identifying the Insect.—A full-grown larva is about 1 inch (25 mm) long, with a shiny, black head. The body has a black stripe on the back and numerous yellow and white spots on the sides. Larvae spin light brown, tough, leathery cocoons on the host tree, other vegetation, and ground litter. Adults resemble flies and are about 3/10 inch (8 mm) long and have four transparent wings.

Identifying the Injury.—Defoliation first occurs in the upper crown, giving it a thin appearance. First generation larvae feed on old needles, and later generations feed on both old and new needles, and sometimes on the bark of twigs. Trees in the most exposed locations and in the overstory suffer the most defoliation. Repeated heavy defoliation can cause branch and even tree mortality.

Biology.—In the southern Appalachians, first generation adults emerge in early spring, about April. Eggs are laid in rows in the needles and covered with a light green substance. Hatch occurs in about 14 days. Larvae feed until cocoons are spun in late June through July. Second generation adults emerge in late July, and most larvae have finished feeding and spin cocoons by late September. There are two generations and sometimes a partial third. As a result of overlapping generations, all life stages can be observed in midsummer.

Control.—Introduced and natural enemies play an important role in control of the introduced pine sawfly. Chemical insecticides are effective in protecting ornamental plantings and Christmas tree plantations from defoliation.

Typical damage on white pine.



Larva.

LOBLOLLY PINE SAWFLY, *Neodiprion taedae linearis* Ross

Importance.—This species is one of the most important defoliators of loblolly and shortleaf pine in the south-central states. In heavily infested areas, trees may be completely defoliated in the spring before new shoots have developed. Periodic outbreaks over large areas cause substantial growth loss and reduced tree vigor, but mortality rarely occurs.

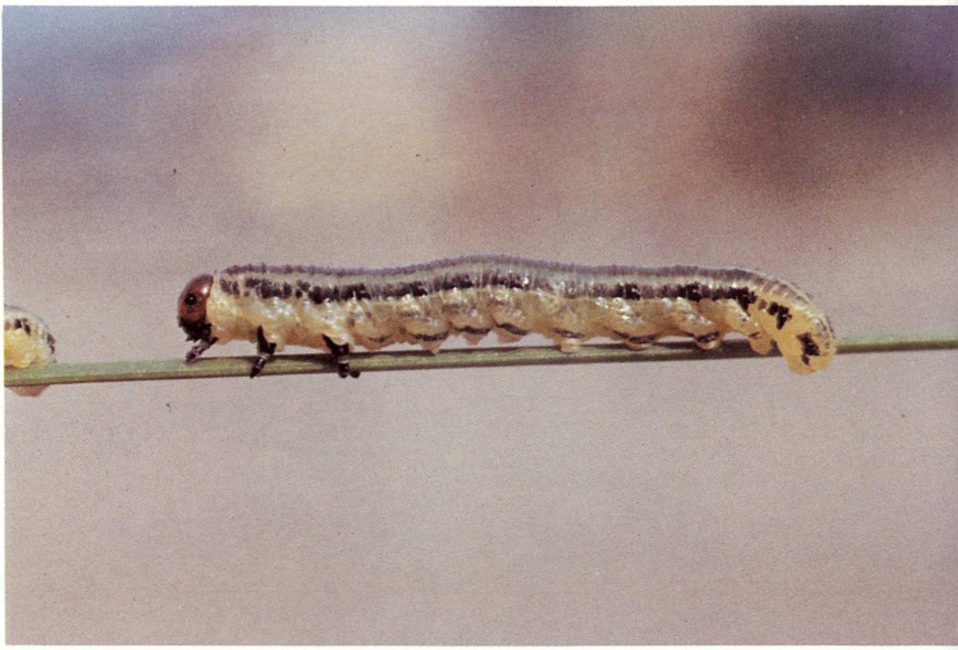
Identifying the Insect.—Larvae are dull green in color, with black stripes along each side and often two lighter stripes below the heavy ones. They are about 1 inch (25 mm) in length, with brown heads. The adult female has a brown body with black markings and is about 2/5 inch (10 mm) long with a sawlike apparatus for depositing eggs.

Identifying the Injury.—Newly hatched larvae feed in groups on the old growth. They consume the soft outer tissue of needles, leaving the remainder to turn reddish brown. Twigs with damaged and discolored needles can be easily seen, and are called "flags". Older larvae feed singly or in pairs and consume the entire needle, leaving short stubs on the branch.

Biology.—There is only one generation per year. The overwintering eggs hatch during March and April. Larvae feed for 3 to 4 weeks before dropping to the ground and spinning cocoons in the litter and soil.

Pupation takes place in October or November, just prior to adult emergence. After the female mates, she lays a row of 2 to 10 eggs in the middle portion of each needle, laying between 90 to 120 eggs overall.

Control.—Natural enemies and a polyhedrosis virus are very effective at controlling outbreaks. Chemical control would be warranted only after several consecutive years of defoliation in the same timber stand.



Larva.

Photo: L.E. Thompson, Univ. of Arkansas

PINE COLASPIS,
Colaspis pini Barber

Importance. — Pine colaspis beetles are commonly found throughout the southeast, but are more prevalent in the Gulf states. They prefer slash pine but have been found on other southern pines, baldcypress, and ornamental spruce. Pine colaspis beetles are not serious forest pests. However, feeding damage caused by large beetle populations can cause a spectacular browning effect.

Identifying the Insect. — Adults are elongate-oval, convex, and rusty yellow or brown with green reflections. These moderate sized beetles are about ¼ inch (6 mm) long. Full grown larvae are sparsely covered with short hairs. Small clusters of longer hairs occur at the lower outer edges of each body segment.

Identifying the Injury. — Adult beetles chew the edges of needles, producing irregular, sawlike edges that turn brown. Later the entire needle may die, causing the whole tree to become brown as though scorched by fire. Occasionally, only the tips of the needles show signs of injury. Trees do not die, and little or no growth loss results. Attacks usually occur in early summer. By late summer the trees appear green and healthy again.

Biology. — There is only one generation per year. Eggs are laid on herbaceous undergrowth during the summer. Larvae emerge, feed on roots of grasses and other vegetation, and overwinter in this stage. The larvae pupate in the spring; adults emerge in early summer.

Control. — Under forest conditions, no control measures are recommended. On ornamentals and shade trees, insecticides can be used to prevent unsightly damage.

Feeding damage on needle.

PINE WEBWORM,
Tetralopha robustella Zeller

Importance. — The pine webworm occurs in southern Canada and throughout most of the eastern half of the United States and attacks pitch, Virginia, white, shortleaf, longleaf, loblolly, and slash pines. The pine webworm usually attacks one and two year seedlings, but will infest saplings and large trees. Rarely is defoliation severe enough to kill the seedlings, but it may have some growth impact.

Identifying the Insect. — The adult moth is dark to medium gray, with dark gray to black forewings on the basal third and outer half. Wingspread is approximately 1 inch (25 mm). The larvae are light gray with darker tan stripes along the body. They are approximately ¾ inch (18 mm) in length when fully grown. The pupae are reddish in color and approximately ½ inch (12 mm) long.

Identifying the Injury. — The most noticeable sign of attack, and usually the first, is a large mass of frass and excrement pellets entangled in a network of silken webbing. Close examination of this mass of material will usually reveal one or more larvae.

Biology. — Eggs are usually laid on seedlings, or occasionally on larger trees, between May and September. After the eggs hatch, the caterpillars live in silken webs surrounded by masses of frass and feed on the needles. After feeding is completed, the caterpillars drop to the ground and pupate in the soil. In the South, there are usually two generations per year.

Control. — In plantations, hand-picking is an effective method of control. When high value nursery stock becomes infested, chemical control may become necessary.

Frass and excrement pellets entangled in webbing.

Larva.

REDHEADED PINE SAWFLY, *Neodiprion lecontei* (Fitch)

Importance. — The redheaded pine sawfly is an important pest in young, natural pine stands and plantations. Heavy defoliation can lead to growth loss and tree mortality. The redheaded pine sawfly occurs in southeastern Canada and throughout the eastern and southern United States. Loblolly and longleaf pines are preferred hosts, although shortleaf, pitch, and slash pines are also attacked.

Identifying the Insect. — The mature larva is easily identified by its bright red head. The body is about 1 inch (25 mm) long and pale whitish yellow to bright yellow in color, with 4 to 6 rows of black spots on the body. The cylindrical cocoon is reddish brown and about ½ inch (12 mm) long. The adults resemble flies. They have four transparent wings and vary from $^1/_5$ to $^2/_5$ inch (5 to 10 mm) in length.

Identifying the Injury. — Larvae feed in colonies containing a few to over a hundred larvae. Larval feeding generally occurs on trees under 15 feet (5 m) in height. Young larvae feed on the outer portion of the needles. The unconsumed portions of needles have a strawlike appearance. Older larvae strip branches of all foliage and sometimes feed on tender bark when foliage is scarce.

Biology. — This sawfly overwinters in the larval stage within cocoons located in the soil or duff. Adults emerge in the spring. The female lays approximately 120 eggs in rows on the needles of a single twig. Each egg is deposited in a small pocket sawed into the edge of the needle. Eggs hatch in about 2 to 4 weeks, and larvae feed gregariously for about 4 weeks. Larvae then drop to the ground and spin their cocoons. In most of the South, there are two generations per year, but in Florida there are usually three.

Control. — Outbreaks occur periodically and tend to subside after 1 to 2 years of heavy defoliation. Natural factors and climatic conditions help control populations. A polyhedrosis virus is being used to control outbreaks of the redheaded pine sawfly. Chemical insecticides also may be used.

Larvae.

TEXAS LEAFCUTTING ANT, *Atta texana* (Buckley)

Importance. — The Texas leafcutting ant, or town ant, is a serious pest of pine regeneration in the upland areas of west central Louisiana and east Texas. It does not occur in other forested areas across the South.

Identifying the Insect. — Leafcutting ants are rust colored with large heads. They live in large colonies. The queen is ¾ inch (18 mm) long, and lives in an underground chamber. The worker ants are most numerous and range in size from $^1/_{10}$ to ½ inches (3 to 12 mm) long. Ant nests consist of numerous crescent-shaped mounds on the surface and extensive underground passageways and chambers. The mounds may be restricted to a small area or extend over an acre or more. Foraging trails cleared of vegetation are often present around the central town area.

Identifying the Injury. — Leafcutting ants will attack hundreds of plant species. They damage all species of southern yellow pine by removing the needles, buds, and bark of seedlings during the winter and early spring when other green vegetation is unavailable. This is when large acreages of pine regeneration can be killed around leafcutting ant colonies. Once the seedlings have reached the height of 2 to 3 feet, they are rarely killed by leafcutting ants.

Biology. — The ants have a mating flight in May or June. After mating, the females establish nests beneath the soil and become the queens of the colonies. Worker ants carry the cut foliage and other vegetative material back to the nest, where it is used to culture the fungus that is their primary food.

Control. — There are few natural enemies. Control can be attained by fumigating the nest.

Adult worker.

Photo: Scott Cameron, Texas Forest Service

VIRGINIA PINE SAWFLY,
Neodiprion pratti pratti (Dyar)

Importance. — Heavy defoliation by the Virginia pine sawfly for two or more years can weaken trees and make them more susceptible to other insects and diseases, particularly when associated with drought. In commercial shortleaf pine stands, the growth loss caused by two successive years of 50 percent defoliation can amount to one-third of the expected increment over a 4-year period. This sawfly is found from New Jersey to North Carolina. The insect prefers Virginia and shortleaf pines, but will occasionally feed on pitch and loblolly pines.

Identifying the Insect. — Larvae are pale green, with black head capsules, and about 1/10 inch (3 mm) long when newly hatched. Full-grown larvae are spotted or marked with longitudinal black stripes and are from 6/10 to 9/10 inch (16 to 23 mm) long. The adults have four membranous wings.

Identifying the Injury. — Young larvae feed gregariously on the previous year's foliage. They consume the outer portion of the needle, causing the remaining part to take on a strawlike appearance, which is characteristic of early sawfly feeding. Mature larvae consume the entire needle and may feed on the buds and tender bark.

Biology. — Adults emerge from cocoons in late October and early November. After mating, the female cuts a slit at the edge of the needle and inserts a small, white, oval egg. Several eggs are usually laid at evenly spaced intervals in each needle. Each female lays from 30 to 100 eggs. The eggs overwinter and hatch the following April. Around mid-May, the full-grown larvae drop to the ground and spin cocoons in the litter or surface soil. They pupate in late September. There is one generation per year.

Control. — Natural enemies, including a polyhedrosis virus, and adverse weather conditions seem primarily responsible for the drastic fluctuations in sawfly populations. Chemical insecticides can be used to control the sawfly.

Larvae.

Feeding damage on terminal.

AMBROSIA BEETLES, *Platypus* spp.

Importance.—Ambrosia beetles of the genus *Platypus* attack most species of pine and hardwood trees. They severely infest weakened and dying trees, green logs, and unseasoned lumber. Trees cut during the summer and left unmilled for more than 2 weeks are often severely damaged. This is especially true of gum, cypress, and oak trees. Ambrosia beetle attacks to green sawlogs and lumber may result in considerable degrade and strength reduction.

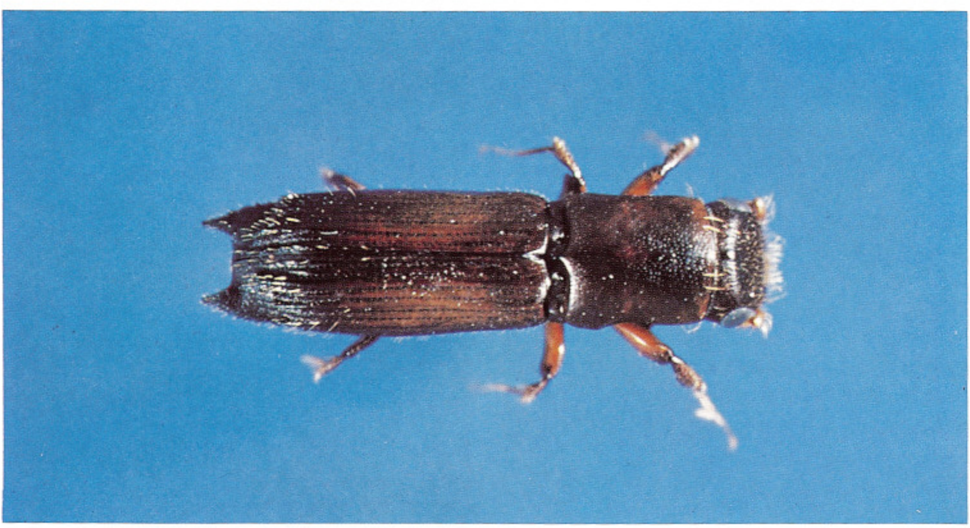
Identifying the Insect.—The adult beetles are elongate, dark reddish brown, about ¼ inch (6 mm) long, and usually have sharp spines at the rear.

Identifying the Injury.—In southern pines, large piles of a fine white granular dust accumulate below the entrance holes or at the base of standing trees. In lumber, the galleries are darkly stained.

Biology.—The adults and larvae do not feed on the wood but on a fungus the beetles carry into the tree and culture in the galleries. The adults bore into sapwood or heartwood of logs and lumber, making pin-sized holes which are stained by the fungus. The females lay eggs in small clusters in the tunnel, and the developing larvae excavate tiny cells extending from the tunnel parallel to the grain of wood. There may be several generations a year. Timber is not attacked unless the moisture content of wood is at least 48 percent. Seasoned lumber is never infested.

Control.—No chemical controls are recommended under forest conditions. Rapid utilization of cut timber and fast drying of lumber will prevent damage. Winter harvesting and water storage are also effective.

Boring dust at base of tree.



Adult

BLACK TURPENTINE BEETLE, *Dendroctonus terebrans* (Olivier)

Importance.—The black turpentine beetle is found from New Hampshire south to Florida and from West Virginia to east Texas. Attacks have been observed on all pines native to the South. This beetle is most serious in pine naval stores, pines stressed for lightwood production, and damaged pines in urban areas.

Identifying the Insect.—The adult insect is dark brown to black in color and ⅜ inch (10 mm) in length. The posterior end is rounded. Full grown larvae are white with a reddish brown head and about 1/3 inch (8 mm) long. Pupae are about ¼ inch (6 mm) in length and yellowish white.

Identifying the Injury.—Black turpentine beetles attack fresh stumps and the lower trunk of living pines. Initial attacks are generally within 2 feet (60 mm) of the ground. Attacks are identified by white to reddish-brown pitch tubes about the size of a half dollar. The pitch tubes are located in bark crevices on the lower tree bole, usually below a height of 10 feet (3 m). Infested pines are often attacked by other bark beetles.

Biology.—Adult beetles bore into the cambium and construct galleries which usually extend downward. Eggs are laid in clusters and hatch in 10 to 14 days. Larvae feed side by side, excavating a large continuous area. The life cycle takes from 2½ to 4 months, depending on the season. There are two to four generations a year.

Control.—Natural enemies and good tree vigor generally keep black turpentine beetle populations at low levels. Newly attacked trees can often be saved by spraying the base to the highest pitch tube on the trunk with an approved insecticide. Preventive sprays are also effective for high value trees. The prompt removal of infested trees also helps to control outbreaks. Forest management practices which promote tree vigor and minimize root and trunk damage help prevent infestations.

Large pitch tube.

Larvae feeding and excavation - note frass.

IPS ENGRAVER BEETLES,

Ips avulsus (Eichhoff), *grandicollis* (Eichhoff), and *calligraphus* (Germar)

Importance.—*Ips* engraver beetles kill more pine timber in the South than any other forest insect, with the exception of the southern pine beetle. *Ips* beetles usually attack injured, dying, or recently felled trees and fresh logging debris. Infestations are particuarly common in trees weakened by drought or lightning strikes.

Identifying the Insect.—Adult beetles are dark red-brown to almost black and ⅛ inch to ¹/₅ inch (3 to 5 mm) long. They are distinguished from other bark beetles by their scooped-out posterior with 4 to 6 spines on each side. Larvae have white bodies with orange-brown heads and are legless. Pupae are waxy-white and similar to adults in size.

Identifying the Injury.—The first signs of attack are reddish-brown boring dust in bark crevices or reddish-brown pitch tubes about the size of a dime on bark surfaces. If the bark is removed, there are Y- or H-shaped egg galleries with short larval galleries extending perpendicular to them. Egg galleries will usually be free of boring dust. The foliage of *Ips*-killed pines will eventually turn yellow, and then red about the time the beetles complete development under the bark. Often only the top portion of the crown is killed, leaving lower branches green. Blue-stain fungi, introduced when the beetles attack the tree, is visible in the sapwood and hasten the death of the trees.

Biology.—The female constructs an egg gallery and lays her eggs beneath the bark of attacked trees. The larvae make individual feeding galleries in the inner bark and pupate at the end of their galleries. New adults emerge after 21 to 40 days during the summer or after several months during the winter.

Control.—The best control is prompt removal and utilization of actively infested trees, making sure that the bark and slabs are destroyed. Insect parasites and predators, woodpeckers, and weather provide natural controls. Chemical control is seldom warranted under forest conditions, but may be used to protect pines in urban or high value areas. Preventive control practices include minimizing logging damage to residual stands and quick removal of felled trees.

Vertical egg galleries.

Ips adult.

SOUTHERN PINE BEETLE, *Dendroctonus frontalis* Zimmermann

Importance.—The southern pine beetle is one of the most destructive pests of pines in the southern United States, Mexico, and Central America. This insect killed approximately 4.5 million board feet of pine timber from 1973 through 1977 in the southern United States. The beetle occurs from Pennsylvania to Texas and from New Mexico and Arizona to Honduras. It attacks and can kill all species of pines, but prefers loblolly, shortleaf, Virginia, pond, and pitch pines.

Identifying the Insect.—The adult is shortlegged, about ⅛-inch (3 mm) long, and dark reddish brown to black in color. The front of its head is notched, and the hind end of its body is rounded. The larva is crescent-shaped and whitish, with an amber head. When fully developed, larvae are approximately the same length as adults. The pupae are also the same size and white. The eggs are pearly-white and found in notches along either side of the adult egg galleries.

Identifying the Injury.—The adults bore directly through the outer bark into the living bark. At each point of attack, the tree usually exudes resin which forms a small pitch tube about the size of a small piece of popped popcorn. Adult beetles construct winding, S-shaped galleries, which cut across one another and girdle the tree. Blue-stain fungi in the sapwood, introduced by the beetles, hasten the death of the tree. The first indication of tree mortality is discoloration of the foliage. Needles become yellowish, change to a red color, and finally turn brown. Trees may be killed singly or in groups, ranging from a few trees to several hundred acres.

Biology.—Adults construct winding galleries in the inner bark, where eggs are deposited in individual niches on each side of the galleries. The eggs hatch into small larvae within 4 to 9 days. The larvae mine for a short distance before boring into the outer bark where they pupate. One life cycle can be completed in about 30 days under ideal conditions. There are from three to seven generations per year, depending on latitude, elevation, and climate.

Control.—Natural enemies, such as diseases, parasites, predators and weather, help maintain beetle populations at low levels and bring cyclic outbreaks under control. Integrated pest management may be achieved through any one or all of the following suppression techniques: rapid salvage and utilization of infested trees, piling and burning of infested materials, chemical control in high value resources, and cut-and-leave (May through October). To select the most appropriate strategy, the user is referred to the Integrated Pest Management Decision Key (IPM-DK). Good forest management is the most effective method of preventing losses from the southern pine beetle.

Egg galleries with larvae in larval mines.

Pitch tubes.

SOUTHERN PINE SAWYER, *Monochamus titillator* (Fabricius)

Importance.—This sawyer occurs throughout the eastern and southern United States and is destructive to pine logs held in storage or pines killed by natural or man-made catastrophes.

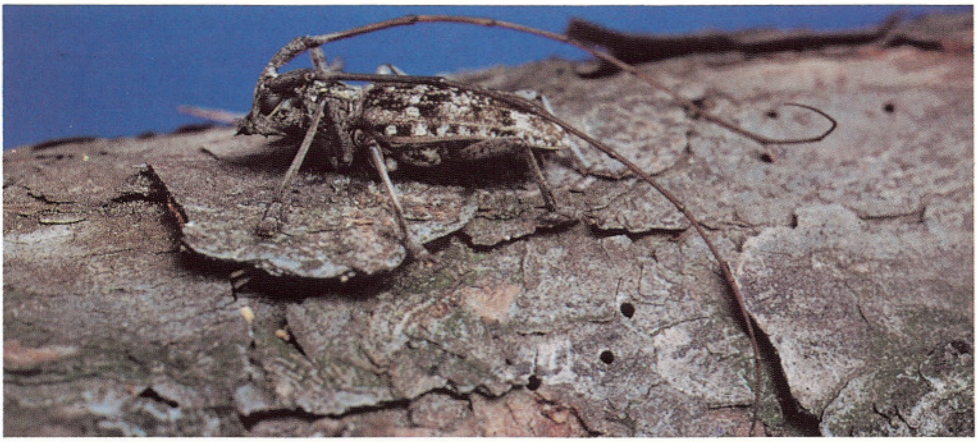
Identifying the Insect.—Adult beetles are mottled gray and brown from 1 to 1 ¼ inches (25 to 31 mm) in length and have antennae which are 2 to 3 inches (50 to 75 mm) long. Full-grown larvae are legless and whitish yellow in color and up to 2 2/5 inches (60 mm) long.

Identifying the Injury.—The first signs of attack are the funnel shaped pits or egg niches in the bark. Removal of bark from infested wood will reveal coarse, excelsior-like wood shavings, and sculptured wood. Elliptical shaped holes tightly packed with excelsior-like frass indicate that the larvae have bored into the sapwood to construct the pupal cell. Round, pencil-sized holes in the wood are exit holes.

Biology.—The adult beetle deposits one to several eggs in the cambium area through the egg niches. After hatching, the larvae feed on the surface of the cambium then bore into the sapwood and heartwood. After pupation is completed, the adult beetles chew through the wood, making the round exit holes. There are at least three generations per year in the southern United States.

Control.—Rapid utilization of dead and dying trees and green logs will reduce infestations and losses caused by this beetle. When large numbers of trees require storage, they may be sprayed with an insecticide or debarked. Logs stored in water may also prevent serious damage.

Larva in gallery with typical frass.



Adult.

DEODAR WEEVIL,
Pissodes nemorensis Germar

Importance.—Deodar weevil adults and larve can kill terminal and lateral branches, as well as girdle the stems of small trees. The weevil also vectors the pitch canker fungus, and its feeding wounds are infection courts for the pathogen. The weevil is found throughout the South and Mid Atlantic states. It attacks deodar and Atlas cedar, cedar of Lebanon, and various southern pines.

Identifying the Insect.—Adult weevils are rusty red to grayish brown, have long snouts, and are about ¼ inch (6 mm) long. The larvae are legless grubs, with a reddish-brown head. The life stages of the deodar weevil are similar in appearance to those of the white pine weevil. Where their geographic ranges overlap, identifiation of the pest is usually based on the host species and the portion of the tree infested.

Identifying the Injury.—During the fall, weevil larvae feed on the inner bark of leaders, lateral branches, and stems of small trees. Infestations usually remain unnoticed until the following January, when infested branches begin to turn brown. Small trees may be girdled and killed.

Biology.—Adults emerge during April and May, and feed briefly on the inner bark of nearby trees, sometimes girdling stems and twigs before dispersing for the summer. Adults feed occasionally during the summer. Feeding activity increases just prior to and during the fall reproduction period. Females lay from one to four eggs in feeding punctures. The newly hatched larvae bore into the inner bark, where they construct winding galleries which girdle the stem. Winter is spent in the larval stage. Pupation occurs in chip cocoons in the wood during March and April. There is one generation per year.

Control.—Keeping shade trees in a vigorous condition by proper watering and fertilization helps reduce their susceptibility to weevil attack. Insecticides can be used to protect high value trees.

Adult.

Pupation in chip cocoon.

NANTUCKET PINE TIP MOTH, *Rhyacionia frustrana* (Comstock)

Importance.—This bud and shoot borer occurs throughout the East and South. Most species of pines are attacked, except longleaf and eastern white pine. Greatest economic losses result from retarding the height growth and deforming the main stems of trees in plantations. In pine seed orchards this pest kills female flowers and conelets.

Identifying the Insect.—Young larvae are cream colored with black heads. Mature larvae are light brown to orange and about 2/5 inch (9 mm) long. The head, body, and appendages of the moth are covered with gray scales, while the forewings are covered with patches of brick-red and copper-colored scales.

Identifying the Injury.—Tip moths injure the growing shoots of young pines. Larvae bore into and feed on inner tissues of buds and shoots. Shoot injury occurs primarily during the first 5 years and decreases as crowns close. In seed orchards, boring frass, on the conelet surface and dead stalk, is the first indication of attack.

Biology.—This pest overwinters as a pupa, and adults emerge in late winter or early spring. Mating and egg laying occur shortly after emergence. Early larvae feed on needles and surfaces of new growth, while later larvae move to shoot tips and begin boring into buds or stem tissues. Pupation occurs within damaged shoots. There are 2 to 5 generations per year.

Control.—Control by insecticides is usually not recommended except for high value trees in seed orchards, nurseries, Christmas tree plantations, or for ornamentals.

Typical damage on shoot.

Adult moth.

Photo: R. Luck,
Univ. of California, Riverside, CA

PALES WEEVIL,
Hylobius pales (Herbst)
and
PITCH-EATING WEEVIL,
Pachylobius picivorus (Germar)

Importance.—In the South, reproduction weevils are the most serious insect threat to newly planted pines, particularly on recently cutover sites. The pitch-eating weevil is more common along the Gulf Coast. Feeding has been reported on most coniferous species, and all species of southern pines are susceptible to attack. Seedling mortality in plantations has been recorded as high as 90 percent, and 30 to 60 percent mortality is not uncommon.

Identifying the Insect.—Adult weevils are oblong, robust, black to reddish brown, and about ½ inch (12 mm) long. The wing covers have small, scattered patches of yellowish hairs. The pitch-eating weevil appears darker because the hairs on the wing covers are sparser and shorter.

Identifying the Injury.—Adult weevils feed on the tender bark of seedlings, twigs, or larger trees. Small, irregular feeding patches in the bark are characteristic of weevil damage. Heavy feeding may girdle the stem, causing wilting or death. Feeding below the root collar and on the roots is common.

Biology.—Adult weevils are attracted by the odor of fresh pine resin, and quickly invade recently logged areas. After mating, eggs are laid in lateral roots of fresh pine stumps. Eggs hatch in approximately 5 to 10 days. Larvae feed on the inner bark tissue of dead roots. Full-grown larvae construct a chip cocoon in the wood and pupate. The time spent in the pupal stage lasts from a few weeks to several months, depending on the temperature. Adult weevils are found year round, usually within flying distance of any pine cutting area. There may be two generations per year.

Control.—The insect can be controlled by delaying planting for one planting season in areas cut over after July, or by treating seedlings with a registered insecticide. Reducing the size of clear cuts prevents large populations of weevils from moving en-masse into new cutting areas.

Adult feeding.

WHITE PINE WEEVIL,
Pissodes strobi (Peck)

Importance.—The white pine weevil is the most serious insect pest of eastern white pine. Weevil larve kill the last two-year's terminal growth and repeated attacks cause trees to become stunted and deformed to the point of being commercially unusable. Trees up to 3 feet tall may be killed. The weevil also attacks Norway spruce and jack pine and, to a lesser extent, pitch pine, red pine, Scots pine, and red spruce. It is found throughout the range of eastern white pine.

Identifying the Insect.—Adult white pine weevils are brown beetles about ¼ inch (6 mm) long. They have a long snout with antennae attached. White and tan spots of various sizes cover the body. The most conspicuous spots are towards the back of the wingcovers. Full-grown larvae are legless grubs with reddish-brown heads. They are ½ inch (12 mm) long.

Identifying the Injury.—In the spring, resin droplets ooze from feeding punctures on the terminal shoot, especially near the terminal bud. The most conspicuous sign of current weevil damage is a drooping of the terminal shoot caused by larval feeding. In the South, this "shepherd's crook" is usually noticeable in early June and by August it turns reddish brown. The terminal shoot dies, and one or more branches in the uppermost live whorl will assume dominance. This gives the tree a forked, crooked, or bushy form.

Biology.—Adults overwinter in the litter beneath host trees and emerge in the spring to feed on the leaders of their hosts. Females deposit eggs in small punctures in the bark of the leaders. The young larvae bore downward, side by side, in a ring. After feeding for 5 to 6 weeks, the larvae construct pupal chambers in the wood or pith of the terminal shoot, and cover themselves with shredded wood and bark. New adults leave the tree by late summer and do some feeding before overwintering. There is one generation per year.

Control.—Control of the white pine weevil is difficult. It is possible, however, to reduce the damage by making conditions in a young stand unfavorable for egg laying. Pine grown under a canopy of hardwoods is relatively free of weevil damage but requires intensive management. Under certain circumstances, insecticides can be used to protect the tops of trees.

Typical damage to terminal.

BALSAM WOOLLY APHID, *Adelges piceae* (Ratzeburg)

Importance.—The balsam woolly aphid was introduced from Europe around the turn of the century. It has become an important pest of true firs and is established throughout the Fraser fir type in the southern Appalachians. It is a serious pest of natural Fraser fir and also causes considerable damage to the Fraser fir Christmas tree industry.

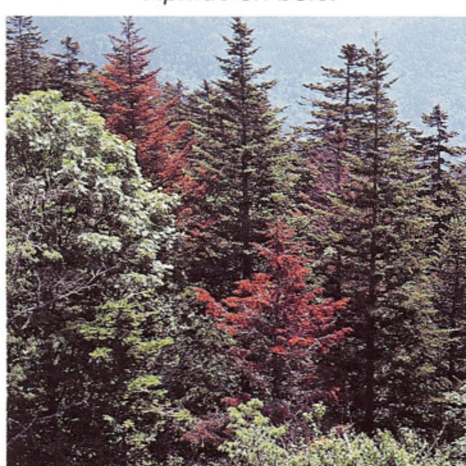
Identifying the Insect.—Adult aphids are blackish purple, roughly spherical in shape, less than $^1/_{32}$ inch (1mm) long, and almost invisible to the naked eye. The aphid produces a covering of white wax threads and appears as white, woolly dots about the size of pin heads on the surface of the tree's bole, limbs, and buds. Eggs are produced under the adults and are orange in color. The immature stage of the aphid, known as a "crawler," is also orange, with legs and black eyes. Eggs and crawlers can be identified with the aid of a hand lens.

Identifying the Injury.—During the aphid's feeding process, the host tree is stimulated to produce abnormal wood cells. This reduces the tree's ability to translocate food and water. Initial symptoms of aphid attack may include gouting of buds or twig nodes and some twig and branch dieback. This is very evident on seedlings, young understory trees, and Christmas tree plantings. Other damage may be stunted shoot and needle growth and loss of apical dominance in natural stands. A heavily infested tree may die within 2 to 7 years. As the tree dies, portions of the crown or the entire crown will turn red.

Biology.—The aphid has two generations per year, and occasionally three in the southern Appalachians. Eggs of the first generation hatch in late June and July, followed by a second generation in September and October. The "crawler" is the only mobile stage in the aphid's life cycle. When a crawler begins feeding, it transforms into a first instar nymph and becomes stationary. Reproduction is parthenogenic; each female lays up to 200 eggs. The aphid overwinters as a first instar nymph and continues its development in the spring when the host tree starts its annual growth cycle.

Control.—Chemical control is effective, but extremely costly. Thus it's usually limited to high value resources such as recreation areas, seed sources, and shade, ornamental, and Christmas tree plantings. Other control measures include removal and destruction of infested trees.

Aphids on bole.



Firs killed by the aphid.

DISEASES

ANTHRACNOSE,
caused by several fungi

Importance.—The greatest impact of anthracnose is in the urban environment. Reduction of property values, resulting from the decline or death of shade trees, is common. Various hosts are affected, including: sycamore, oak, ash, dogwood, and walnut.

Identifying the Fungi.—The fungi which cause anthracnose are different for each host. The fruiting bodies, which occur on twigs and leaves, are distinctive in color and shape. Samples of affected twig and leaf material should be sent to a specialist if this disease is suspected.

Identifying the Injury.—Injury usually includes irregular patches of dead leaf tissue (blotches), blackened bases of the leaf stem, cankering of the branch at the base of the leaf stem, and shoot dieback. Cankering is not commonly seen on walnut.

Biology.—Infection of oaks and sycamores begins with the leaves. The fungus grows through the veins, down the leaf stem, and into the branch. The fungus survives through the winter in branch canker tissue, and infection of emerging leaves occurs in subsequent years from spores produced on these cankers. The fungi also overwinter in diseased leaves in all hosts. Adverse impact of this disease is directly related to heavy rainfall, low temperature, and low host vigor.

Control.—No control is practical in the forest due to the cost. In high value trees, pruning, raking, and burning infected material, coupled with fertilization, improves appearance and may reduce subsequent infection.

Anthracnose on sycamore twigs.

Sycamore anthracnose.

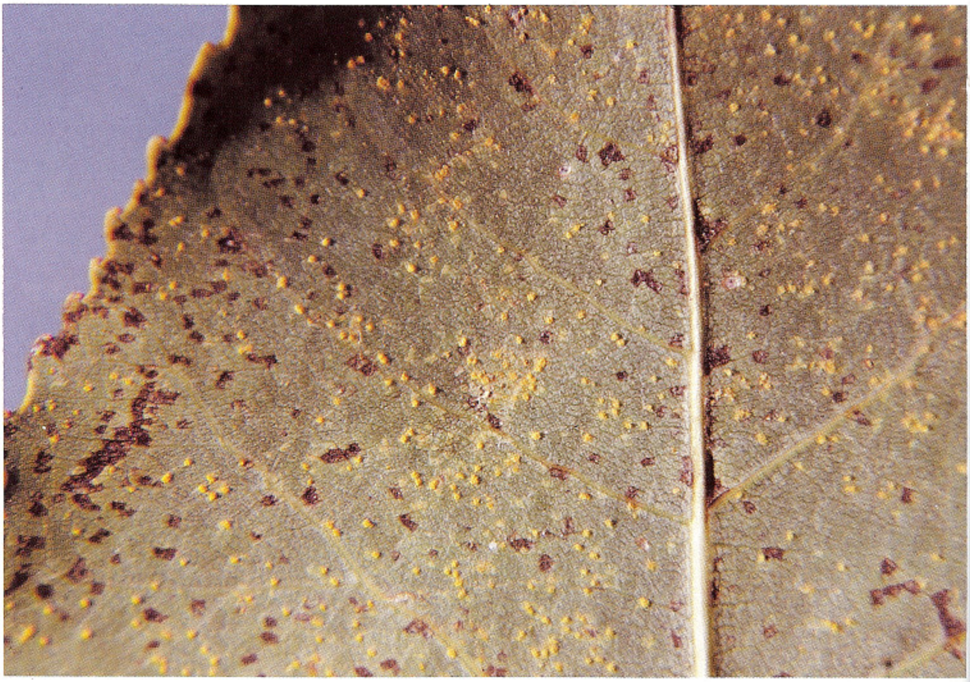
COTTONWOOD RUST,
caused by *Melampsora medusae*

Importance.—All sizes of cottonwood are affected, but cottonwood rust is particularly severe in plantations and nurseries. Heavy infection and subsequent defoliation may kill trees. The rust may also act as a predisposing agent to other diseases. Affected trees may be partially or completely defoliated.

Identifying the Fungus.—Yellow or orange pustules, containing spores, form on the under-surface of the leaves in midsummer. These are replaced by dark brown fungal growths in the fall.

Biology.—The orange pustules (uredia) are the summer reproductive state of the fungus. They are followed by dark brown pustules (telia) which develop in fall and winter. In the South, the alternate host (larch) is not present in the forest, and the fungal life cycle is reduced to the uredia-urediospore cycle only. Some families are immune to rust infection and disease-free trees or groups of trees often occur in the midst of other heavily infected trees.

Control.—Resistant varieties of cottonwood are used to minimize damage. Generally, no control is attempted in forest stands.



Rust infected cottonwood leaf.

BLACK KNOT,
caused by *Dibotryon morbosum*

Importance.—Black knot is an important disease of cherry, because it degrades this valuable veneer and lumber species. Except for southern Florida and southern Louisiana, this disease is found throughout the Southeast. Many species of cherry are affected, but black cherry is the only commercially important species. The disease is rarely fatal.

Identifying the Fungus.—Swellings on the branch of the host plant are covered with an irregular, rough, fruiting layer of fungal tissue. Spore bearing fruiting bodies form within this fruiting layer. The fruiting bodies and the spores are easily recognized by a specialist.

Identifying the Injury.—Black knot is a disease that causes irregular black swellings on black cherry stems, branches, and twigs. Often a white fungus is found growing over the swellings. Later, the swellings blacken and appear rough.

Biology.—Infection occurs during the spring, and swellings develop the following spring. These swellings are overgrown by a black irregular mass of fungal fruiting bodies.

Control.—Control is generally achieved by pruning out diseased tissue along with at least 12 inches (30 mm) of uninfected wood. In forest stands, trees with infections on their boles should be removed during improvement thinnings.

Black knot swellings on cherry.

HARDWOOD LEAF DISEASES OF MINOR IMPORTANCE

Disease Agent	Injury	Control
Powdery mildew, caused by *Microsphaera* spp., *Phyllactinia* spp. and others. These fungi overwinter on dead leaves. Spores are windblown to healthy leaves.	A white, powdery mold occurs on leaves and buds. Leaves may be distorted, stunted and fall prematurely.	2 3
Leaf blister, caused by *Taphrina* spp. This fungus overwinters on bud scales. When buds expand, infection of new leaves occurs. Spores produced on leaves are disseminated by wind.	Yellowish-green to purple blisters appear on leaves. Blistered leaves remain on the tree.	1 2 3
Leaf spots, caused by various fungi. Fungi overwinter in leaf tissue; spores are disseminated by wind and rain.	Small round to angular spots, variable in size and color appear on leaves. Defoliation may occur in extreme cases.	1 2 3
Nutrient deficiencies. These physiological conditions are soil related. Soil condition, such as pH, may make nutrients unavailable to plants, or the soil may be exhausted of some nutrients.	Leaf tissue turns yellow to brown; often this happens first along the veins. Some leaf fall may occur. Dieback may occur later if uncorrected.	4

Controls for Urban Trees

1. Rake and destroy fallen, infected leaves.
2. Maintain high vigor through cultural practices.
3. Control with chemical fungicide.
4. Control with appropriate fertilizer.

Pesticides

There are EPA registered chemicals for the control of these leaf diseases. Consult a specialist if the damage appears to be unusually severe and chemical control is needed.

Leaf blister on oak.

Leaf spots.

NECTRIA CANKER,
caused by *Nectria galligena* and *N. magnoliae*

Importance.—Nectria canker is the most common canker disease of hardwood trees. It seriously reduces the quantity and quality of forest products. This disease usually does not kill trees, but causes serious volume losses. It is common on yellow birch, black walnut, and sassafras. It also occurs on aspen, red oak, maple, beech, poplar, and birch.

Identifying the Fungus.—The fungus can be identified by the creamy-white fruiting structures that appear on cankers soon after infection. It can also be identified by the pinhead-sized, red, lemon-shaped perithecia near canker margins after 1 year.

Identifying the Injury.—Well-defined localized areas of bark, cambium, and underlying wood are killed by the fungus. Concentric, annual callus ridges develop around the expanding canker, and bark sloughs off the older parts of the canker. After several years, the canker resembles a target.

Biology.—The fungus survives through the winter in cankers, and produces spores during the spring. Windblown and water-splashed spores infect tree wounds and branch stubs.

Control.—Cankering may be minimized in high value areas by avoiding wounds and pruning out branch cankers. Sterilize pruning tools before moving to an uninfected tree and conduct pruning operations during dry periods when spores are less abundant.

Target-shaped nectria canker on walnut.

HYPOXYLON CANKER,
caused by *Hypoxylon* spp.

Importance.—Fungi in the genus *Hypoxylon* generally cause a white rot of hardwood slash. However, some species are known to cause severe cankering of stressed hardwoods. Cankering caused by this fungus contributes to the premature death of trees stressed by drought, construction damage, or other problems. Rapidly rotting tissue leads to structural weakening, which causes serious hazard to people or property in high-use areas.

Identifying the Fungus.—The fungus is usually visible as a definite fruiting layer that has dislodged the bark. Fruiting layers vary in color. Hundreds of small, black fruiting bodies are imbedded in this layer.

Identifying the Injury.—The fungus invades the tree's cambium, and the fruiting layer exerts sufficient pressure to dislodge the bark. Careful observation is sometimes needed to see the fruiting layer, since it can resemble the bark of some trees, such as hackberry.

Biology.—Weakened trees are most often attacked by *Hypoxylon* spp. The fungal spores enter wounds, germinate, and grow into the cambium, severely cankering and often girdling the tree very quickly. Concurrently, white rot of the sapwood under the canker begins. Fruiting structures eventually cover the cankered area and rupture the bark. Spores are produced at a rapid rate and are wind borne to new hosts.

Control.—Disease prevention can be achieved in high value trees by keeping the tree vigorous and unwounded. Fertilize high value trees and water them during drought periods. Once infection has occurred, remove infected limbs or trees, because they rapidly become hazardous to people and property.

Hypoxylon canker on oak.

STRUMELLA CANKER,
caused by *Strumella coryneoidea*

Importance.—Strumella canker is less common in the southern Appalachians than in the Northeast. Its most common hosts are members of the white oak group; however, beech, basswood, blackgum, and shagbark hickory are occasionally affected.

Identifying the Fungus.—The fungus produces dark brown, cushion-like structures, about $^1/_{20}$ to $^1/_{10}$ inches (1 to 3 mm) in diameter, on dead bark and surrounding tissue. *Urnula craterium* has been described as the perfect or sexual stage of the fungus causing strumella canker. The urnula fruiting body is cup-shaped and grows on infected branches and stems that have fallen to the ground.

Identifying the Injury.—Strumella cankers are of two types; diffuse and the more common target shape. Diffuse cankers develop on smooth-barked saplings and rapidly girdle and kill the trees. Target-shaped cankers are more common and are formed by the alternation of cambium killed by the fungus around the canker perimeter and then the formation of a callus ridge by the host. Cankers can reach several feet in length.

Biology.—As with many canker diseases, the fungus usually enters the tree through a branch stub. The remnants of this stub can be seen at the canker center. Frequently, diseased trees bear multiple cankers.

Control.—There is no control for this disease under forest conditions. However, cankered trees should be removed during sanitation or commercial thinning operations. Severely diseased trees in recreation areas should be removed for safety.

Oak killed by strumella canker.

CHESTNUT BLIGHT,
caused by *Endothia parasitica*

Importance.—The chestnut blight fungus has virtually eliminated the American chestnut, as a commercial species, from eastern hardwood forests. Although roots from trees cut or killed many years ago continue to produce sprouts that survive to the sapling stage before being killed, there is no indication that a cure for this disease will be found. The fungus is widespread and continues to survive as a nonlethal parasite on chinkapin, Spanish chestnut, and post oak.

Identifying the Fungus.—The fungus forms yellowish or orange fruiting bodies (pycnidia) about the size of a pin head on the older portion of cankers. Spores may exude from the pycnidia as orange, curled horns during moist weather.

Identifying the Injury.—Stem cankers are either swollen or sunken, and the sunken type may be grown over with bark. The bark covering swollen cankers is usually loose at the ends of the canker. Trees die back above the canker and may sprout below it. Frass and webs from secondary insects are common under loose bark.

Biology.—Host infection occurs when fresh wounds in the bark become infected with spores that are disseminated by wind, birds, rain, and insects. Cankers kill the cambium and girdle the stem. Multiple cankers on infected trees are common.

Control.—No effective control has been developed for chestnut blight, even after decades of intensive research. Current research is targeted toward finding a blight-resistant species and the further development of the hypovirulent strains of the fungus. These strains tend to inactivate the pathogen and promote healing, but only when applied directly to developing cankers.

Cracking, and fruiting bodies, on chestnut.

Basal cracking caused by chestnut blight fungus.

OAK WILT,
caused by *Ceratocystis fagacearum*

Importance.—Oak wilt is the most destructive disease of oaks in the upper Mississippi Valley. It also occurs throughout most of the South and can kill oaks rapidly, causing heavy losses. Red oaks are affected more frequently and severely than white oaks.

Identifying the Fungus.—The fungus can be identified in the field by the presence of fungal mats which form cushions under the bark of infected trees. However, these fungal mats are infrequently found in the South. Identification can also be made by observing laboratory isolates of the fungus.

Identifying the Injury.—Symptoms are bronzing or browning of green leaves from tips and margins downward toward the leaf base, premature defoliation, and eventually death of the tree. The red oaks develop symptoms over the entire crown shortly after infection, but white oaks develop symptoms slowly, a few limbs at a time.

Biology.—The wilt fungus is favored by moderate temperatures. It spreads from infected to noninfected trees through root grafts. In addition, insects can carry spores of the fungus over long distances.

Control.—In the forest, kill infected trees with silvicides to reduce inoculum and prevent root graft transmission of the disease. In urban areas, sanitation by removing infected trees and trenching to eliminate root grafts will minimize the losses.

Oak wilt infected tree.

Oak wilt symptoms on live oak.

DUTCH ELM DISEASE,
caused by *Ceratocystis ulmi*

Importance.—Dutch elm disease primarily affects American and European species of elm, and is a major disease problem throughout most of the range of elm in the United States. The greatest economic loss results from death of high value urban trees.

Identifying the Fungus.—No fruiting bodies of this fungus are seen in the field. In the laboratory the fungus readily produces easily identified, spore bearing structures.

Identifying the Injury.—Symptoms of the disease include wilting, yellowing, and browning of the leaves, brown or purplish brown streaking of the wood under the bark, and crown dieback. Symptoms normally progress rapidly through the crown. Complete wilting often occurs within six weeks of infection.

Biology.—The fungus is transmitted to healthy trees in two ways: bark beetles transmit spores from diseased to healthy trees, or the fungus grows through root grafts between diseased and healthy trees. Generally, death of the infected tree is rapid. However, some asymptomatic trees have been found that had been infected for several growing seasons.

The specific manner in which the fungus kills trees is unknown. The vascular system of the infected tree is affected, reducing the conduction of water and nutrients.

Control.—The most available control is removing infected trees and promptly destroying the wood. If infected wood is to be used as firewood, it should first be debarked. Trenching to disrupt root grafts is recommended to protect healthy elm trees near diseased ones.

In urban situations, insecticide spraying of high value trees has been effective in keeping bark beetles from attacking susceptible trees. Space trees further apart to prevent root grafts or use mixed tree species in ornamental plantings.

Sterilize pruning equipment before use from one elm to the next to prevent spreading the fungus.

Yellow foliage caused by the Dutch elm disease fungus.

ELM PHLOEM NECROSIS,
caused by *Mycoplasma*

Importance.—This disease kills more elms than Dutch elm disease in many urban areas. It is prevalent in the eastern half of the nation. The disease is common on winged and American elms, but attacks all elms.

Identifying the Cause.—Mycoplasma, which are microscopic plants, cannot be field identified. Consult a specialist.

Identifying the Injury.—Symptoms appear initially on one branch or a small portion of the crown. Leaves wilt, become chlorotic, and their margins curl upwards. Defoliation follows, and the crown appears bushy. Defoliation and death can occur in a few weeks. Some of the brown, wilted leaves persist, separating these symptoms from Dutch elm disease.

This disease is identified by the butterscotch discoloration of the inner bark of the host tree. A wintergreen odor can sometimes be smelled after placing the affected bark in a vial or plastic bag.

Biology.—Leafhoppers that have previously fed on infected elms transmit the mycoplasma to healthy elms.

Control.—Removal of dying or dead trees will reduce the spread of this disease by reducing the source of the mycoplasma.

Butterscotch discoloration of inner bark.

MIMOSA WILT,
caused by *Fusarium oxysporium* var. *perniciosum*

Importance.—Mimosa wilt is the most devastating disease of mimosa. In many areas it has almost eliminated ornamental mimosas. The disease can be found from Maryland to Florida and west to Texas.

Identifying the Fungus.—Fruiting of the fungus is inconspicuous. Small pads of fungal tissue which bear spores are sometimes formed on dead twigs. Laboratory culturing and diagnosis are needed to identify the causal fungus.

Identifying the Injury.—Symptoms include chlorotic and wilting foliage. Discoloration of the outer ring of sapwood usually occurs, and trees may die within 6 weeks after becoming infected.

Biology.—The organism survives in soil and enters through the tree roots. While the specific mode of action of this fungus is not known, the effect is to disrupt the upward movement of nutrients and water.

Control.—Plant resistant varieties of mimosa.

Wilting, chlorotic foliage caused by the mimosa wilt fungus.

VERTICILLIUM WILT,
caused by *Verticillium albo-atrum*

Importance.—*Verticillium albo-atrum* causes wilt disease in trees growing in ornamental settings, but diseased trees can occasionally be found in forest stands. Maples (sugar, silver, red, Norway) are favored hosts, but elms and other species are also infected.

Identifying the Fungus.—Laboratory culturing and microscopic observations are necessary for accurate identification.

Identifying the Injury.—Sympton expression can be quite variable. The foliage may yellow before wilting, and this may involve only a few twigs or branches. Occasionally, the entire crown may suddenly wilt. Dieback of twigs and branches may occur. Elongated stem and branch cankers may develop. Sometimes, green or green-brown discoloration occurs in the outer sapwood of the affected branches or stems. This discolored tissue readily yields the fungus on culturing.

Biology.—This is a soil fungus that requires wounds in order to infect the host. Infection normally occurs through roots and is spread throughout the tree by spores transported through the vascular system. Branch or tree death results from the disruption of the water-conducting tissue.

Control.—Control is most successful when initiated early. Fertilization with nonnitrate fertilizers, accompanied by adequate but not excessive irrigation, is recommended. If the tree dies, replanting with less susceptible species may prevent future disease.

Sapwood discoloration in maple twig.

CANKER ROTS,
caused by
Polyporus hispidus, Poria spiculosa, Irpex mollis, and others

Importance.—Many hardwood trees are susceptible, but oaks and hickories are commonly infected. Degrade and decay of hardwood lumber are the most important losses.

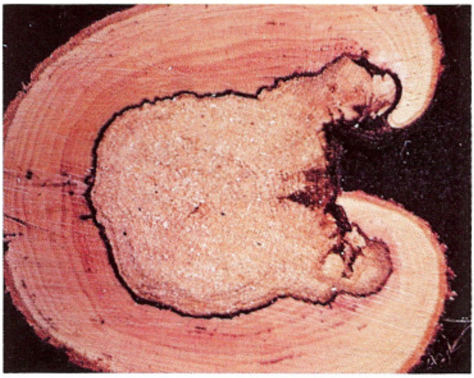
Identifying the Fungi.—Fungal fruiting bodies (conks) may be associated with the cankers and are variable. They can be toothed or pored; shelflike or flat, short-lived or persistent. *Poria spiculosa* produces sterile fungus material in the canker and only produces a fruiting body after tree death.

Identifying the Injury.—Cankers and associated localized decay vary in size, shape, and degree of callus formation. Dead branch stubs usually are located at the centers of the cankers.

Biology.—Airborne spores produced by the conks land on wounded areas and initiate new infections. An internal decay column can extend rapidly, sometimes by as much as 6 to 10 inches (15 to 25 cm) annually. It normally exceeds the external canker face in length. The fungus interrupts normal decay resistance processes and eventually kills the cambium. Callus tissue may be killed when the canker expands.

Control.—Removal of trees with cankered main stems provides more growing space to surrounding healthy trees and can also reduce conk and spore production. The pruning of declining branches may help prevent cankers in urban trees.

Polyporus hispidus conk growing above canker caused by the fungus.



Cross section of P. hispidus canker.

HEART ROTS,
caused by *Hericium erinaceus, Pleurotus sapidus, Polyporus fissilis,* and *Laetiporus sulphureus*

Importance.—Heart rot is the single most important disease of merchantable, hardwood timber in the South. Heart rot can affect all parts of the tree, but frequently occurs in the butt log, where its impact on the value of the tree is greatest.

Identifying the Fungi.—Many fungi are responsible for heart rot in hardwoods; however, four species cause about half the damage. These are *H. erinaceus, P. sapidus, P. fissilis,* and *L. sulphureus.* These and other fungi can be identified by the conks they produce.

Identifying the Injury.—Damage resulting from most heart rots can be easily observed. Most begins at basal injuries, like those caused by fire and logging damage. In addition, poorly healed and decayed branch stubs and other stem defects are strong indications of heart rot.

Biology.—Heart rots begin through wounds, if the wounds are sufficiently deep or large. Healing is slow and permits a succession of chemical changes, and bacterial and fungal colonization. If the succession is complete, decay will be initiated and will continue for many years.

Control.—Once the decay process begins, there is no control. Consequently, prevention through the reduction of wounds from all agents is crucial to controlling heart rot. Affected trees that have any merchantable volume should be salvaged, while those that do not should be felled or girdled.

Heart rot developing on oak sprouts.

Basal heart rot on oak.

LUCIDUS ROOT AND BUTT ROT, caused by *Ganoderma lucidus*

Importance.—This disease is one of the most common root and butt rots of southern hardwoods. It has a wide host range including oaks, maples, hackberry, ash, sweetgum, locust, elm, mimosa, and willows, and is found throughout the South. Host trees normally decline for a variable period of time and then die.

Identifying the Fungus.—Fruiting bodies (conks) are produced at the butt or on exposed roots of affected trees. They have a stem, the tops are reddish to buff-colored, and the white undersurface is porous. Conks are tough, woody, and persistent.

Identifying the Injury.—Affected trees usually show a rapid decline, evidenced by shortened twig growth, off-color foliage, dwarfed and sparce foliage, and branch dieback. The rotten roots are white and spongy, with black flecks or dark lines.

Biology.—This fungus invades trees stressed or wounded by a variety of agents, including fire, soil compaction, construction injury, vehicular damage, herbicide injury, and lawnmowers. Airborne spores contact the wounds and invade susceptible tissue, spreading up into the butt of the tree or down into the root system, or both. Colonization of healthy trees may also occur through root grafts or contacts with diseased roots.

Control.—Preventing basal wounds is the best method of avoiding damage by root and butt rots. Irrigation and fertilization can help promote rapid wound healing and minimizes exposure of susceptible tissue to decay organisms. Susceptible tree species, like mimosa and oak, should not be planted where serious damage has occurred in the past.

Fruiting body of lucidus root and butt rot.

SHOESTRING ROOT ROT,
caused by *Armillariellia mellea*

Importance.—This root rot fungus causes major losses throughout the United States. Windthrow of infected trees in urban and high-use areas creates safety hazards, contributing to the economic importance of this disease. Additional losses occur from reduced vigor in both conifer and hardwood species.

Identifying the Fungus.—In the fall, clumps of yellow mushrooms grow on the ground near the tree and occasionally on the bole several feet above the ground. *A. mellea* produces thin, black rhizomorphs that grow on the root surface. The rhizomorphs resemble black shoelaces.

Identifying the Injury.—Infected trees may have low vigor. Roots may show various degrees of decay, which generally becomes evident only on windthrown trees.

Biology.—The fungus can live in dead roots and stumps for many years. The fungus spreads through the soil via roots. Healthy roots that come in contact with infected ones can become infected. Mushrooms produce an abundance of spores, but they probably are not important in infecting living trees. The fungus is most pathogenic on slow-growing trees.

Control.—There is no practical control of the disease in forest stands. Spread can be reduced in urban environments by removing the infected trees, stumps, and large roots, and by sterilizing the soil before replanting. Any cultural practices that reduce stress and increase tree vigor will also reduce the potential for infection.

Decay caused by shoestring root rot fungus.

Shoestring root rot mushrooms.

NEEDLE CASTS,
caused by *Hypoderma* sp. and *Lophodermium* sp.

Importance.—Needle cast fungi are common diseases of conifers throughout the South. Infected trees in forest stands normally recover. However, losses to non-forest conifers, such as Christmas trees and nursery seedlings, can be substantial. Eastern white, loblolly, slash, shortleaf, Virginia, and Scotch pines, as well as spruce and firs, are susceptible.

Identifying the Fungus.—There are over 25 needle cast fungi known in the South. They can be identified only after examining the spores microscopically.

Identifying the Injury.—Depending on the identity of the infecting fungus, needles begin to turn yellow-brown by winter or early spring. Later, the browning progresses, and fungal fruiting bodies are produced. These small, black, fruiting bodies may be bordered by brown or yellow margins, or both. In the more advanced stages, the tree has a scorched appearance.

Biology.—Generally, new needles are infected in the spring or summer. The fungi colonize the needle tissue, turning it yellow and later brown. Fruiting bodies are formed in these brown areas, which produce spores that are spread during wet weather to reinfect new needles on other trees.

Control.—No controls are practical in forest stands. Fungicide sprays may be applied in Christmas tree plantings and nurseries.

Needle cast on slash and loblolly pine.

Needle spots caused by a needle cast fungus.

BROWN SPOT NEEDLE BLIGHT,
caused by *Scirrhia acicola*

Importance.—Longleaf pine is the only species in the South that is damaged by this disease. Seedlings are often heavily infected while in the grass stage and often die after repeated defoliations.

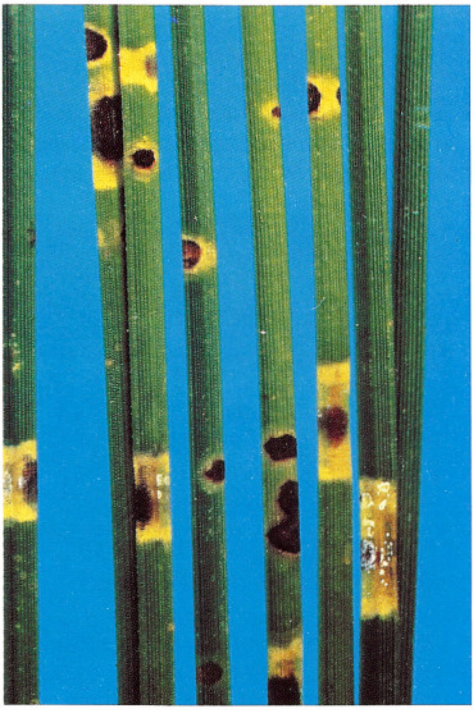
Identifying the Fungus.—Boat-shaped spores are produced in the yellow bands on the needles. Positive identification can be made by examining the spores under a microscope.

Identifying the Injury.—Infected needles develop grey-green spots, which later turn brown. Eventually, a yellow band develops on the needle. The affected area then increases in size, resulting in death of the needle.

Biology.—Spores are released from the fruiting bodies (acervuli) on the needles throughout the year. The spores are splashed short distances by rain drops. During the winter and early spring, perithecia are produced on dead needles. Spores from these perithecia are responsible for longer distance spread of the fungus.

Control.—Plant resistant or high-quality seedlings on intensively prepared sites. When seed trees are used, burn in the fall to destroy diseased needles. Where seedlings are established, burn during the dormant season. Remove seed trees when seedlings are 1 or 2 years old. Fungicide sprays are effective in controlling this disease in nurseries.

Brown spot needle blight on longleaf seedling.



Spots and discoloration caused by the fungus.

PINE NEEDLE RUST,
caused by *Coleosporium* sp.

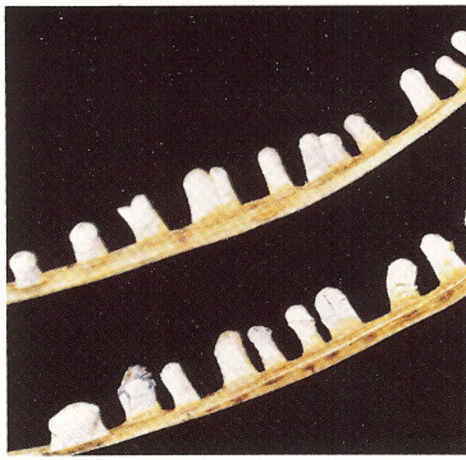
Importance.—Needle rust is most prevalent on young trees. The disease usually does not seriously damage trees, and is of most concern in Christmas tree plantings and nurseries. Most two- and three-needle pines throughout the South are susceptible. Goldenrod, asters, and other plants serve as the alternate hosts.

Identifying the Fungus.—The fungus has four stages. The aecial stage on the pine needles looks like small, white-orange "sacks." Aeciospores infect the alternate host, which results in orange, powdery spores on the leaves. Later orange, cushion-like objects, called telia, are produced on the underside of the leaf. The last stage (pycnial) looks like frosty, orange droplets on the pine needles.

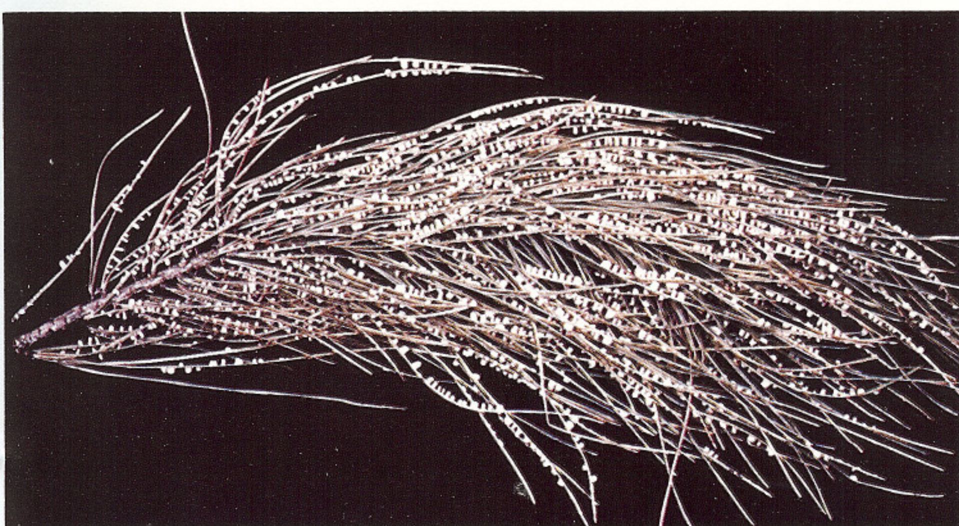
Identifying the Injury.—Infected pines often have white-orange blisters on the needles. Although these are actually fruiting structures of the fungus, they are an obvious feature of infection.

Biology.—Pycniospores form on pine needles in the spring; then orange, aecial blisters form. The spores from the aecial blisters infect the alternate hosts, which produces urediospores on the leaf. These spores reinfect the alternate host, but not the pine. Later, telia form on the leaves. These produce orange-yellow spores, which infect the pine.

Control.—No control is needed in forest stands. The alternate host can be reduced through mowing or the use of herbicides. This would only be justified around high-value areas, such as nurseries.



Fruiting bodies of pine needle rust.



Heavy pine needle rust infection.

CEDAR APPLE RUST,
caused by *Gymnosporangium juniperi-virginianae*

Importance.—The golfball-size galls that form on eastern redcedar (alternate host) are unsightly, but cause little harm to the tree. The primary hosts—apples—experience foliage loss, growth loss, reduced quantity and quality of fruit, and, in some cases, death.

Identifying the Fungus.—The fungus forms galls on the branches of eastern redcedar. In the spring, these galls produce long, orange tendrils or "horns." Leaf spots form on the apple host in the spring. These spots produce yellow spores on the lower surface of the leaf.

Identifying the Injury.—Brown, round galls form on the branches of redcedar, but they cause no injury. On apple leaves, yellow spots occur that later turn brown and result in cupping and curling of the leaf.

Biology.—The redcedar needles are infected in the summer by aeciospores from the apple host. The next spring, brown galls begin to appear on the needle. Later, larger brown galls, with small round depressions, form on the twigs. The next spring, orange, jellylike horns (telia) protrude from these galls. Spores, produced in these horns, infect the apple host, which results in leaf spots and the production of aeciospores.

Control.—Picking and disposing of the galls can improve the appearance of the redcedar. The stage on apple is generally controlled with fungicides. Reducing the number of eastern redcedars may reduce the occurrence of the disease on apple.

Fruiting on apple leaf.

Tendrils of cedar apple rust gall.

PHOMOPSIS BLIGHT,
caused by *Phomopsis juniperovora*

Importance.—Phomopsis blight is primarily a problem in nurseries, where entire crops can be lost. Although older trees are affected, the normal result of infection is only appearance. Eastern redcedar, Rocky Mountain cedar, arborvitae, cypress, and Atlantic white-cedar are hosts.

Identifying the Fungus.—The fungus forms small, black fruiting bodies on the needles and stems. These bodies contain small, oval spores.

Identifying the Injury.—Tips of branches are killed and turn brown. Formation of small, black fruiting bodies at the point between living and dead tissue is common.

Biology.—Young needles are infected by airborne and water-splashed spores. The fungus grows into the stem and causes death of the shoot. Fruiting bodies are then formed, which produce spores that infect other plants.

Control.—No economical control is available for forest trees. For nursery seedlings, fungicides are the primary means of control. Removing infected nursery stock, avoiding the movement of infected seedlings, moving the location of the beds, reducing the number of seedlings per square foot, and not using cedar mulch around the beds should also help.

Phomopsis blight on eastern red cedar.

Phomopsis blight.

FUSIFORM RUST,
caused by
Cronartium quercuum f. sp. *fusiforme*

Importance.—Fusiform rust infections that occur on the main stem within the first 5 years of a tree's life normally cause tree death. Infections that occur later in the life cycle of the tree weaken the stem, resulting in wind breakage at the canker or quality loss at rotation. Losses in individual nurseries can exceed 80 percent. Loblolly and slash pine are the most susceptible species. Longleaf is fairly resistant, while shortleaf pine is highly resistant. Oak is the alternate host.

Identifying the Fungus.—The fungus produces orange spores on the surface of fusiform-shaped pine galls in the spring. Orange spores are produced on the lower surface of the oak leaves. Later, hairlike structures are also produced on the leaf.

Identifying the Injury.—Spindle-shaped swellings or galls develop on the branches or main stem. Main stem infections on older trees are somewhat depressed on one side. Trees commonly break at the canker. In the spring, the galls turn orange. Infection on the oak host produces orange leaf spots and hairlike telia, which can cause cupping and curling of the leaf.

Biology.—Orange-yellow blisters form on the pine gall: the blisters produce aeciospores. In late spring, uredia are formed on the underside of young oak leaves. During late spring or early summer, brown, hairlike structures (telia) form on the oak leaves. Spores produced on the telia infect the pine.

Control.—The control strategies for fusiform rust are complex for forest stands and nurseries, and are too numerous to discuss here. The user is referred to the Integrated Pest Management Decision Key (IPM-DK) for more information. Discuss this with a State or Federal forest pest management specialist.

Fusiform rust fruiting on loblolly pine.

Fusiform rust damage to main stem.

COMANDRA BLISTER RUST,
caused by *Cronartium comandrae*

Importance.—Comandra blister rust occurs in northern Arkansas, eastern Tennessee, and northern Alabama. Losses are low, but can exceed 40 percent in individual stands. The primary hosts are loblolly, shortleaf, pond, and Virginia pines. False toadflax (comandra), the alternate host, suffers minimal damage.

Identifying the Fungus.—The fungus produces orange spores on the surface of the pine galls in the spring. A different orange spore type is produced on the lower surface of the toadflax leaf. Later, hairlike structures are formed on the leaf.

Identifying the Injury.—Spindle-shaped galls form on the main stem or branches of the pine host. Portions of the tree beyond the galls normally die. In the spring, the galls turn orange. In the summer, orange leaf spots develop on the toadflax. The leaves later cup, curl, and turn brown.

Biology.—The fungus infects pine through the young needles and grows into the stem, where a gall is formed. Orange spores (aeciospores) are produced on the gall in the spring and infect the leaves or stems of comandra. Uredia are produced on the lower surface of the leaf. Urediospores, from the uredia, are windblown and infect toadflax plants. Later, hairlike structures (telia) are produced on the toadflax leaves and stems. The telia produce basidiospores, which infect the pine.

Control.—Forest management practices which reduce the alternate host—toadflax—may reduce the occurrence of pine galls.

Comandra blister rust fruiting on pine.

EASTERN GALL RUST,
caused by
Cronartium quercuum f.sp. *quercuum*

Importance.—This disease normally causes little or no damage in forest stands. It can, however, cause serious damage in nurseries where seedlings become infected and die. Losses also occur when infected, outplanted stock dies. The alternate host—oak—is not seriously damaged. A variety of pines are primary hosts, but Virginia, sand, and shortleaf pines are the most susceptible.

Identifying the Fungus.—The fungus produces orange spores on the surface of the round pine galls. Orange spores are produced on the lower surface of the oak leaves. Later, hairlike structures are produced on the oak leaves.

Identifying the Injury.—Round galls form on the main stem or branches. Portions of the tree beyond the galls normally die. In the spring, the galls on pines turn orange. In the summer, orange leaf spots develop on the oak host.

Biology.—Infection in the pines occurs through young needles. The fungus grows into the stem, where a gall is formed. Orange spores (aeciospores) are produced on the gall in the spring and infect oak leaves. Uredia are produced on the lower surface of the oak leaf. Urediospores, from the uredia, are windblown and infect the same or other oak plants. Later, hairlike structures (telia) are produced on the oak leaves. The telia produce basidiospores, which infect the pines.

Control.—Fungicides are used to control the disease in forest tree nurseries. The best control in forest stands is the removal of infected trees during thinning operations. Practices that reduce the oak population may reduce the occurrence of the disease on pine.

Eastern gall rust fruiting on pine.

SOUTHERN CONE RUST,
caused by *Cronartium strobilinum*

Importance.—This fungus seriously affects slash and longleaf pine cone crops in Georgia and along the Gulf Coast from Florida to Texas. Damage to oak, the alternate host, is minimal.

Identifying the Fungus.—The fungus requires two hosts. Orange spores are produced in blisters in the first-year conelets. These blisters burst, causing the cones to appear yellow-orange. Orange leaf spots are produced on the oak. Later, hairlike structures are produced on the oak leaf.

Identifying the Injury.—Infected first year conelets enlarge and swell 3 to 4 times their normal size. The swollen conelet scales are reddish in color. Later, the conelet appears orange in color. Infection on the oak host produces orange leaf spots and hairlike telia, which can cause cupping and curling of the leaf.

Biology.—Teliospores, which are produced on the oak host, infect the mature female pine flowers about the time of pollination. By May, the conelets are 3 to 4 times their normal size. Spores (aeciospores) are produced in blisters in the conelets. These spores are windblown to the oak host, where uredia are produced. The uredia produce spores (urediospores) which reinfect the oak host. Later, hairlike structures (telia) are produced on the leaves. These telia produce basidiospores, which then infect pine.

Control.—Applications of fungicides in seed orchards have been successful in fighting the disease.

Enlarged cone infected with southern cone rust.

PITCH CANKER,
caused by *Fusarium moniliforme* var. *subglutinans*

Importance.—Pitch canker can damage many pine species, including all of the commercially important southern pines. In forest stands, only plantations of slash, and occasionally loblolly pine, are seriously affected. While mortality can result from abundant cankering, losses from growth suppression are more common.

Identifying the Fungus.—Pinkish fruiting bodies (sporodochia) containing fungus spores are produced on cankered shoots in the needle scars and on the outer surface of bark. Microscopic features of the spore-bearing structures aid in identification.

Identifying the Injury.—Infected trees exhibit shoot dieback of the current year's growth, and abundant resin flow from the affected area. The wood beneath cankers is resin-soaked. The main terminal and upper laterals are most often affected.

Biology.—Fungus spores are airborne and spread in the summer during windy, wet periods. The spores infect wounds. The deodar weevil, which breeds in dying trees and feeds on the phloem of young branches, can transmit the disease. Spores are abundant in the litter beneath diseased stands, and fruiting bodies persist for months on diseased shoots.

Control.—No specific control procedures are available for pitch canker. Forest practices which maintain stand vigor—for example, thinning—may minimize disease hazard. Salvage harvesting of heavily diseased stands is recommended. Genetic resistance to the disease exists and should be included in future pest management strategies.

Shoot dieback caused by pitch canker fungus.

Resin soaked branch.

RED HEART,
caused by *Fomes pini*

Importance.—Red heart is of greatest significance in mature and overmature pines of all species. Infected trees suffer a loss of merchantable volume, in addition to being structurally unsound. The trees are valued, however, as woodpecker nesting sites.

Identifying the Fungus.—The fungus produces perennial conks, which are frequently hoof-shaped. Those that are not, lie flat against the stem, projecting a light brown surface outward. Hoof-shaped conks have a dull gray to dark brown upper surface, with concentric furrows parallel to the margin. The underside is light brown to brownish-gold, and velvety in texture.

Identifying the Injury.—Infected heartwood is often light red to reddish-brown. The advanced stages of heart rot appear as elongated white pockets or flecks parallel to the grain and separated by apparently firm wood. Affected trees exhibit swollen knots.

Biology.—Infection normally occurs through dead branch stubs. Infected trees can survive indefinitely, but can be structurally unsound. This is of particular importance in recreation areas, where large old-growth pines are common.

Control.—Control is limited to harvesting mature and overmature pines where woodpecker habitat is not a consideration. In areas of intense public use, trees of high aesthetic value can be somewhat protected by correctly pruning dead and dying branches on the main stem to minimize infection.

Red heart conk.

Advanced heart rot caused by red heart fungus.

ANNOSUS ROOT AND BUTT ROT, caused by *Heterobasidion annosum*

Importance.—Annosus root and butt rot is a commercially important disease of conifers. All southern pines are susceptible, but loblolly and slash pine are most severely affected.

Identifying the Fungus.—Conks are often present in the litter at the base of dead or dying trees or tree stumps, or under root masses of windthrown trees. Conks, when fresh, are tan to brownish on the upper surface and white with tiny pores on the lower surface. They are rubbery and tough to tear. In the southern United States, conks are most common from December through March.

Identifying the Injury.—Damage from annosus root and butt rot may be scattered throughout a stand or in pockets of dead and dying pine trees called "infection centers." Mortality is sometimes preceeded by thinning and yellowing of the crown; however, some trees simply turn red and die. Trees in various stages of dying or death may suffer windthrow. Infected roots exhibit resin or pitch-soaking, and stringy root decay.

Biology.—Annosus root and butt rot probably enters the stand when fungal spores land on fresh cut stump surfaces. The fungus grows through the remaining root system into nearby live trees via root grafts or contacts. Mortality usually begins 2 to 3 years after thinning and often ceases 5 to 7 years later. Damage increases with the sand content of the soil. Twelve inches (30 mm) or more of sand or sandy loam above a clay subsoil in a soil with good internal drainage is considered a high hazard site for tree mortality.

Control.—Prevention and control strategies for annosus root rot include stump treatment, timing of thinnings, prescribed burns, and the manipulation of planting density. To select the most appropriate strategy, the user is referred to the Integrated Pest Management Decision Key (IPM-DK).Discuss this with a State or Federal pest management specialist.

Annosus root and butt rot conks.

Resin soaked root.

Annosus root and butt rot infection center.

BROWN CUBICAL ROT,
caused by *Polyporus schweinitzii*

Importance.—This disease can affect all southern pines and is most prevalent in trees that have suffered basal wounds from fire, logging, soil compaction, or root injury. Diseased trees are subject to windthrow and breakage.

Identifying the Fungus.—The fungus produces annual conks which develop in late summer and fall, particularly during moist weather. When conks are produced on the base of trees, they are bracket-shaped, while those arising from infected roots are supported by a stalk and are circular with sunken centers. The upper surface is reddish-brown with a light yellow margin and has a velvety texture. The underside is dark olive or green, with large irregular pores.

Identifying the Injury.—The fungus develops primarily in the roots and butt and seldom extends more than 15 or 20 feet up into the stem. The initial stage of decay appears as a light yellow stain. In the advanced stage, the heartwood becomes brittle and breaks into large yellow-brown to reddish-brown cubes.

Biology.—Overmature, suppressed and weakened, or off-site trees are commonly attacked. Spores of the fungus enter living hosts through damaged roots, fire scars, and other wounds near the tree base. The fungus may also spread from infected to healthy trees through root contacts and grafts.

Control.—In forest stands, no method of controlling the disease is known. Losses may be reduced by minimizing stand entries and basal fire injuries. To avoid human injury or property damage, trees with advanced root and butt rot should be removed from recreation sites, parking lots, trails, and buildings.

Brown cubical rot conk.

Brown cubical rot.

RED ROOT AND BUTT ROT,
caused by *Inonotus circinatus*

Importance.—*Inonotus circinatus* causes a root and butt rot of slash, sand, and shortleaf pines in the South. It is the fungus most often associated with diseased sand pines over 20 years old.

Identifying the Fungus.—The fungus produces fruiting bodies in the fall and winter on the bases of affected trees and from infected subsurface roots. Fruiting bodies are firm-textured and yellowish-brown, and can be bracket-shaped or have a well-defined stem. The lower surface of the fruiting body is composed of many pores.

Identifying the Injury.—Infected trees appear thin-crowned, with dwarfed, yellow needles. As the disease progresses, windthrow becomes common. Infected roots show a dark, reddish-brown stain. Resin often impregnates stained wood and exudes through the bark at the base of the tree. Roots with advanced decay have small, elliptical pockets filled with white mycelium.

Biology.—Red root and butt rot is a slow-acting disease, primarily of older pine stands. Trees may be infected by airborne spores that are deposited on basal wounds. Fusiform rust galls on slash pine seem particularly susceptible to infection. Once established in a tree's root system, the fungus can spread to healthy trees via root contacts. Diseased pieces of roots can persist in the soil for a number of years.

Control.—Direct controls for this disease are not available. Management techniques to minimize its impact are: sanitizing or completely salvaging affected portions of stands, including trees with basal rust galls; avoiding wounding trees during stand entries; lowering rotation age; and harvesting overmature stands.

Red root and butt rot conks.

LITTLELEAF DISEASE,
caused by a complex of agents

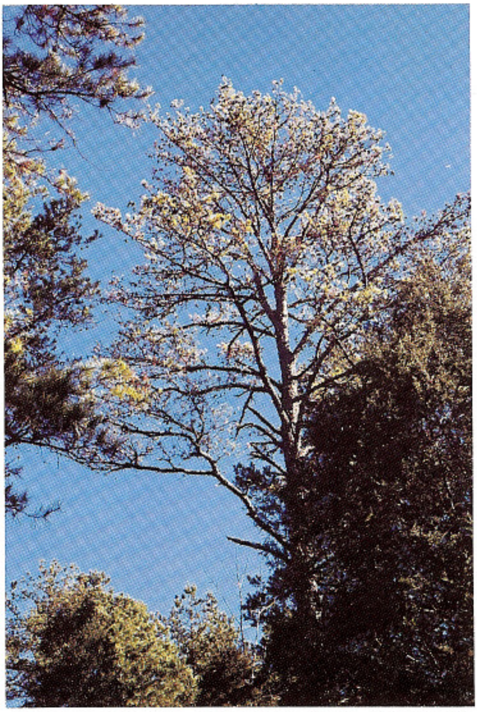
Importance.—Littleleaf disease is the most important disease affecting shortleaf pine in the South. Loblolly pine is also affected, but to a lesser degree. Affected trees often die within 6 years of first symptom expression.

Identifying the Causal Agents.—This disease is caused by a complex of factors which include *Phytophthora cinnamomi*, heavy clay soil, and soil that is low in nitrogen. Also, *Pythium* spp. and nematodes often contribute to the damage. While the soil can be evaluated on site, laboratory analysis is required for confirmation of the fungi, nematodes, and nitrogen deficiency.

Identifying the Injury.—While the damage is to the roots, the obvious symptoms are seen in the crown. The first symptom is needle yellowing. New needles are shorter and fewer in number. Eventually, the crown looks sparse and often has a tufted appearance. A heavy crop of small, very persistent cones normally develops 2 to 3 years prior to tree death. Often there is a flush of epicormic branches on the bole of the tree.

Biology.—This disease occurs on trees growing on low quality sites—such as old fields. For various reasons, including nitrogen depletion, poor aeration, and rootlet competition, the rate of new rootlet formation by the tree declines and the rate of loss resulting from the killing action of *P. cinnamomi* increases. On poor sites, infected trees showing early symptoms are expected to survive about 6 years. On better sites they may persist 15 to 20 years.

Control.—In the forest, losses can be minimized by salvage, favoring loblolly pine within its range, or, where silviculturally appropriate, converting to hardwood. In an urban or high value forest situation, a high nitrogen fertilizer can be used to delay mortality for as much as 6 to 12 years.



Shortleaf tree infected with littleleaf complex.

SAND PINE ROOT DISEASE,
caused by *Inonotus circinatus, Phytophthora cinnamomi, Phaeolus schweinitzii, Verticicladiella procera, Armillariella tabescens, Heterobasidion annosum*

Importance.—Sand pines are affected by a complex of root disease fungi acting alone or in various combinations. Trees of all ages and in all types of growing situations may be damaged or killed. Losses are especially severe in stands over 20 years old.

Identifying the Fungi.—Most of the fungi involved are discussed elsewhere in this guide. In the spring, *Armillariella tabescens* produces clusters of gilled, cream-colored mushrooms near the base of diseased, older trees. Perforated mats of fungus material are formed between the bark and wood of killed roots. *Phytophthora cinnamomi* must be cultured for positive identification.

Identifying the Injury.—Young trees may die suddenly or slowly, as isolated individuals or in groups. Dwarfed, yellow needles and slowed, radial growth are symptoms in older trees that die slowly. Windthrow is common. Affected roots and stems are resin-soaked and often exude resin through the bark.

Biology.—Young plantations are infected by *P. cinnamomi,* while natural stands are not. As trees age, *V. procera* and the other root rot fungi become established in both natural stands and plantations, and infect through wounds or root contacts.

Control.—Planting should be done only on sandy soils, 6 or more feet deep. Planted seedlings should be disease-free. Avoid root and butt injuries during stand entries. Stand rotations should be shortened to between 25 and 30 years.

Pitch flow through bark.

Resin soaking in main stem.

Damage of sand pine root disease.

WHITE PINE ROOT DISEASE,
caused by *Verticicladiella procera*

Importance.—Until recently, white pine root disease was of greatest importance in Christmas tree plantations and newly established forest plantations. However, the fungus is now associated with dying, mature eastern white pines in natural stands in the southern Appalachians. Infection centers of up to a dozen trees have been found in mature sawtimber stands.

Identifying the Fungus.—There are no fruiting bodies associated with this fungus that can be seen with the unaided eye. However, the fungus can be readily identified when grown in pure cultures and observed under the microscope.

Identifying the Injury.—Affected, mature white pines may die from the top down, one whorl at a time. Older and younger trees alike may also turn yellow and lose some needles before turning brown uniformly. Some trees may die within a year after symptoms appear. Others may linger for several years, with mortality occurring apparently at random, and 1 to 3 percent of the affected trees dying annually. A chocolate-brown to dark olive-brown canker may occur under the bark around the root collar. However, cankers are not always present, and tree death may result from the killing of numerous small roots $^{3}/_{16}$ inch (5mm) in diameter and smaller.

Biology.—In Christmas tree and forest plantations, wet sites appear to favor the disease.

Control.—Avoid planting eastern white pine on wet areas. In young plantations, particularly Christmas tree plantations, either avoid replanting in areas of known infection or remove as much of the infected root systems as possible.

Basal canker caused by white pine root disease fungus.

URBAN TREE DECLINE

Importance.—Among the problems leading to urban tree decline are: air pollution, soil compaction, mower- and machine-caused injuries, poor pruning, heat reflected from streets and buildings, direct root damage from excavations and turf cultivation, paving, improperly applied herbicides, potting above and below ground level, overplanting, and lack of understanding about tree growth and development. For these and other reasons, urban trees generally suffer a diseased existence and must be frequently replaced. Those that survive are often aesthetically unpleasing.

Identifying the Cause.—In addition to the above, a variety of fungi can attack trees that have been weakened. Most are heart, butt, and root rotting fungi that can affect trees structurally, making them unsafe. Others attack the roots, causing the tops to die back. Only rarely will all the causal agents in urban decline be identified.

Identifying the Injury.—Identifying the injury is usually easy. Affected trees show a dieback of the crown, beginning with the uppermost and outermost branches first. In the final stages, the trees may have only a few green sprouts and leaves attached to the main stem.

Biology.—Tree crowns most frequently begin to die back when the roots have been damaged or are diseased. This is due to the fact that plants grow with a carefully balanced root/shoot ratio. When a portion of the roots ceases to function, a portion of the crown dies as well. Often, disease fungi enter the weakened portion of the tree and further damage it.

Control.—Protect, fertilize, and irrigate trees that are declining. Plant trees that are resistant to air pollution injury and drought, and provide trees with adequate root space and aeration. Remove dying trees to avoid danger to people and property.

Maple declining from paving - and possibly other factors.

Elm declining from construction and compaction.

AIR POLLUTION

Importance.—Chemical discharges into the atmosphere have increased dramatically during this century, but the total effect on forest tree crops is virtually unknown. It has been demonstrated that air pollutants can cause mortality and losses in growth of forest trees. Nearly all species of deciduous and coniferous trees are sensitive to some pollutants.

Identifying the Cause.—There are many chemicals released into the atmosphere singly and as compounds. In addition, other compounds are synthesized in the atmosphere. Some chemicals can be identified through leaf tissue analysis, while others can be detected by analyzing the air itself. Identifying the single chemical or chemicals that are the cause of tree damage in a polluted environment can be extremely difficult and should be left to one trained in this field.

Identifying the Injury.—Generally, pollution injury first appears as leaf injury. Spots between the veins, leaf margin discoloration, and tip burns are common. These symptoms can also be influenced by host sensitivity, which is effected by genetic characteristics and environmental factors. Symptoms similar to those caused by air pollution, but resulting from nutritional deficiencies, drought, and other stresses, are often confused with pollution injury.

Air pollution damage to white pine.

Biology.—Many of the materials, such as sulfur dioxide, form acids inside leaves after they enter through the stomata. Others may enter the leaf tissue directly.

Control.—The best control is limiting atmospheric pollutants. Since this is difficult for the individual to do, the use of resistant plants is a practical alternative. Maintaining existing trees in a healthy condition will afford them some protection from air pollution damage.

HERBICIDE DAMAGE,
caused by various chemicals

Importance.—Drift and misapplication of herbicides can often damage nontarget trees. The total extent of such damage remains unknown, but localized, severe damage occurs. All tree species can be damaged by herbicides.

Identifying the Causal Agent.—Identification of the causal chemical is done primarily through symptom expression of the tree and determination of the method and rate of nearby herbicide applications. Symptom expression can be variable for a given chemical and is often unreliable when used as the only diagnostic tool.

Identifying the Injury.—Symptoms of herbicide injury are variable due to chemical mode of action, dosage, duration of exposure, tree species, and environmental conditions. Some herbicides cause growth abnormalities such as cupping or twisting of foliage while others cause foliage yellowing or browning, defoliation, or death. Environmental conditions such as temperature and humidity affect the degree of symptom expression by the host. Since symptom expression is so variable, professional help is desirable in diagnosing the problem.

Control.—Protect trees from unwanted or misapplied herbicides.

Chemical burn to nursery stock.

PINEWOOD NEMATODE,
Bursaphelenchus xylophilus

Importance.—The importance of the pinewood nematode as a forest disease agent in the United States is unknown. It may be native to our country. In Japan, where the nematode may have been introduced, as many as 20 percent of the trees in some stands have been killed. In this country, the disease has been found more often in shade trees. The disease occurs mostly on species of pine, particularly the nonnative species. It is rare on some other species of conifers.

Identifying the Parasite.—The pinewood nematode can be identified only through microscopic examination of a specimen.

Identifying the Injury.—Affected trees show symptoms of wilting, coupled with a significant reduction in resin flow. Wilted trees will turn from yellow to brown within 3 months after becoming infested.

Biology.—The nematode is carried from previously colonized dead pine by wood-boring beetles in the genus *Monochamus*. The young adult beetles feed on young tissues of healthy trees and, in the process, inoculate them with nematodes.

Control.—At the present time, no control for nematodes is known in the United States. In Japan, chemical control for the beetles is being tested.

Virginia pine infested with pinewood nematode.

SLIME FLUX, caused by Bacteria

Importance.—This disease results in persistent, bad-smelling, bleeding cankers on the stem or at the base of many species of hardwoods. Oaks are the most seriously affected species. Incidence is low, but severe quality loss occurs to the infected tree.

Identifying the Cause.—The prime wounding agents are insect borers, mechanical injuries, and natural cracks and splits which are rarely observed. Clear sap flowing from the wound becomes colonized with bacteria, darkens, and develops an unpleasant odor. The specific bacteria causing the dark color and odor are rarely identified.

Identifying the Injury.—Patches of wet bark having a sour smell are generally the first symptom of this disease. In additon, insects are attracted to the wet area. Often the bark in the area of the slime flux separates from the tree bole and gives a hollow sound when tapped.

Biology.—Wounding of hardwoods causes sap to flow from the injured area. Bacteria colonize the sap causing the typical odor. The bacteria-laden fluid is toxic to the bark and enlarges the wound with time.

Control.—In the forest, practices that minimize wounding will reduce the spread of this disease. For urban trees, maintaining vigorous, healthy growing conditions (through fertilization, watering, and mulching) and avoiding wounds will reduce the probability that trees will be affected by this disease. Removing bark from the affected area will reduce damage to an individual tree.

Damp discoloration of slime flux.

MISTLETOE, *Phoradendron* spp.

Importance.—Many species of hardwood trees are affected by mistletoe, but oaks and hickories are most commonly attacked. Mistletoe is used in Christmas greens and can be found throughout the South. The impact of infestation is not normally severe, but the parasite may lower individual branch vigor. Where infestations are severe, tree decline may progress to the point where insect and fungus pests combine to kill trees.

Identifying the Parasite.—Perennial, broad-leafed, evergreen plants appear in the tree crown. Identification is easier in winter, when the host tree's leaves are absent. The plant has opposite leaves and inconspicuous flowers that produce white to red berries in the fall.

Identifying the Injury.—The presence of the plant is the only reliable sign of an infestation.

Biology.—Seeds are animal- and bird-dispersed between and within tree crowns. A sticky substance on the seeds helps them adhere to susceptible young branches. Upon germination, a peglike root penetrates to the tree's vascular system, extracting water and needed nutrients.

Control.—Control is usually not necessary. If desired, tree branches may be pruned at least one foot back from the plant's attachment point, and then discarded.

Clusters of mistletoe.

Mistletoe plant.

PLANT PARASITES OF TREE ROOTS,

caused by members of the families *Olacaceae, Santalaceae, Scrophulariaceae, Orobanchaceae,* and *Krameriaceae*

Importance.—The impact of parasitic plants on stand and tree growth is not known in detail, except for a few species which attack young trees. Young slash pine in at least one Florida plantation have been killed by the root parasite senna seymeria (*Seymeria cassioides*). *Commandra umbellata* can parasitize roots of many species of plants and is also the alternate host for commandra stem rust of pines. Many of these parasitic plants have a wide geographic and host range.

Identifying the Parasites.—Root parasitic plants come from many genera. Many are green plants which can be treelike, shrublike, or herbaceous in growth form. They can be annual, biennial, or perennial weeds that can survive for varying periods without root penetration of hosts. Others are nongreen, succulent annuals, which require functional root attachments to survive and reproduce.

Identifying the Injury.—Reduced tree growth, sometimes leading to tree mortality, has been reported in a few cases. Infected roots have swollen pads of parasite root tissue (haustoria) where host penetration has occurred.

Biology.—The host range for most parasites—including herbaceous weeds and grasses and woody plants—is quite broad. However, a few are quite specific to a small group of related species. After seed germination, the radicle contacts a host root, and a holdfast is formed on the surface. A peglike root penetrates the host's root surface and grows into the water- and nutrient-conducting tissues, removing the materials needed for development. If no host root is contacted soon after germination, some parasites will die. Others can live long enough to bear seed without ever initiating root infections.

Control.—No control has been adequately investigated.

"Bear corn" parasite on oak roots.

GLOSSARY

Abdomen—The third and rearmost region of the insect body.

Aecium (pl. aecia)—One of the reproductive structures in the life cycle of a rust fungus. Aecia normally appear as blisters on the host plant.

Aeciospores—Spores produced in an aecium.

Alternate host—Host in the life cycle of a rust fungus on which the pycnial and aecial stages are formed.

Ascospores—Spores produced in a saclike structure (the ascus). This structure is typical of a large group of fungi, the Ascomycetes.

Basidiospore—A spore borne on the outside of the reproductive structure called a basidium. This structure is typical of the group of fungi called the Basidiomycetes.

Cambium—A layer, one- or two-celled thick, between the xylem and phloem in higher plants. The cambium produces both of these tissues, resulting in diameter growth.

Canker—A localized necrotic lesion of the cambium.

Chlorosis (adj. chlorotic)—The loss of green pigment in a plant due to the plants inability to produce chlorophyll.

Conk—A fruiting body of a wood decay fungus that bears basidia.

Dormant—Having growth, development, or other biological activity suspended; resting, inactive.

Dorsal—Of or relating to the back; belonging to or situated on or near the upper surface.

Epicormic—Growing from a dormant bud that has been exposed to light and air.

Frass—Solid larval excrement, as left by defoliators; wood fragments made by a wood-boring insect, usually mixed with excrement.

Fruiting Bodies—Any structure formed of mycelia that contains spore bearing cells.

Fungus (pl. fungi)—A nongreen plant with a vegetative body formed of tubular filamentous cells (hyphae). Fungi reproduce by spores.

Generation—Period of time required to complete the life cycle of an insect.

Gouting—Tumorlike swellings on boles, branches, or twigs, caused by feeding of sucking insects.

Haustorium (pl. haustoria)—A specialized structure of a pathogen that is capable of direct penetration into, and nutrient absorption from, a host plant.

Head—The first region of the insect body. Eyes, mouth parts, and antennae (where present) are attached in this region.

Honeydew—A sweetish secretion produced by sucking insects, particularly aphids and scales.

Host—A plant which provides nutrition for an invading parasite.

Host Range—The various plants which a pathogen can infect.

Infection—The establishment of a feeding relationship between a host and a parasite.

Infection Court—Point of entry and establishment of a pathogen in the host organism.

Instar—The life stages of an insect larva between molts.

Larva (pl. larvae)—A young insect differing fundamentally in form from the adult (compare to nymph).

Metamorphosis—Series of changes through which an insect passes in developing from egg to adult.

Mycelium—A mass of fungal filamentous cells. It forms the vegetative body of the fungal plant.

Mycoplasma—A group of microscopic organisms intermediate between bacteria and viruses.

Necrotic—Dead.

Nymph—Young stage of insect which does not fundamentally differ in form from the adult (compare to larva).

Parasite—An organism that lives on or in, and obtains its food from, another organism (host).

Parthenogenesis—Reproduction without male fertilization.

Pathogen—An agent that causes disease.

Perithecium (pl. perithecia)—A closed bulb- or ball-shaped fruiting body with a pore through which ascospores are extruded, usually in a gelatinous paste.

Primary host—The host of a rust fungus on which the telial stage of the fungus is produced.

Prothorax—First thoracic segment bearing the first pair of legs but no wings.

Pupa (pl. pupae)—The intermediate life stage between the larva and the adult.

Pupate—To become a pupa; to pass through a pupal state.

Resinosis—Exudation of pitch from a wound or infection on a conifer.

Resistance—The ability of a host to slow the development of a disease.

Resistance Breeding—The selection and deliberate propagation of those individuals in the population which display resistance to a specific pest.

Rhizomorph—A thick strand of mycelium in which the hyphae have lost their individuality; similar in appearance to a small root.

Saprophyte—Any organism which feeds on dead organic matter.

Segment—A subdivision of an animal body or appendage.

Sooty Mold—A dark or black velvety coating of mycelium of various fungi growing in insect honeydew on the leaves, fruit, or other exposed parts of plants.

Spores—The reproductive unit of fungi. Spores function in the same way that seeds do for higher plants.

Sporodochium (pl. sporodochia)—A cushion-shaped vegetative structure covered with spore bearing cells.

Stroma (pl. stromata)—A compact vegetative structure on, or within which, fruiting bodies are formed.

Telium (pl. telia)—Specialized fruiting structure of a rust fungus which produces teliospores. Generally, telia appear as hair-like filaments on the underside of leaves of the host.

Teliospores—In a rust fungus life cycle these resting spores are the normal overwintering spore form. They germinate in the spring and generate basidiospores.

Thorax (Adj. thoracic)—The second (middle) region of the insect body. The six true legs are normally attached in this region.

Thoracic legs—True legs located on the second region of the insect body.

Uredium (pl. uredia)—One of the five reproductive tissues in the complete rust life cycle. This tissue gives rise to a large number of spores on a continuous basis for an extended period of time.

Urediospores—Spores produced in a uredium.

Vector—Any organism that transmits a disease-causing organism.

Ventral—Of or relating to the belly; belonging to or situated on or near the lower surface.

Windthrow—The uprooting or overturning of trees by the wind.

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Guide to Insect Borers in North American Broadleaf Trees and Shrubs

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Pesticide Precautionary Statement

Pesticides used improperly can be injurious to humans, animals, and plants. Follow the directions and heed all precautions on the labels.

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.

Do not clean spray equipment, or dump excess spray material, near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary landfill dump, or crush and bury them in a level, isolated place.

Note: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the United States Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

Contents

Solomon, J.D. 1995. Guide to insect borers of North American broadleaf trees and shrubs. Agric. Handbk. 706. Washington, DC: U.S. Department of Agriculture, Forest Service. 735 p.

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.

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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

Family Hepialidae—Ghost Moths or Swifts

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

Genus and Species

Sthenopis quadriguttatus Grote

[poplar ghost moth] (figure 1)

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

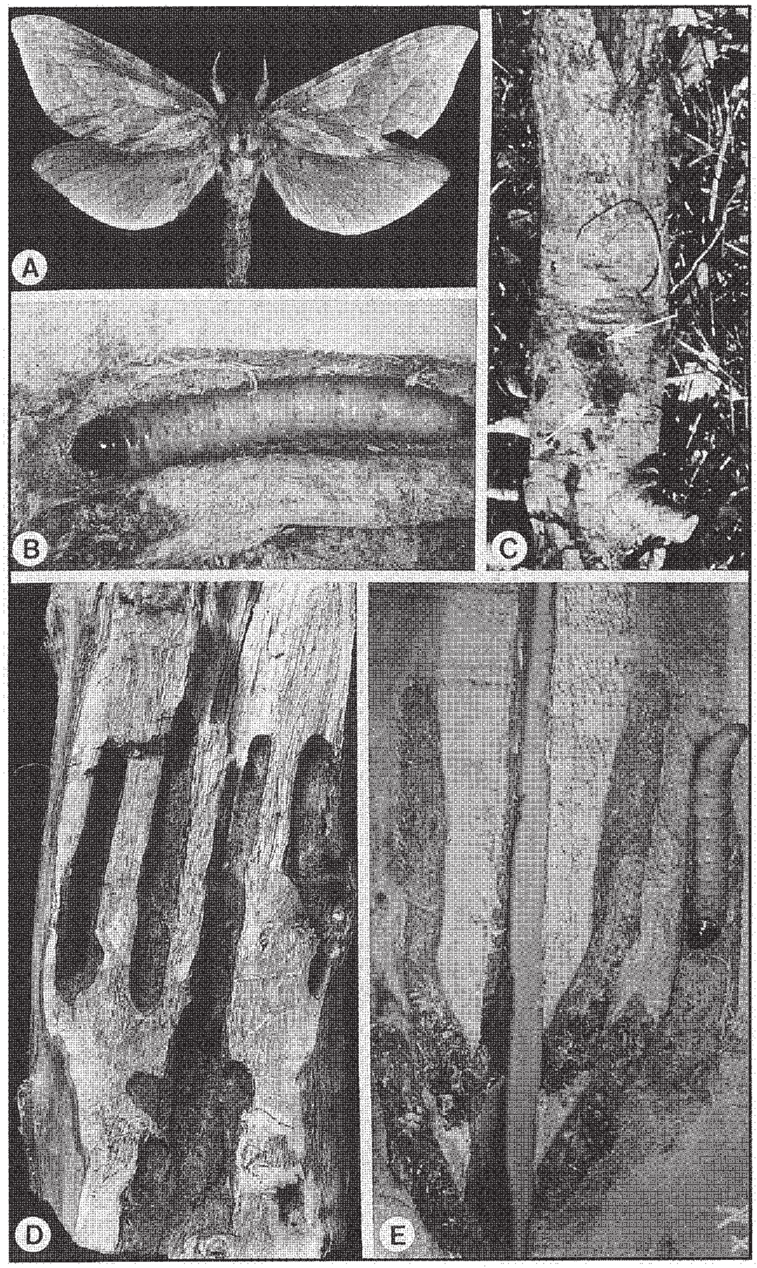

Figure 1—Sthenopis quadriguttatus, *[poplar ghost moth]: A, adult; B, larva in gallery; C, rootstock with entrance holes; D, multiple galleries in root collar; E, H-shaped gallery with larva (A, specimen courtesy R. Hodges; B-E, courtesy G. Vallee and R. Beique).*

Lepidoptera

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

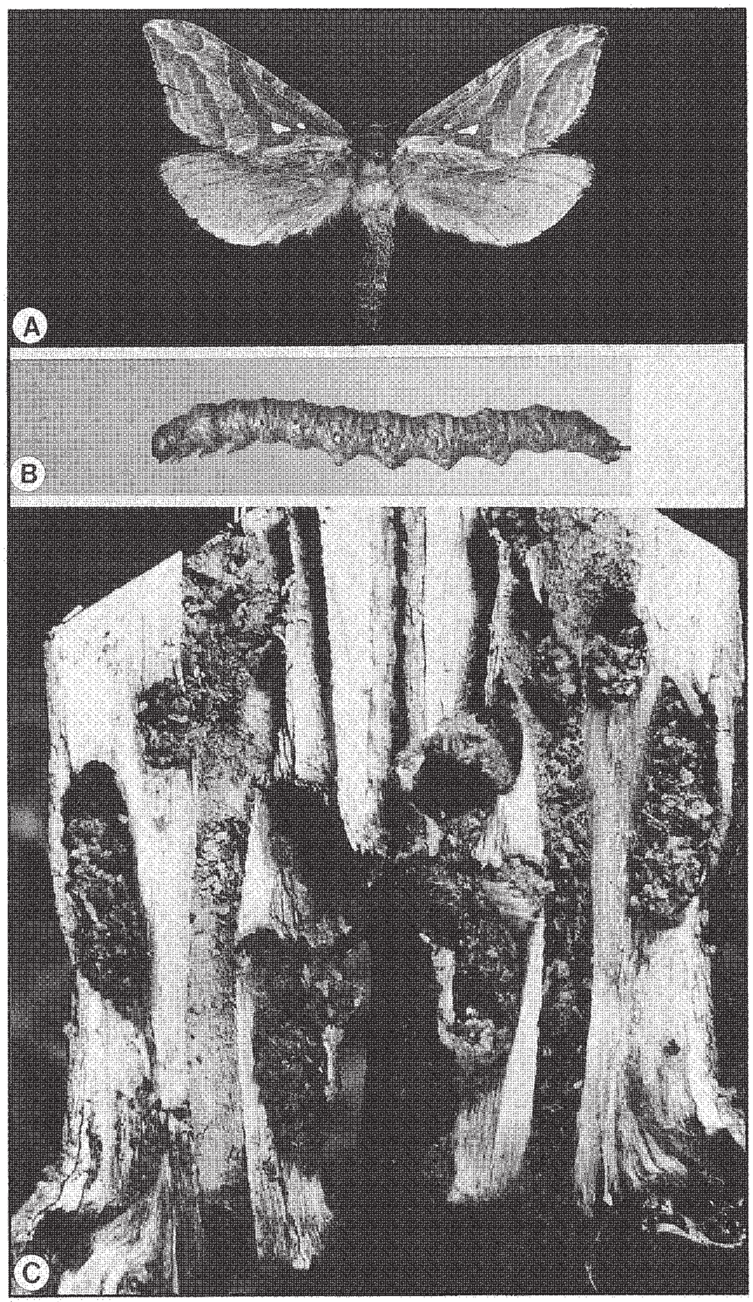

Figure 2—Sthenopis argenteomaculatus, *[alder ghost moth]: A, adult; B, mature larva; C, multiple galleries at base of trunk (specimens, courtesy R. Hodges).*

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

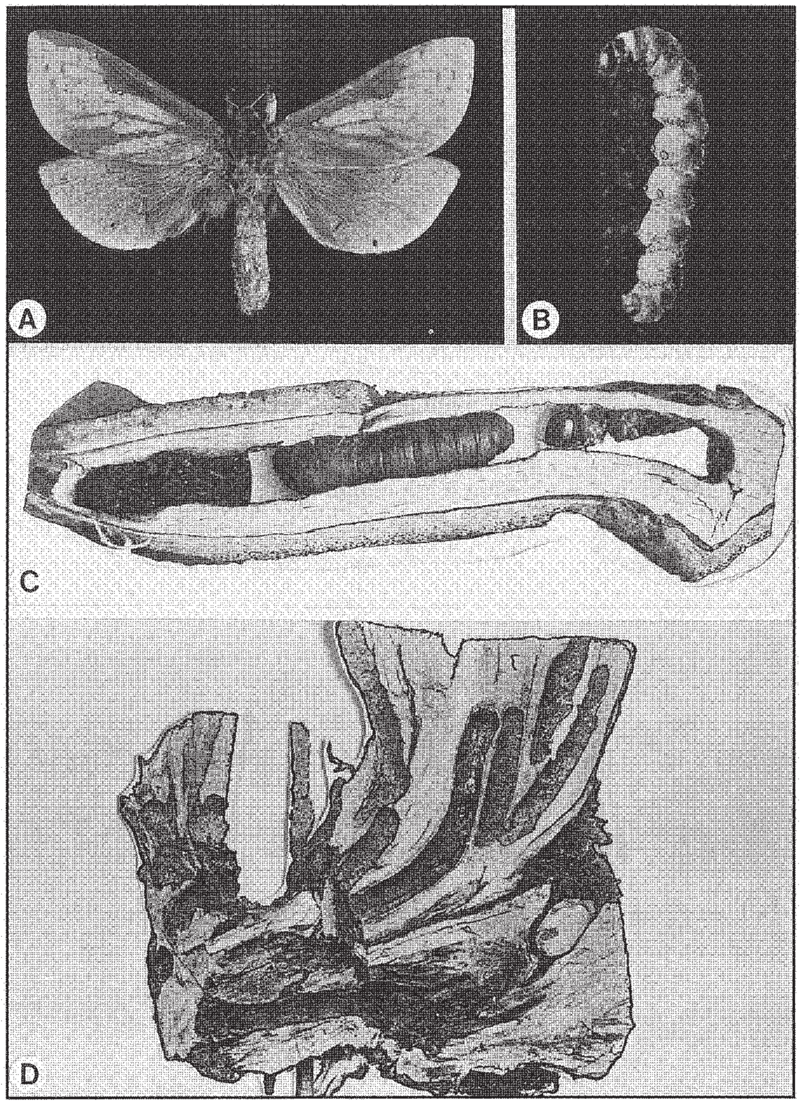

Figure 3—Sthenopis thule, *[willow ghost moth]: A, adult; B, larva; C, tunnel with pupa in root; D, root collar mass with multiple galleries (A, specimen courtesy R. Hodges; B-D, reproduced from Swaine [1909]).*

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.

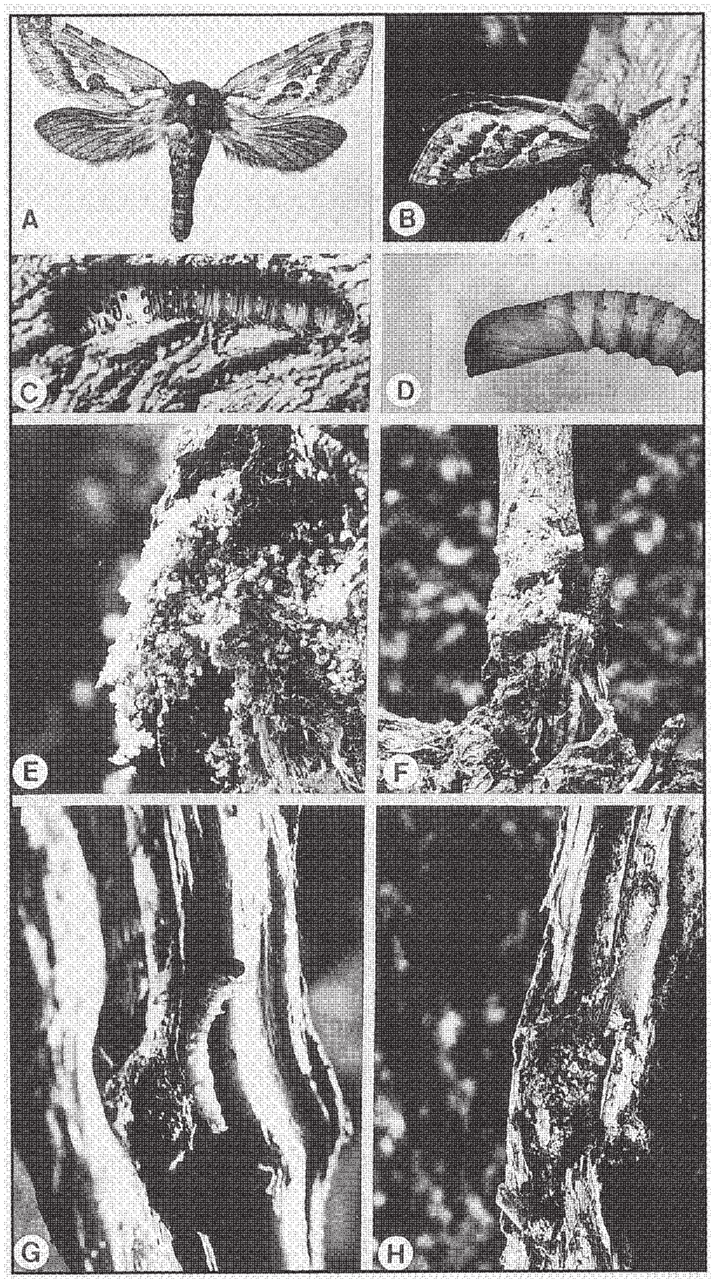

Figure 4—Hepialus californicus, *[lupine ghost moth]: A, adult; B, newly emerged moth in resting position; C, larva; D, pupa; E, frass clump; F, attack sites around branch crotches; G, split stem with galleries; H, protruding pupal skins (courtesy D. Wagner).*

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

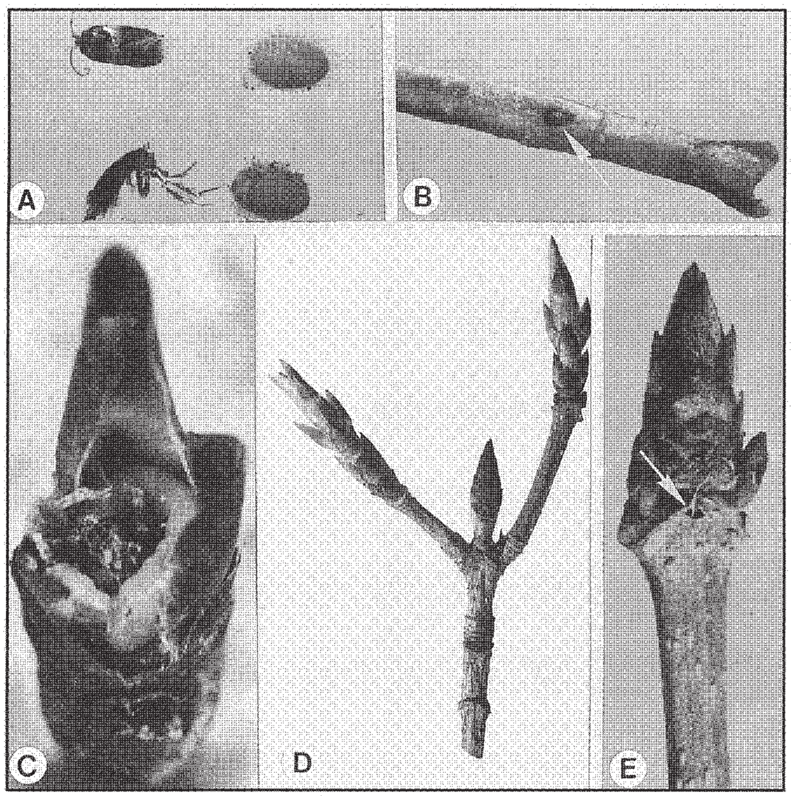

Figure 5—Obrussa ochrefasciella, *hard maple budminer: A, adults and cocoons; B, egg on leaf petiole; C, larva burrowing in maple bud; D, terminal bud killed allowing fork to develop; E, larval exit just below terminal bud (courtesy H. Kulman).*

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-

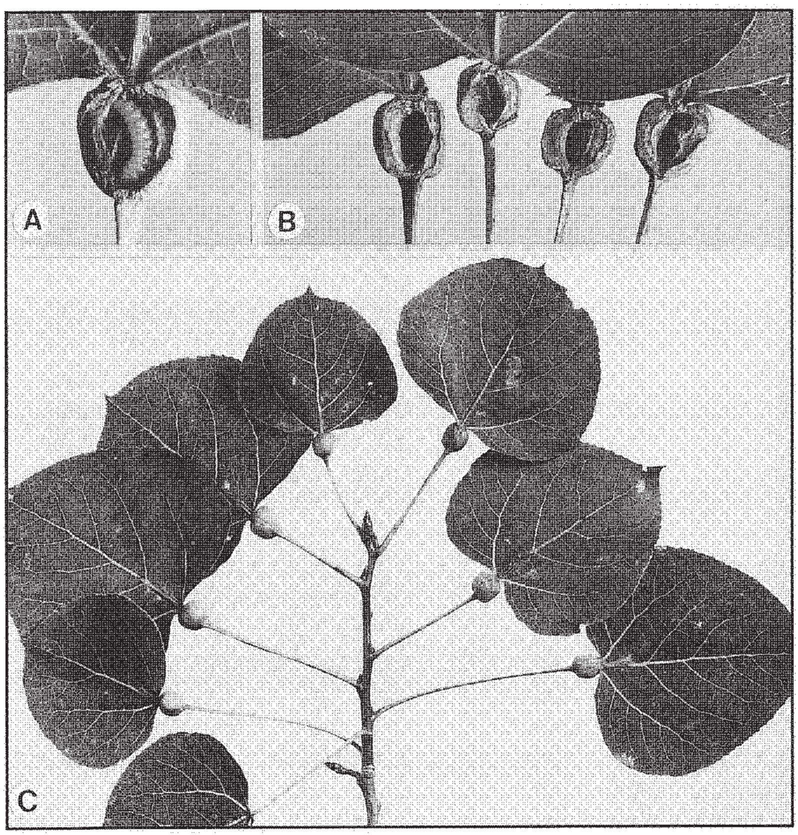

Figure 6—Ectoedemia populella, *[aspen petiole gall moth]: A, closeup of larva feeding inside gall; B, galls dissected to expose cavities and tabletlike frass mass on one side; C, pea-sized galls on petioles of aspen (specimens courtesy D. Wagner).*

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

Lepidoptera

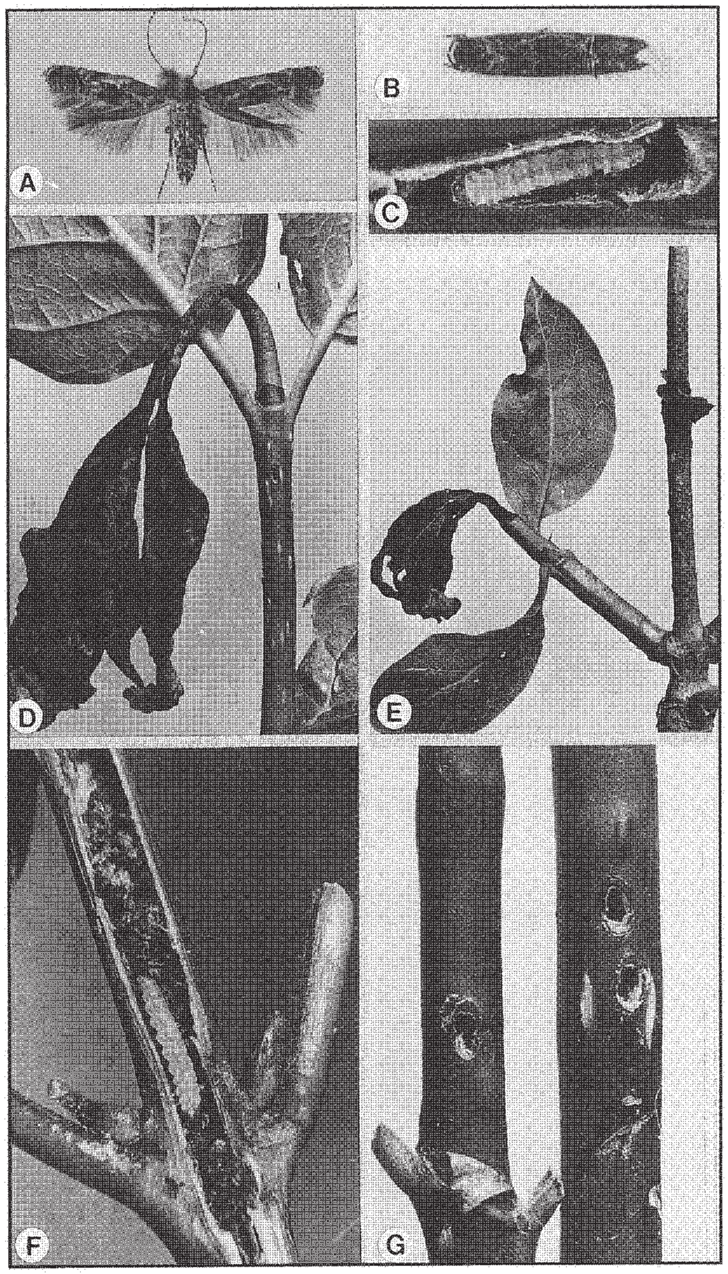

Figure 7—Mompha *n. sp., [buttonbush shoot borer]: A, adult; B, adult in resting position; C, larva in gallery; D, wilting, drooping terminal shoot; E, lateral shoot dieback; F, shoot hollowed out and loosely filled with frass; G, closeup of larval exit holes.*

indistinct in others.

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

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

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

Family Agonoxenidae—Agonoxenids

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

Genus and Species

Glyphipteryx linneella (Clerck) *20*

Glyphipteryx linneella (Clerck)

[linden bark borer] (figure 8)

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

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

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

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

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

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

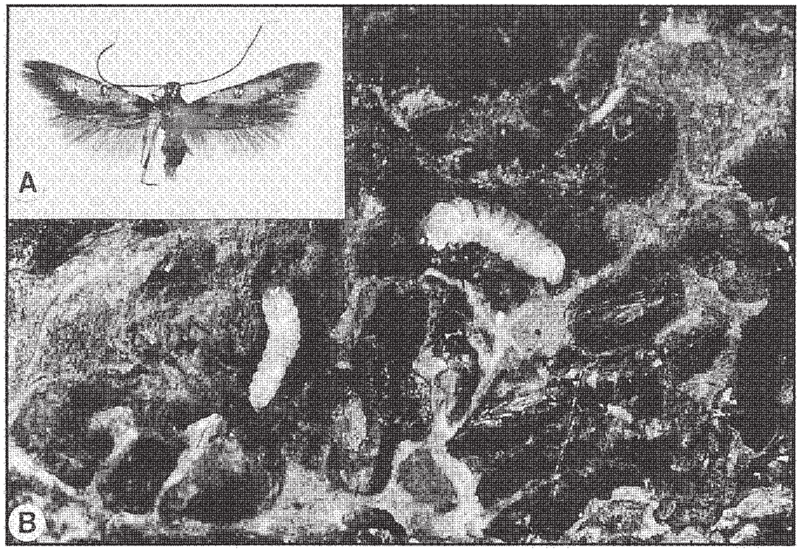

Figure 8—Glyphipteryx linneella, *[linden bark borer]: A, adult; B, outer bark removed to expose the larvae and burrows in the inner bark (A, specimen courtesy R. Hodges; B, courtesy Great Lakes Forestry Centre).*

Family Gelechiidae—Gelechiids

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

Genus and Species

Anarsia lineatella Zeller

peach twig borer (figure 9)

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

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

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

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

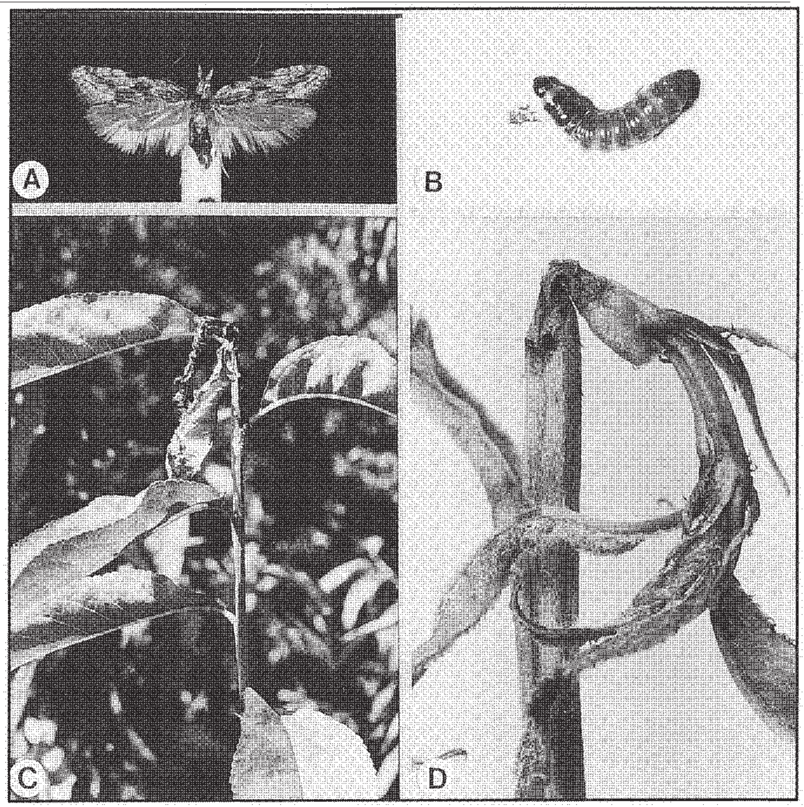

Figure 9—Anarsia lineatella, *peach twig borer: A, adult; B, larva; C, peach shoot wilting and drooping; D, dying shoot with hole in stem (A, specimen courtesy R. Hodges; B, courtesy L. Smith).*

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

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

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

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

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

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

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

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

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

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

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

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

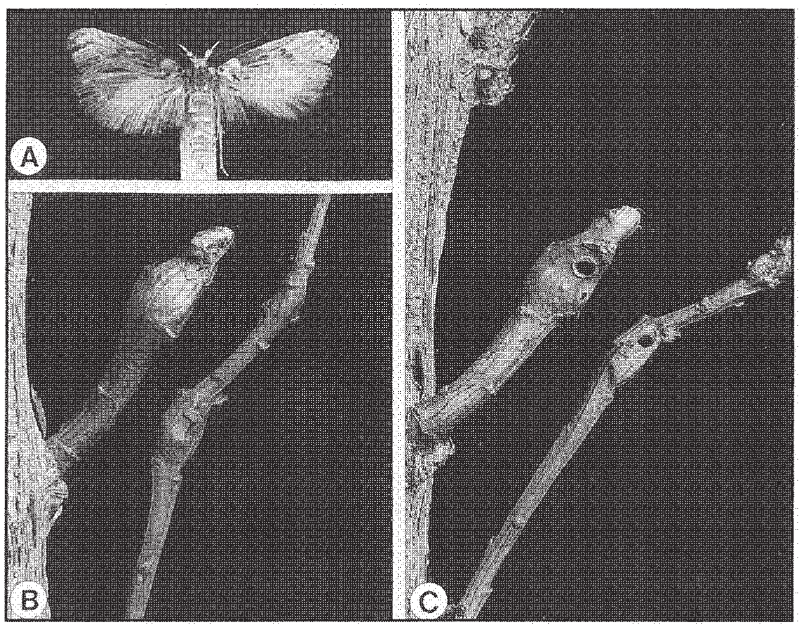

Figure 10—Gnorimoschema baccharisella, *[coyote brush gall moth]: A, adult; B, galls on shoots; C, exit holes in shoot galls (A, specimen courtesy R. Hodges).*

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

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

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

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

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

Family Argyresthiidae—Argyresthiids

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

Genus and Species

Argyresthia oreasella Clemens

[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

Lepidoptera

***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

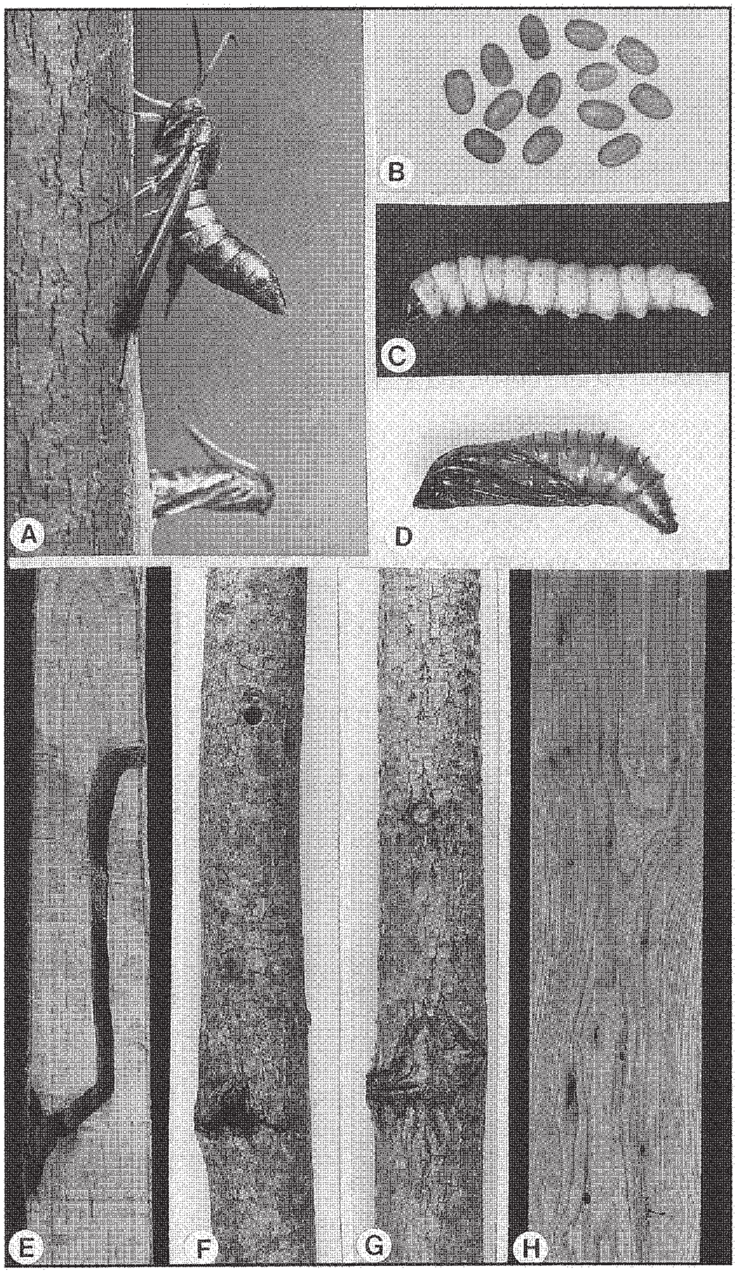

Figure 11—Podosesia syringae, *ash borer: A, newly emerged adult, pupal skin below; B, eggs; C, larva; D, pupa; E, completed gallery; F, entrance hole below, round exit hole above; G, bark scars of healed entrance and exit; H, wormhole defects in ash lumber.*

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

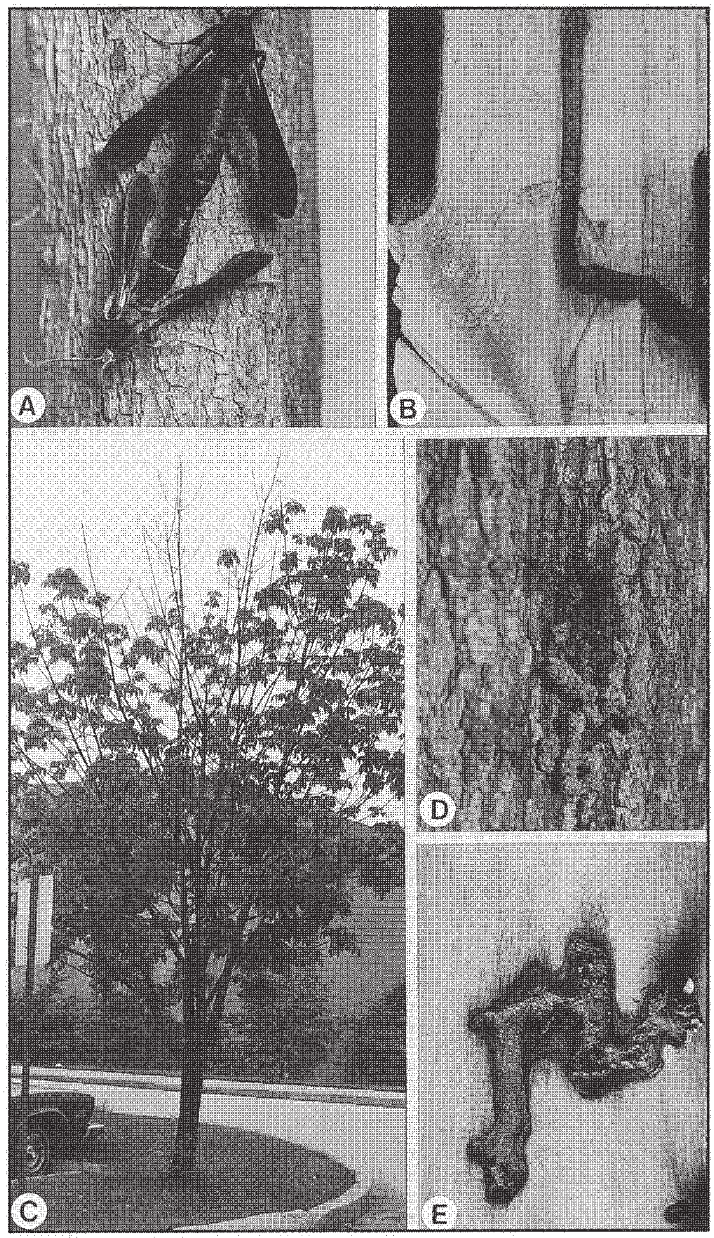

Figure 12—Podosesia aureocincta, *banded ash clearwing: A, mating adults; B, gallery with cambial cavity; C, tree under heavy attack with crown dieback and basal sprouts; D, active attack site with sapstained bark and frass; E, cambial burrow on surface of sapwood.*

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

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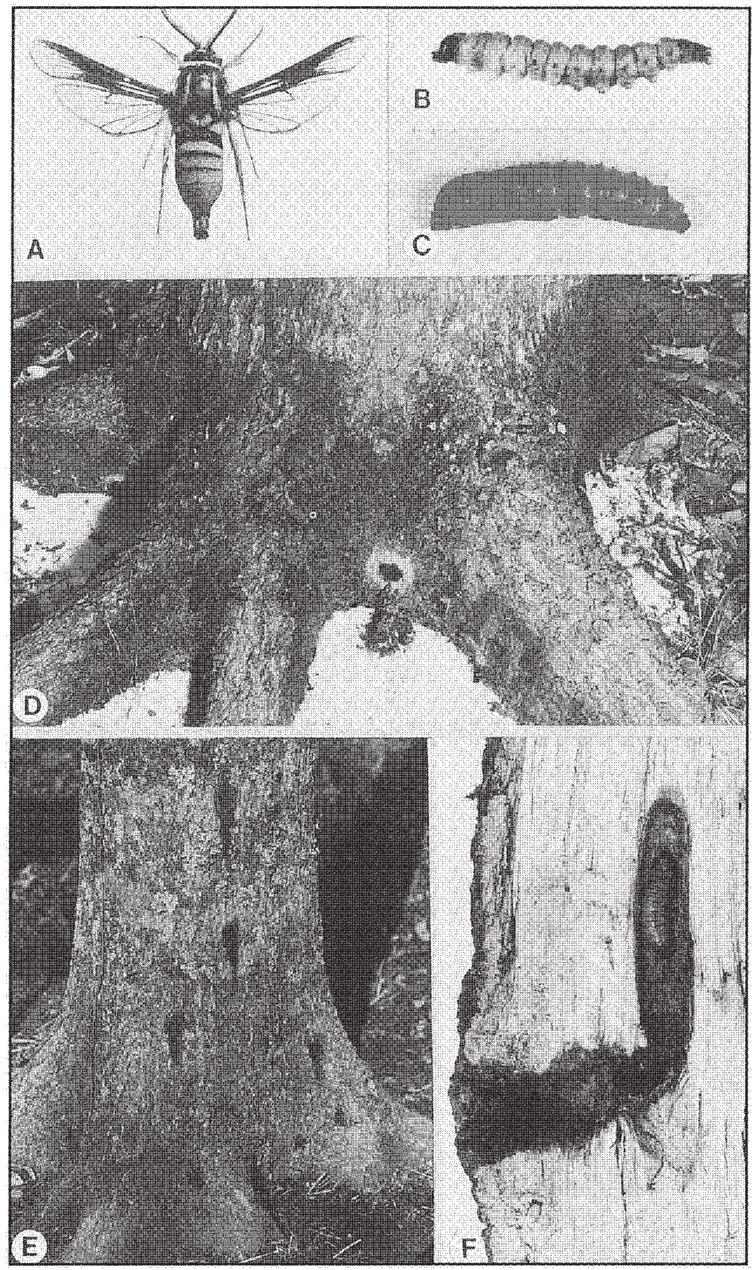

Figure 13—Paranthrene simulans, *[red oak clearwing borer]: A, adult; B, larva; C, pupa; D, entrance hole and frass pile between root flanges; E, sap spots indicating new attack sites; F, completed gallery.*

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

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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

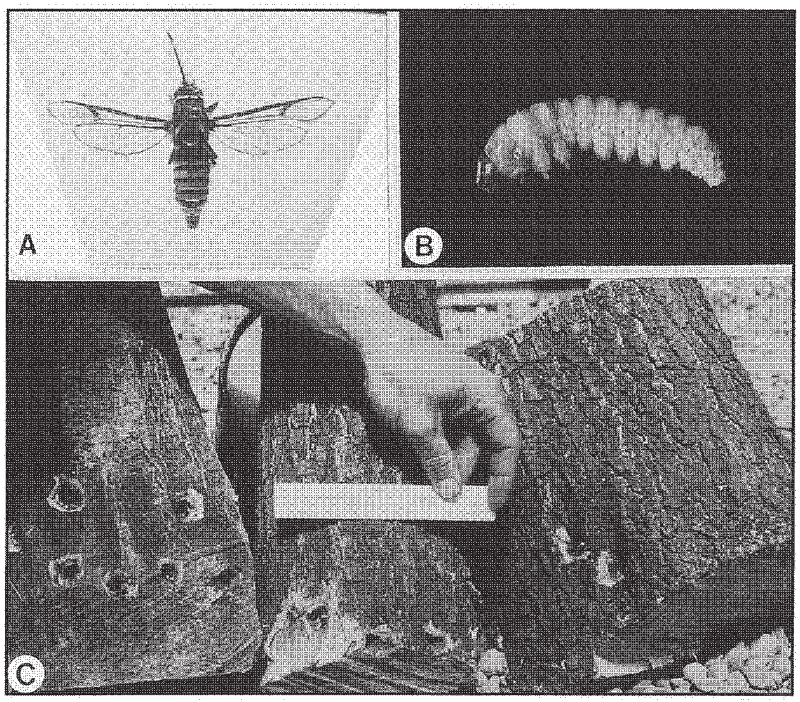

Figure 14—Paranthrene pellucida, *[pin oak clearwing]: A, adult; B, larva; C, entrance holes in oak trunk sections (courtesy F. Purrington).*

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

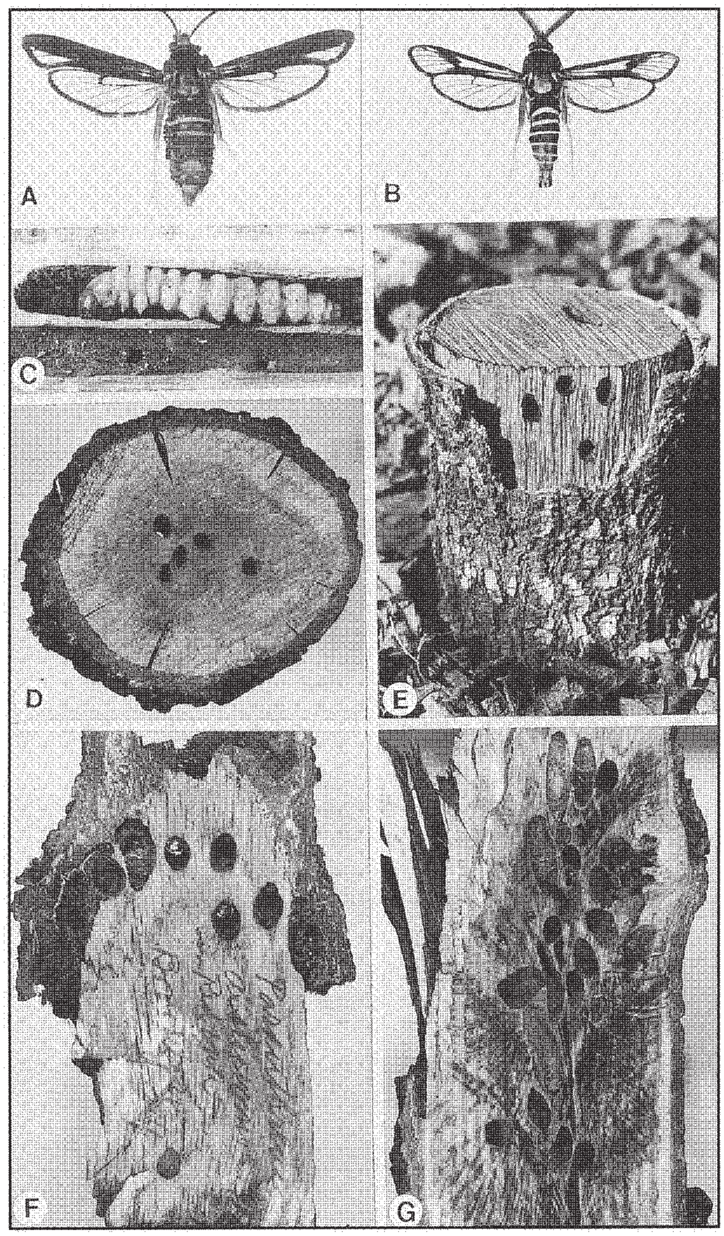

Figure 15—Paranthrene asilipennis, *oak clearwing moth: A, adult female; B, adult male; C, larva; D, cross section of galleries; E, entrance holes in stump; F, bark slab removed to expose holes; G, stump split to expose multiple galleries (A, B, F, & G, specimens courtesy R. Hodges).*

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

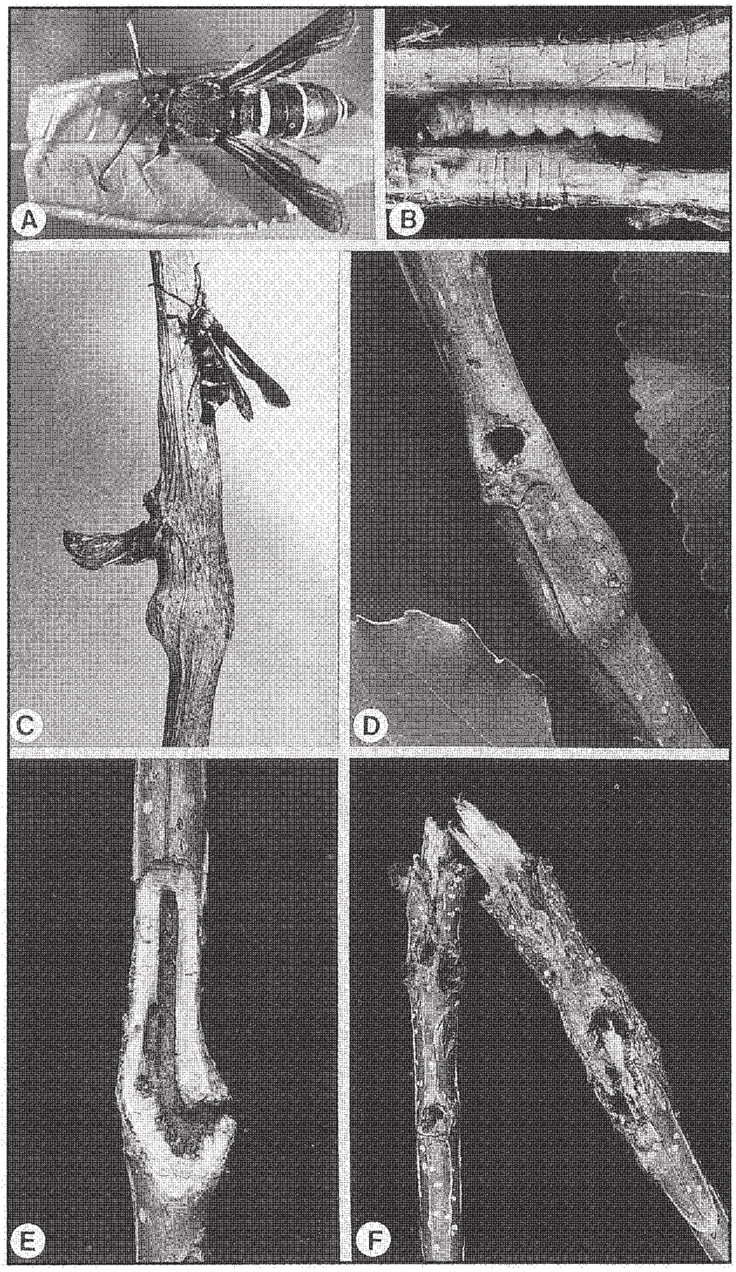

Figure 16—Paranthrene tabaniformis, *[dusky clearwing]: A, adult; B, larva; C, newly emerged adult, pupal skin below; D, swollen branch with exit hole; E, completed gallery; F, stem broken at site of attack.*

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.***

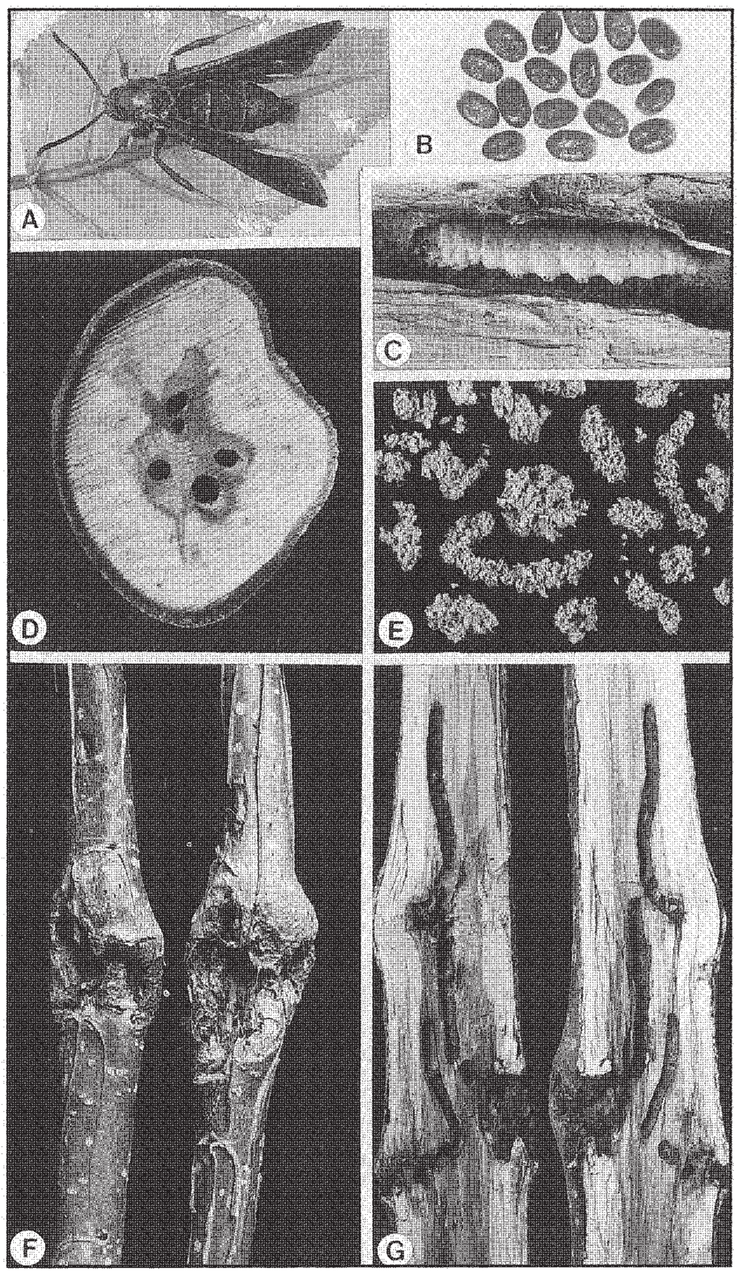

Figure 17—Paranthrene dollii, *[cottonwood clearwing borer]: A, adult; B, eggs; C, larva; D, cross section of galleries; E, frass clumps; F, active attack sites on nursery switches; G, stem split exposing galleries.*

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

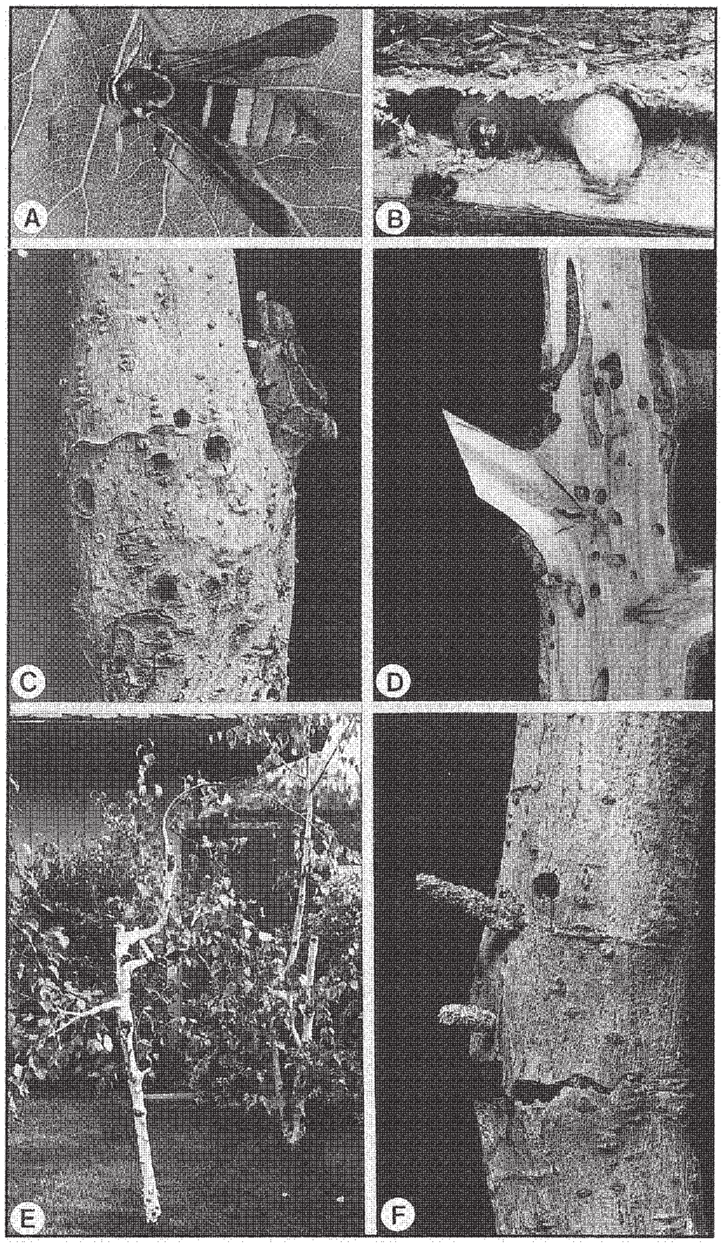

Figure 18—Paranthrene robiniae, *western poplar clearwing: A, adult; B, larva; C, exit holes in willow trunk; D, split to expose galleries; E, infested birch; F, frass tubes over exit holes (B, courtesy T. Eichlin; C & F, specimens courtesy J. Donahue; D, specimen courtesy R. Hodges; E, courtesy H. Kaya).*

head and thoracic shield (figure 18B). Larva with pair of jointed legs on each thoracic segment and reaches 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 undoubtedly 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

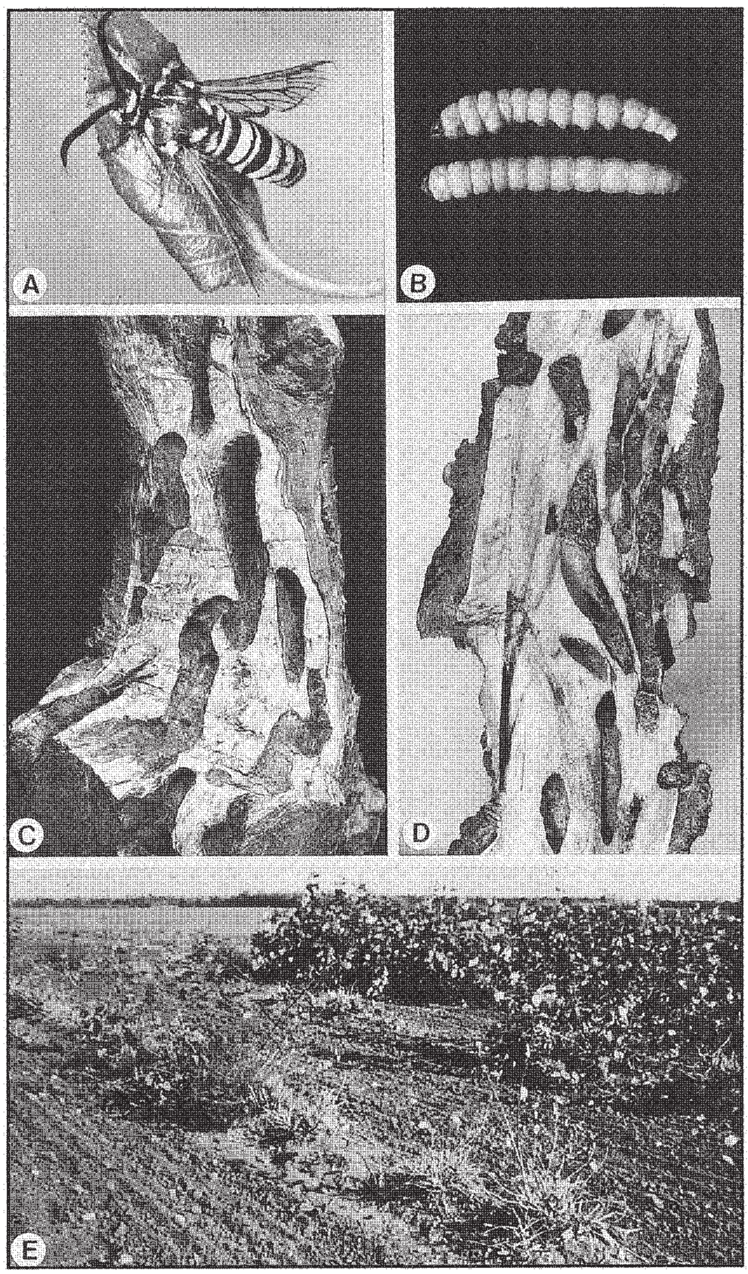

Figure 19—Sesia tibialis, *American hornet moth: A, adult; B, larvae; C, surface removed from poplar rootstock exposing galleries; D, split poplar rootstock showing heavy damage; E, poplar stocks in portion of nursery killed by borers (courtesy G. Neill).*

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).

Lepidoptera

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

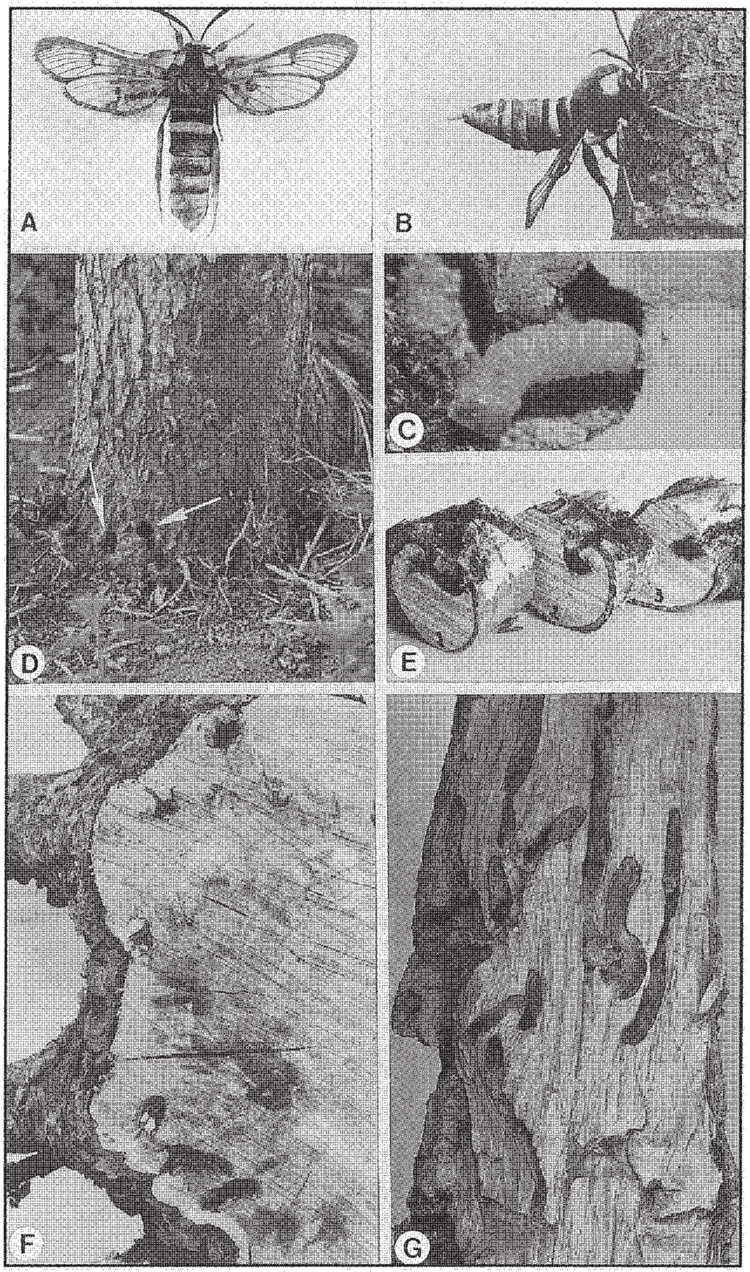

Figure 20—Sesia apiformis, *hornet moth: A, adult; B, calling female; C, larva; D, entrance holes and frass at root collar; E, gallery in root; F, stump cross section showing galleries; G, stem split to expose galleries (A & G, specimens courtesy R. Hodges; B, courtesy J. Burzynski; C & D, courtesy J.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

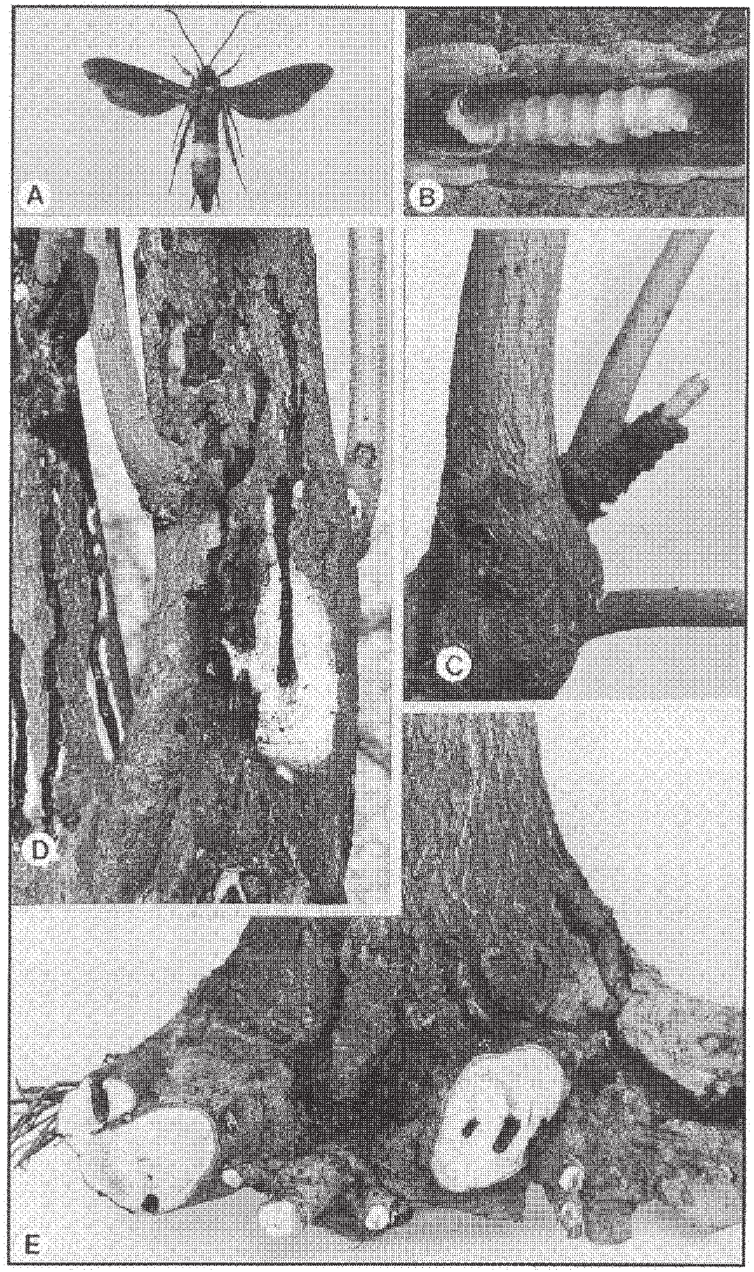

Figure 21—Sannina uroceriformis, *persimmon borer: A, adult; B, larva; C, frass tube with protruding pupal skin at base of tree; D, galleries in lower trunk; E, galleries at root collar and in roots.*

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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 diagnosis (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

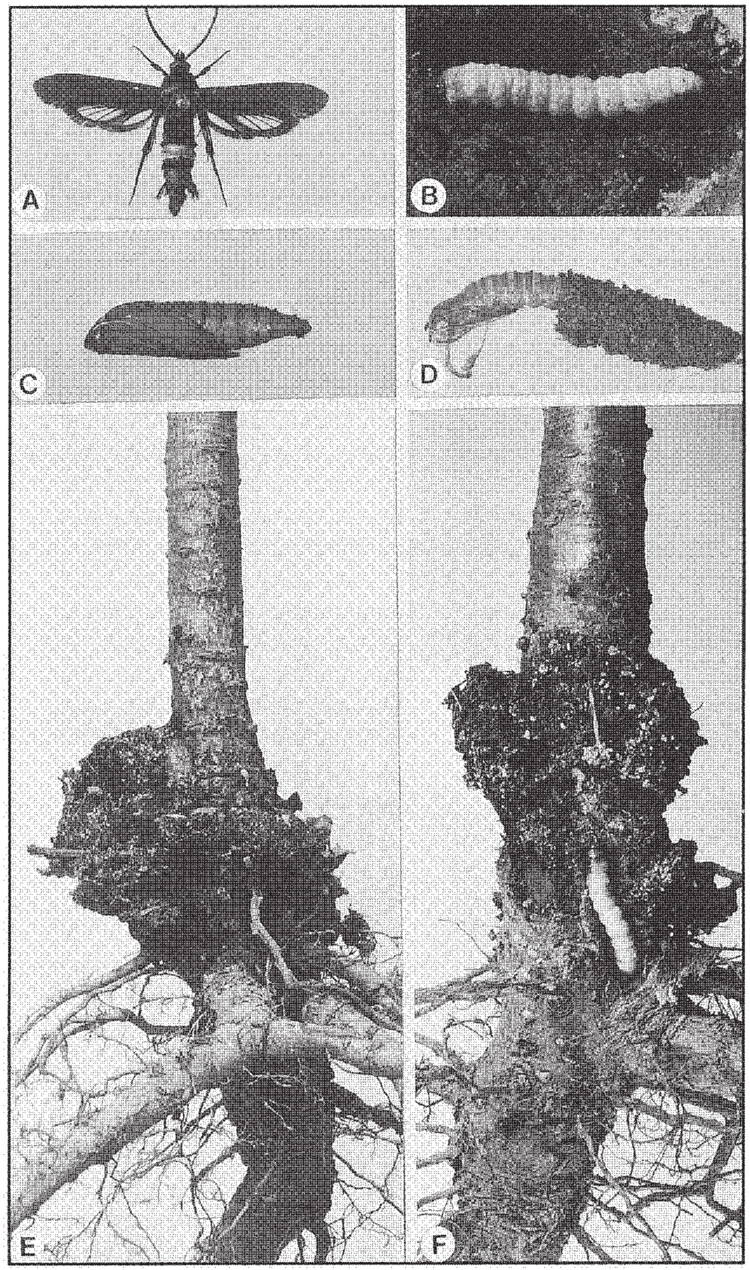

Figure 22—Synanthedon exitiosa, *peachtree borer: A, adult; B, larva; C, pupa; D, frass-covered cocoon with pupal skin protruding; E, young tree with large frass-jelly mass at root collar; F, frass-jelly mass pulled back to expose burrow and larva.*

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).

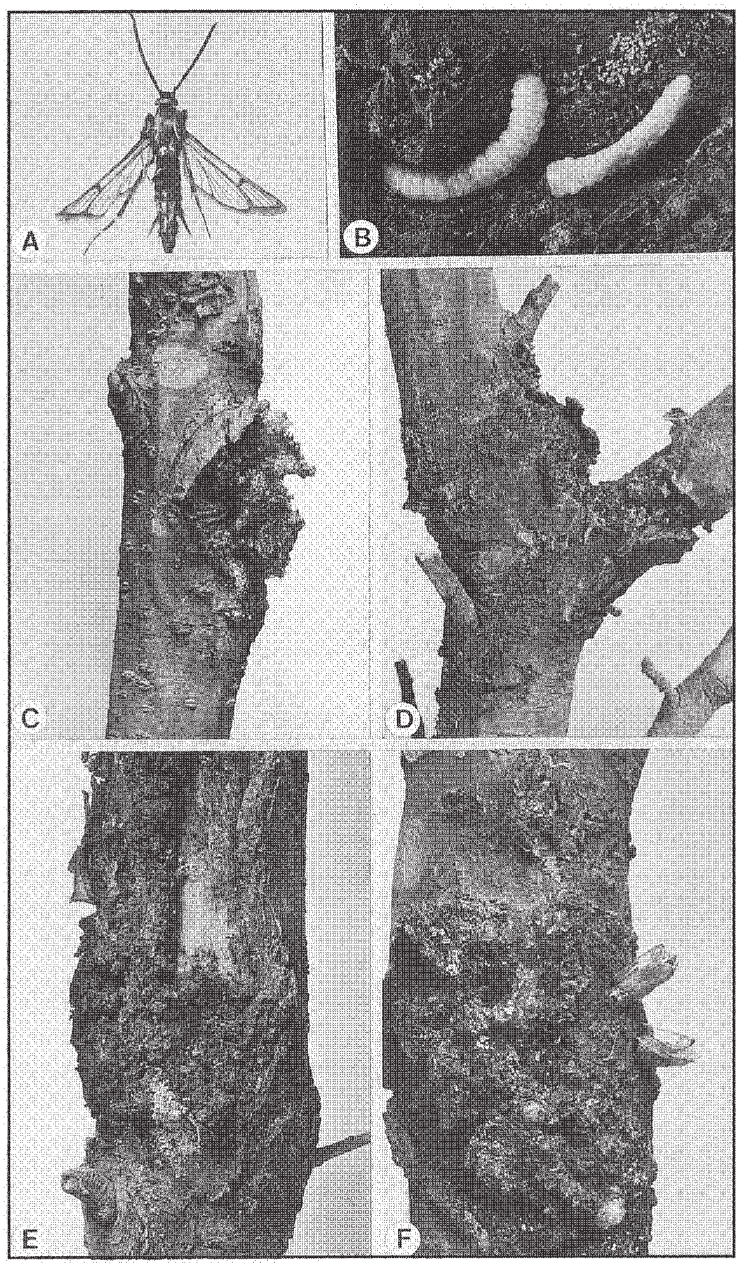

Figure 23—Synanthedon pictipes, *lesser peachtree borer: A, adult; B, larvae; C, frass adhering to bark; D, active attack site at branch crotch; E, attack sites with frass at cankered site; F, pupal skins protruding from infested bark.*

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

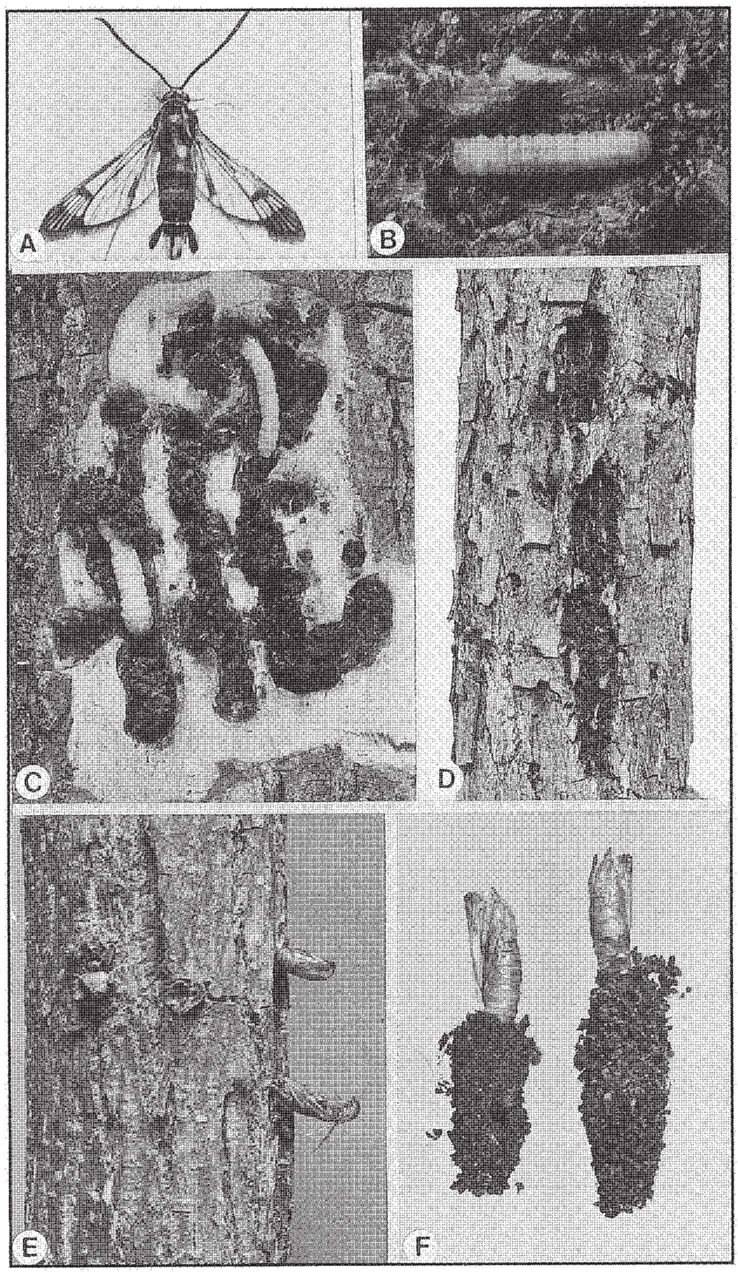

Figure 24—Synanthedon scitula, *dogwood borer: A, adult; B, larva; C, burrows under bark of pecan; D, sapstained bark and frass at site of attack; E, pupal skins protruding from bark; F, frass-covered cocoons with pupal skins.*

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

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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

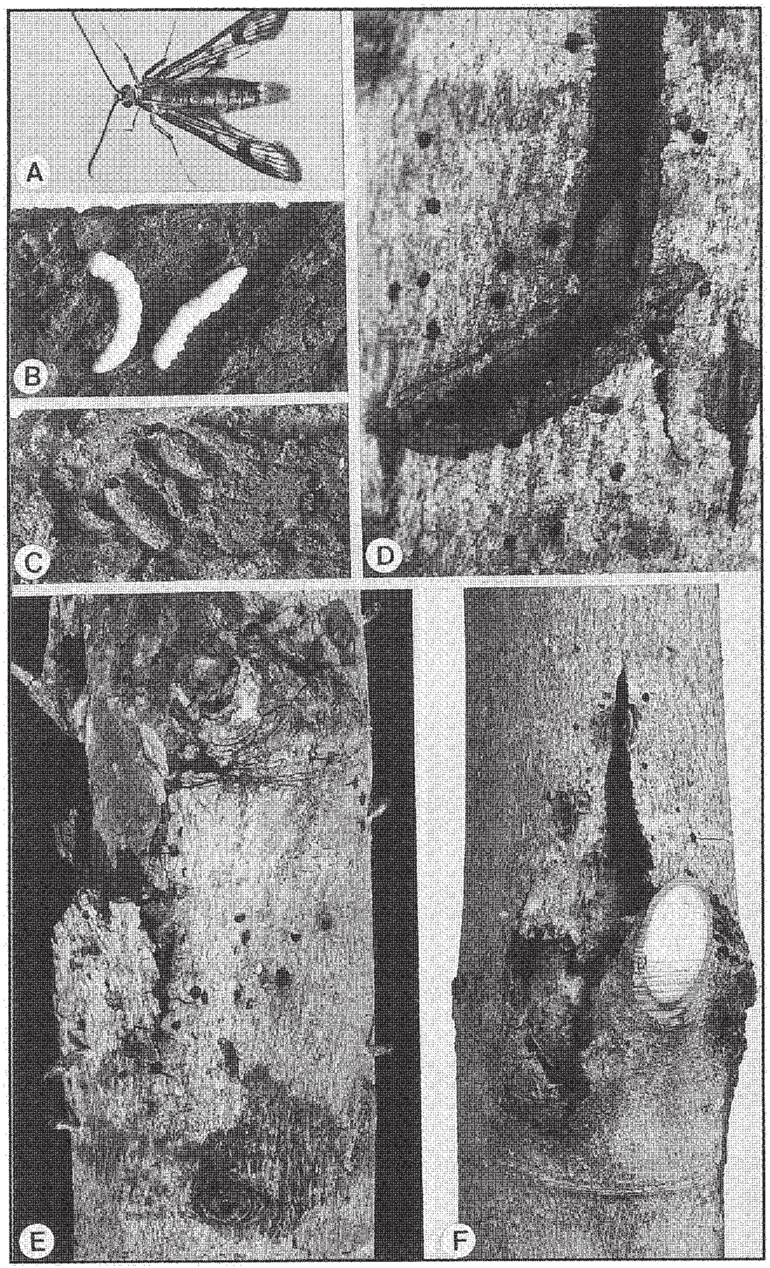

Figure 25—Synanthedon acerni, *maple callus borer: A, adult; B, larvae; C, frass-covered cocoons under bark; D, exit holes around ax wound; E, pupal skins protruding from bark; F, infested site with exit holes at branch crotch.*

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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

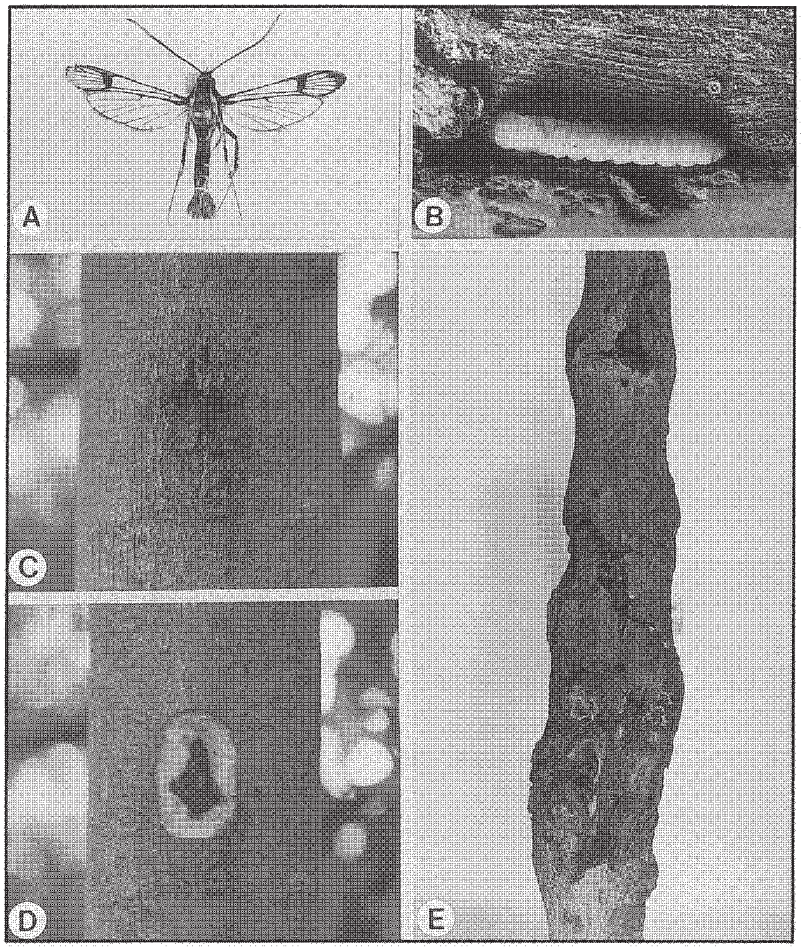

Figure 26—Synanthedon acerrubri, *[maple clearwing]: A, adult; B, larva; C, sapstained bark at site of attack; D, bark removed to expose burrow; E, gnarled, swollen stem from repeated attacks.*

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

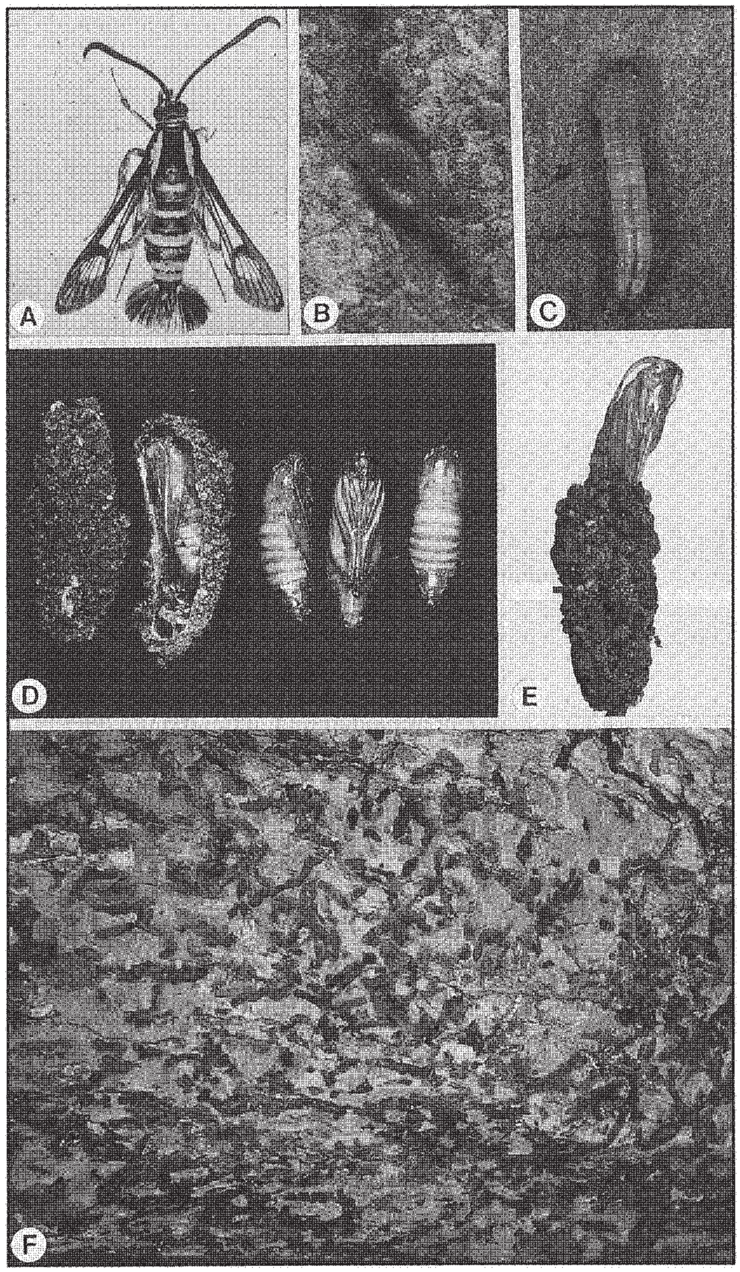

Figure 27—Synanthedon resplendens, *[sycamore borer]: A, adult; B, egg; C, larva; D, pupae and cocoons; E, cocoon with pupal skin protruding; F, outer bark removed exposing extensive tunneling (courtesy L. Brown).*

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

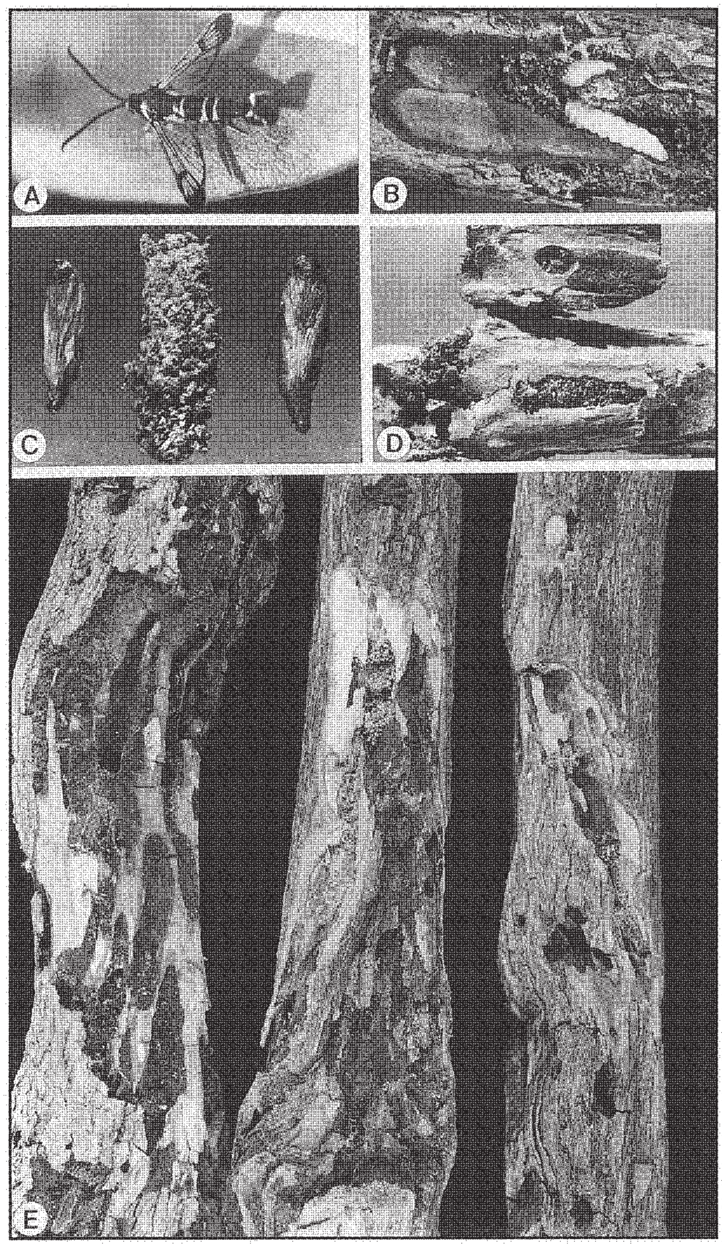

Figure 28—Synanthedon rhododendri, *rhododendron borer: A, adult; B, larva; C, pupae and frass-covered cocoon; D, bark removed exposing pupation chamber and cocoon; E, extensive larval burrows under bark of rhododendron stems (A, C, & D, courtesy J. Neal; B, courtesy D. Nielsen; E, courtesy C. Pless).*

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

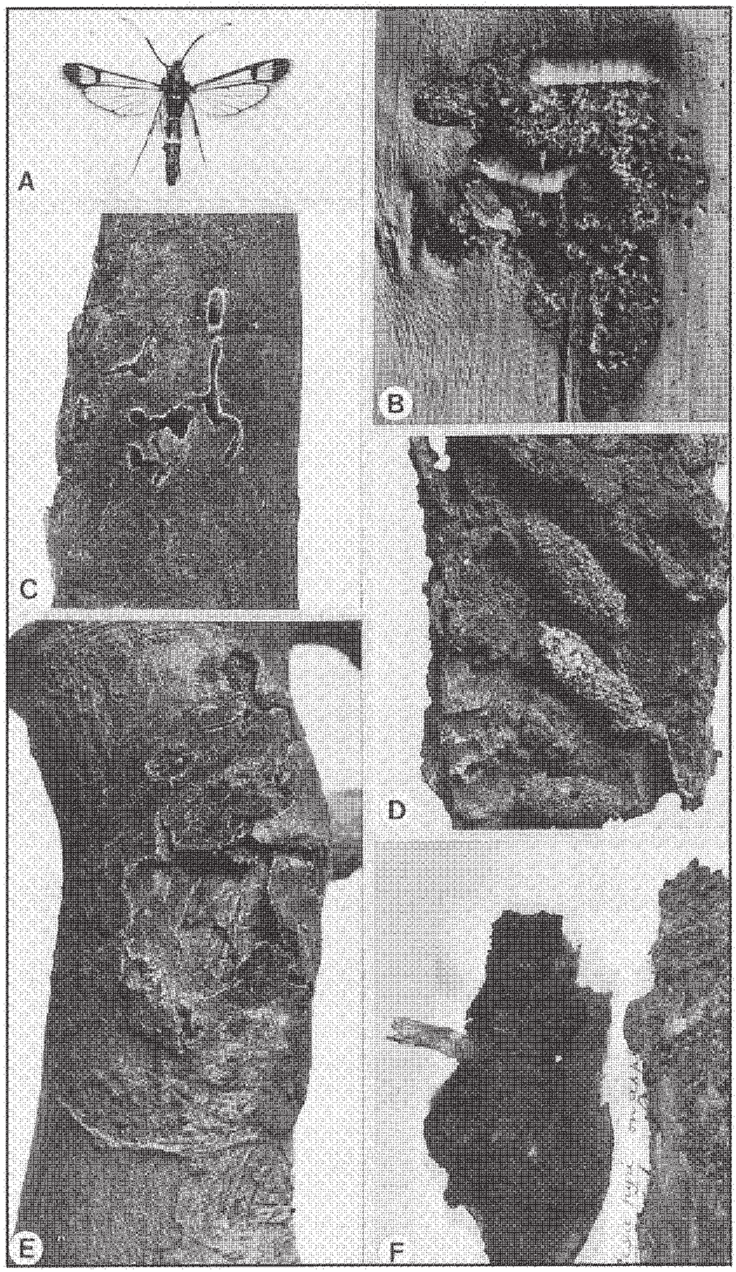

Figure 29—Synanthedon pyri, *apple bark borer: A, adult; B, larvae; C, active attack sites on trunk; D, cocoons under bark; E, bark scars over previous attacks; F, bark with pupal skin protruding (A & F, specimens courtesy R. Hodges).*

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

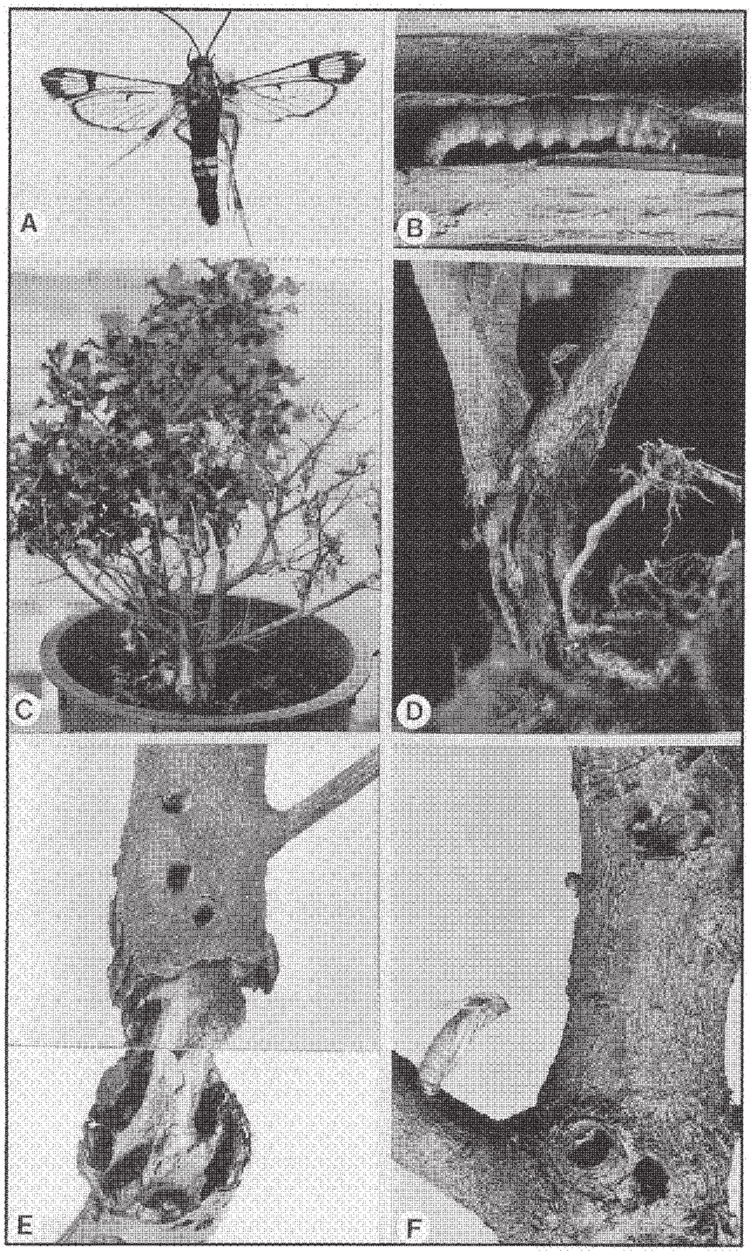

Figure 30—Synanthedon kathyae, *[holly clearwing borer]: A, adult; B, larva; C, potted holly with girdled stems dying; D, bark removed at root collar to expose galleries; E, multiple galleries and pupal exits; F, pupal skin protruding from stem. (specimens courtesy G. Ghidiu and L. Vasvary).*

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

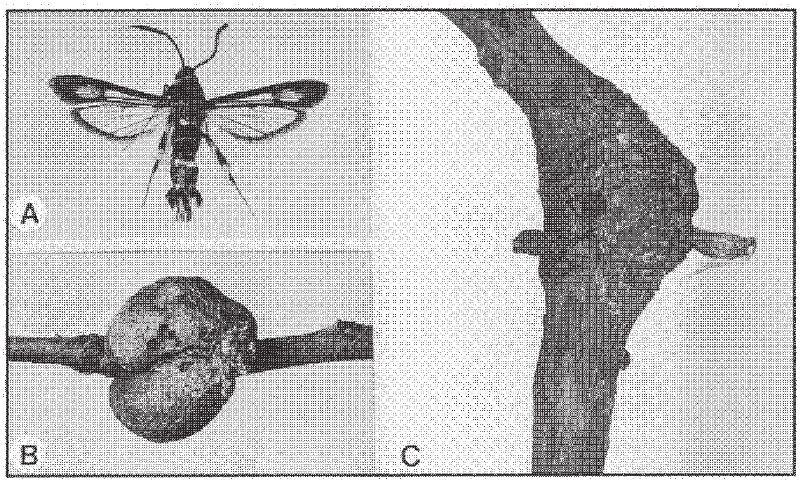

Figure 31—Synanthedon decipiens, *[oakgall clearwing]: A, adult; B, oak gall with entrance holes and frass; C, galled branch with pupal skin protruding (specimens courtesy R. Hodges).*

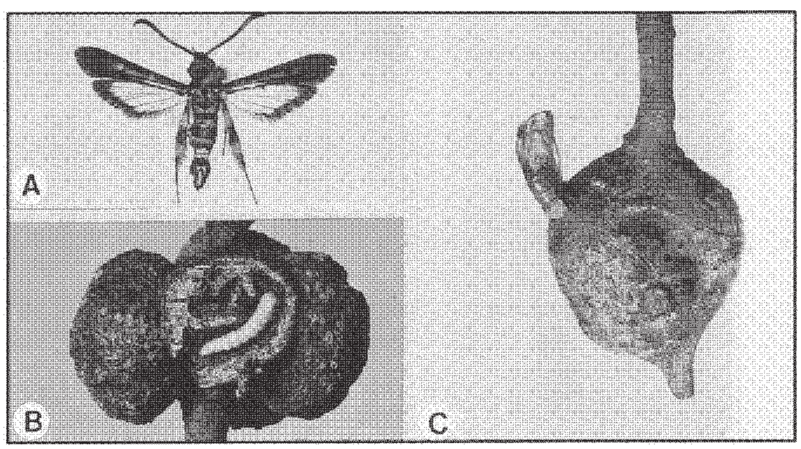

Figure 32—Synanthedon sapygaeformis, *[Florida oakgall clearwing]: A, adult; B, gall with burrows and larva; C, gall with pupal skin protruding (specimens courtesy R. Hodges).*

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.

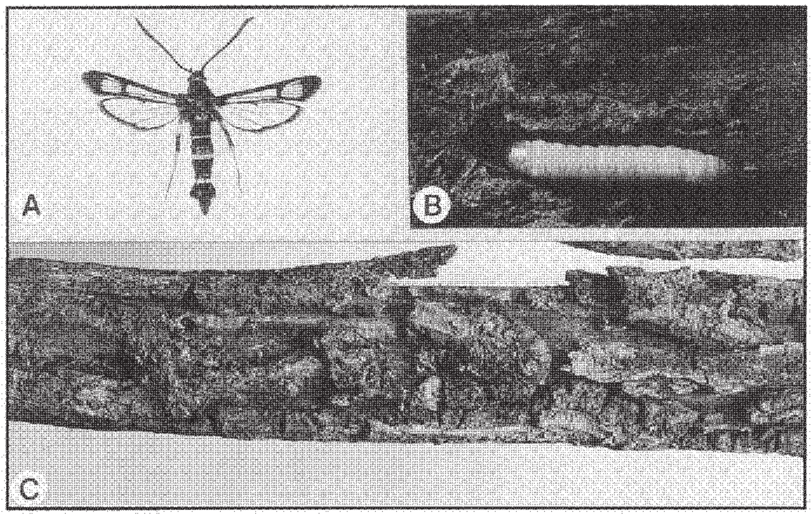

Figure 33—Synanthedon geliformis, *[pecan clearwing borer]: A, adult; B, larva; C, rough, loosened bark at attack site (A, specimen courtesy R. Hodges; B & C, specimens courtesy R. Mizell).*

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.

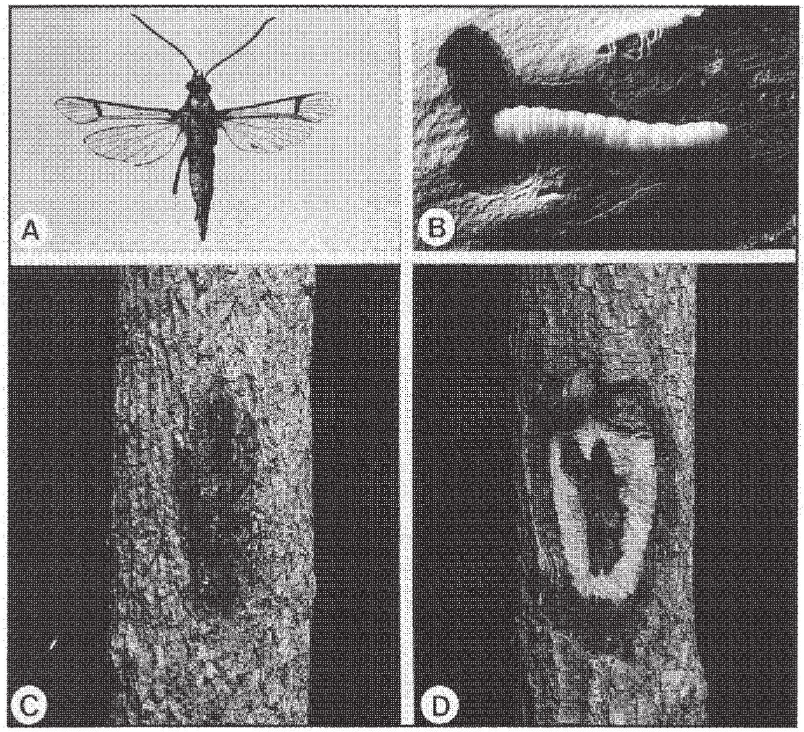

Figure 34—Synanthedon rubrofascia, *[tupelo clearwing borer]: A, adult; B, larva; C, sapspot at site of attack; D, bark removed to expose larval burrow (A, specimen courtesy W. Snow).*

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

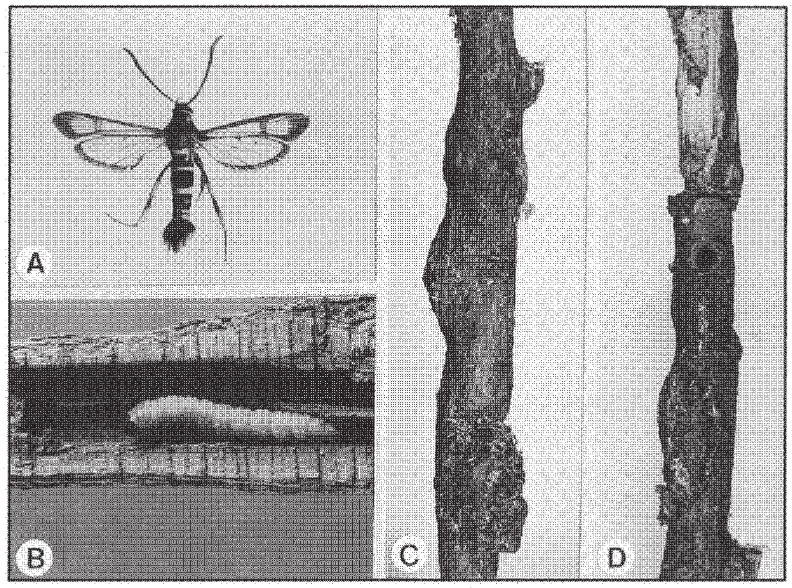

Figure 35—Synanthedon sigmoidea, *[willow clearwing]: A, adult; B, larva; C, openings, swellings, and frass on infested stem; D, round exit hole in bark (specimens courtesy R. Hodges).*

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

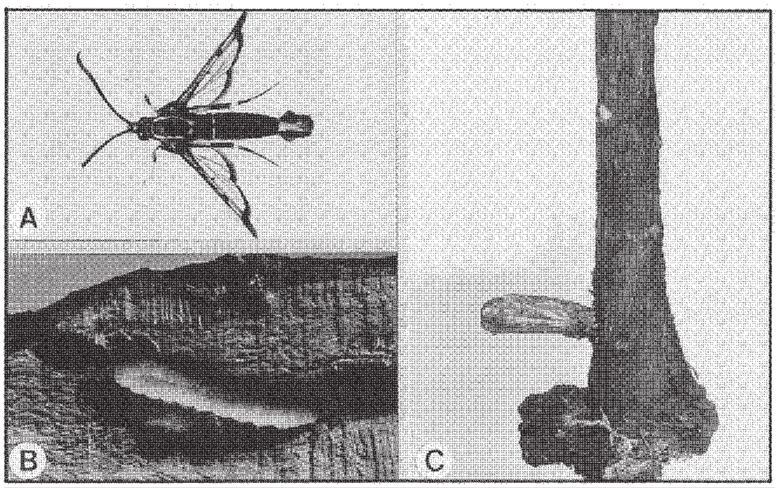

Figure 36—Synanthedon albicornis, *[western willow clearwing]: A, adult; B, larva; C, young willow with frass clump and protruding pupal skin.*

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

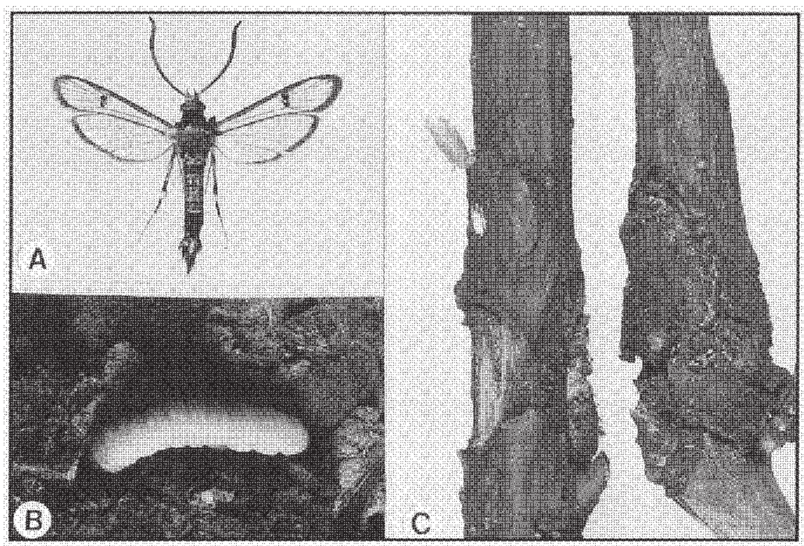

Figure 37—Synanthedon viburni, *[viburnum clearwing borer]: A, adult; B, larva; C, gnarled scarred stems with pupal skin protruding from bark (A & C, courtesy R. Hodges).*

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

Lepidoptera

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 l7 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

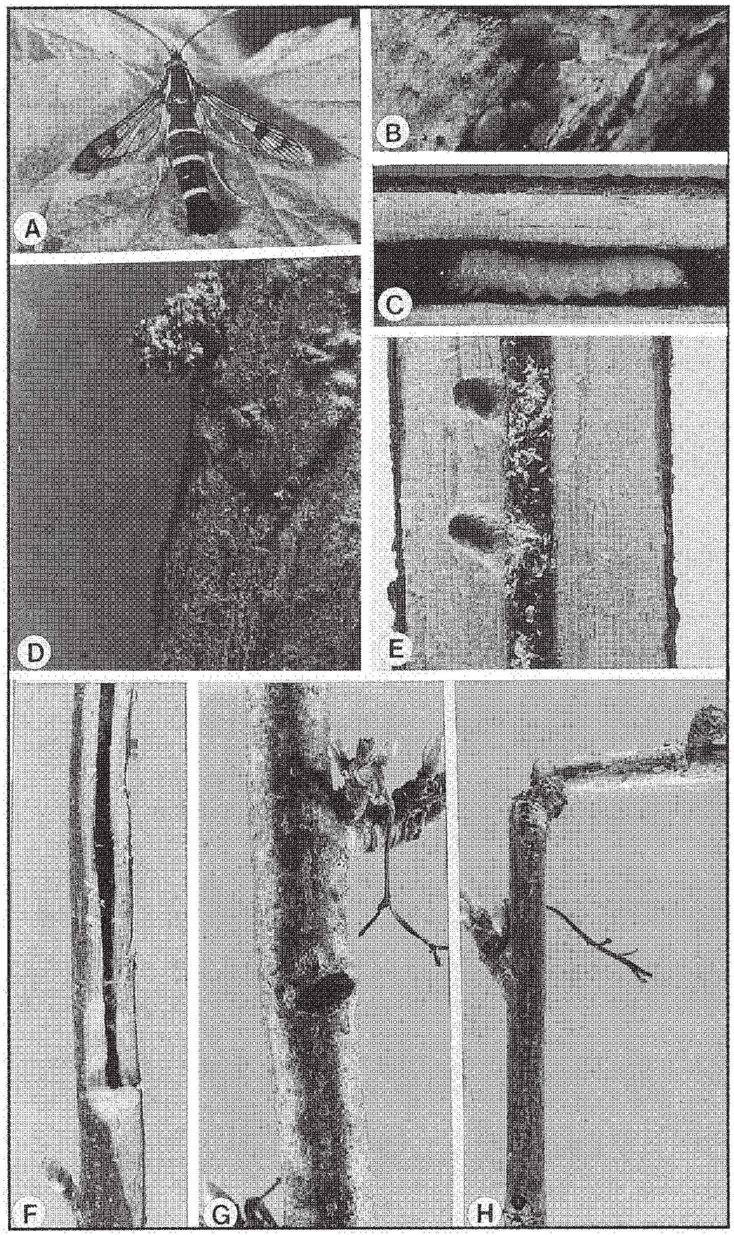

Figure 38—Synanthedon tipuliformis, *currant borer: A, adult; B, eggs; C, larva; D, frass clump on bark; E, larval burrows in wood; F, larval burrow in pith; G, entrance hole in cane; H, cane broken at entrance site (A-C, F-H, courtesy R. Bedding; D, courtesy A. Antonelli; E, courtesy R. Scott).*

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

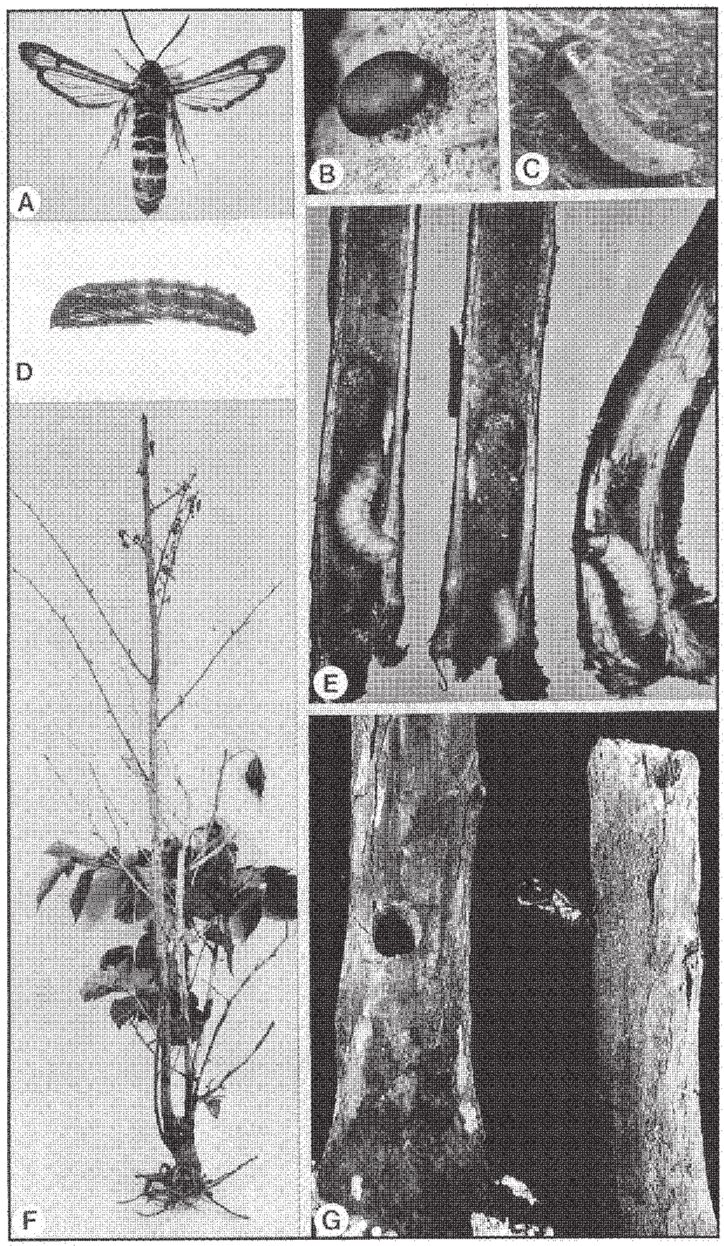

Figure 39—Pennisetia marginata, *raspberry crown borer: A, adult; B, egg; C, larva; D, pupa; E, tunneled canes; F, cane dieback with new shoots; G, exit hole and pupal skin protruding (A, specimen courtesy R. Hodges; B, C, courtesy R. Williams; D, E, G, courtesy A. Antonelli and E. Breakey).*

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

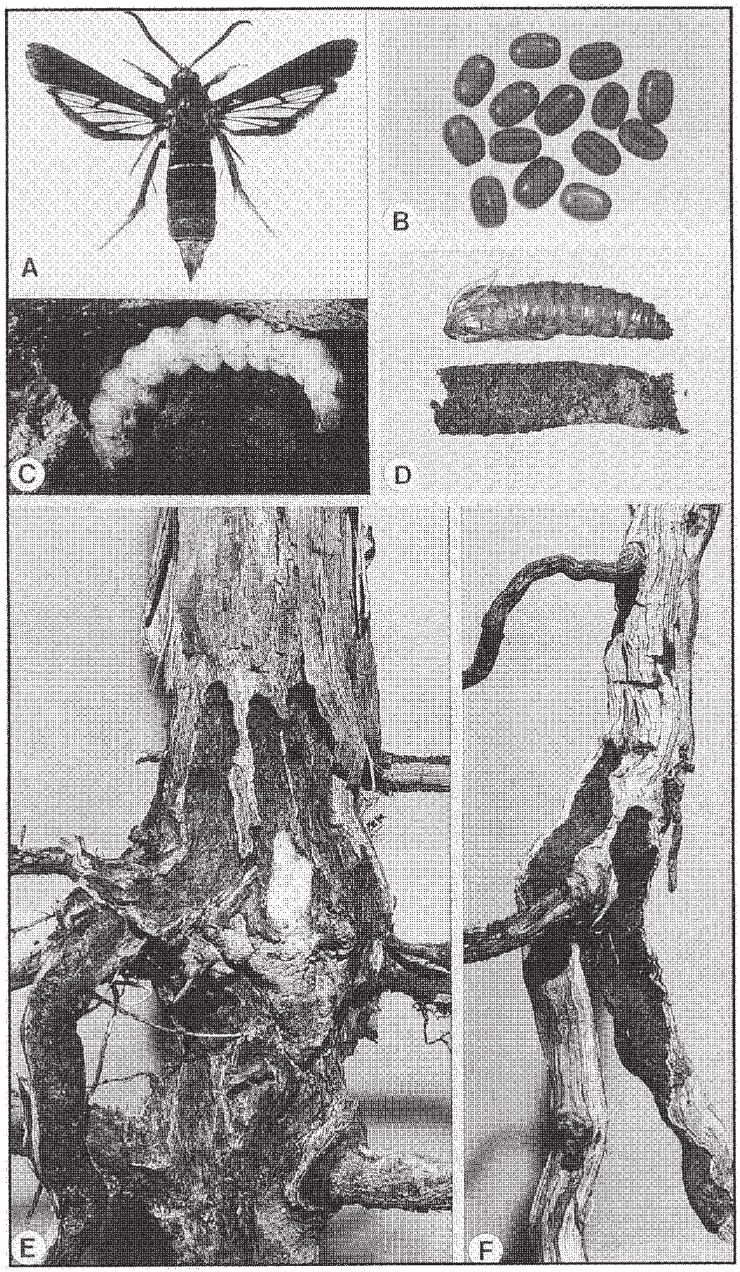

Figure 40—Vitacea polistiformis, *grape root borer: A, adult; B, eggs; C, larva; D, pupal skin and earthen cocoon; E, multiple galleries at root collar; F, burrows extending along main roots (B-D, courtesy D. Pollet).*

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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

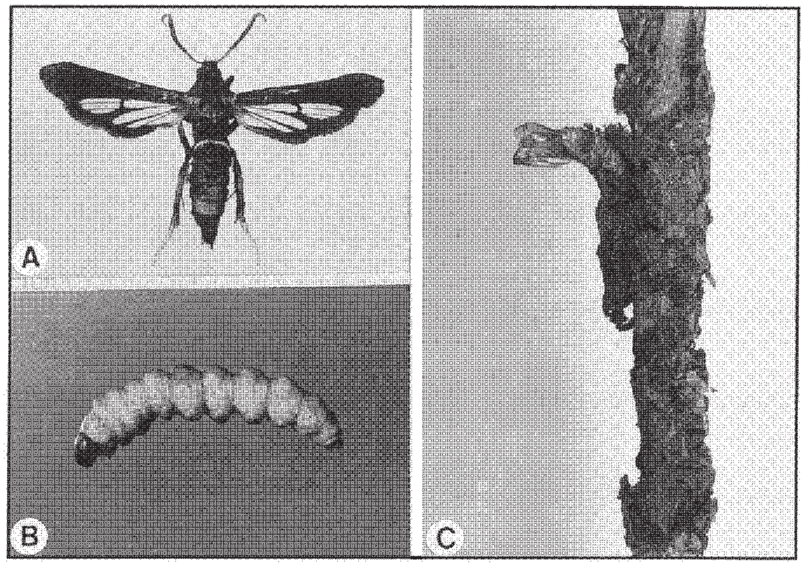

Figure 41—Vitacea scepsiformis, *[Virginia creeper clearwing]: A, adult; B, larva; C, damaged stem with pupal skin protruding from bark (specimens, courtesy R. Hodges).*

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

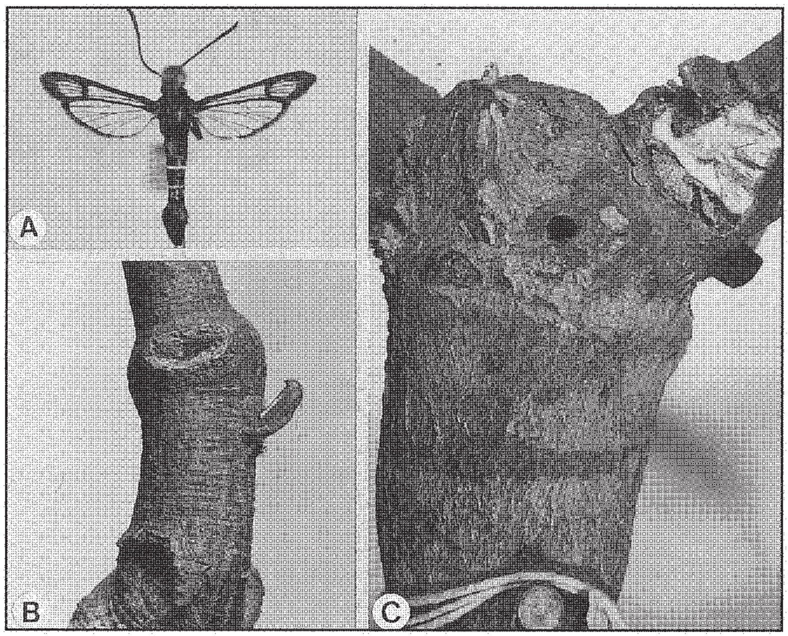

Figure 42—Carmenta phoradendri, *[mistletoe borer]: A, adult; B, pupal skin protruding from stem; C, feeding injury and exit hole (specimens courtesy R. Hodges).*

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

Lepidoptera

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.

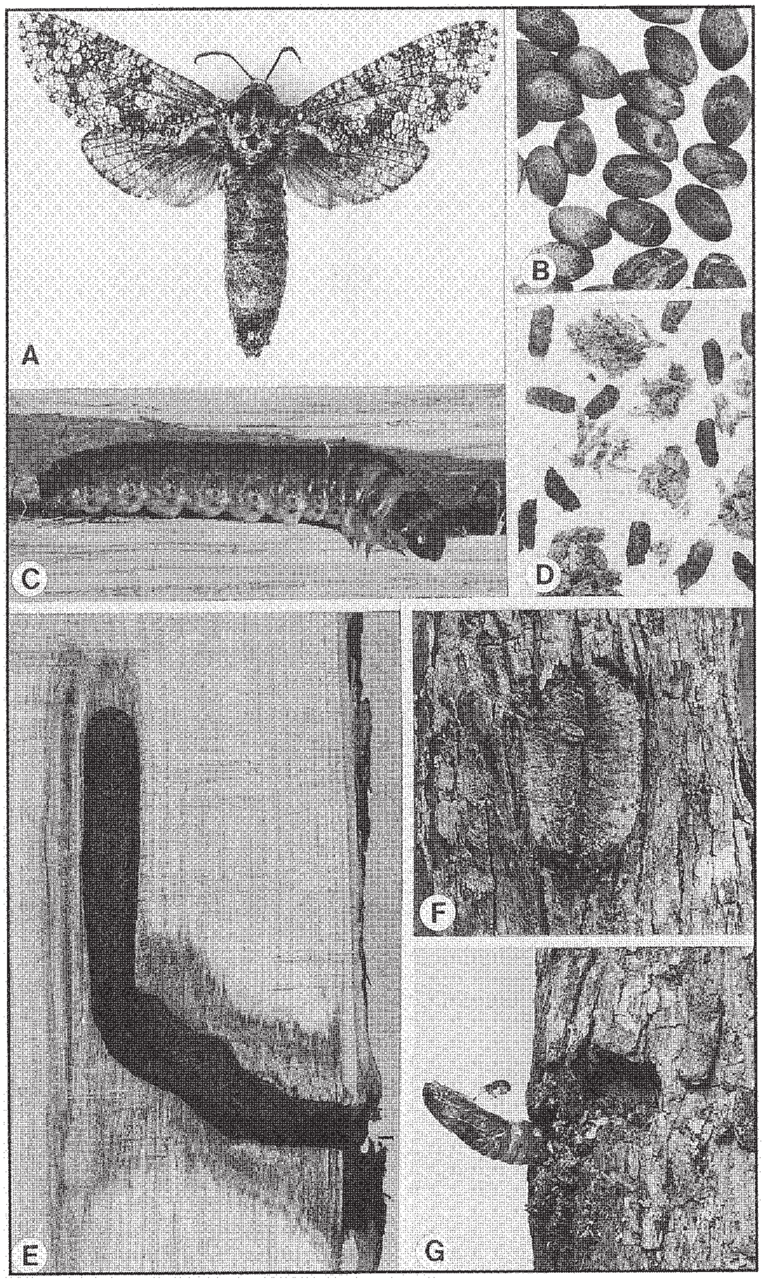

Figure 43—Prionoxystus robiniae, *carpenterworm: A, adult female; B, eggs; C, larva in gallery; D, frass of wood chips and excrement pellets; E, typical gallery; F, oval bark scar; G, pupal case protruding from exit hole.*

Lepidoptera

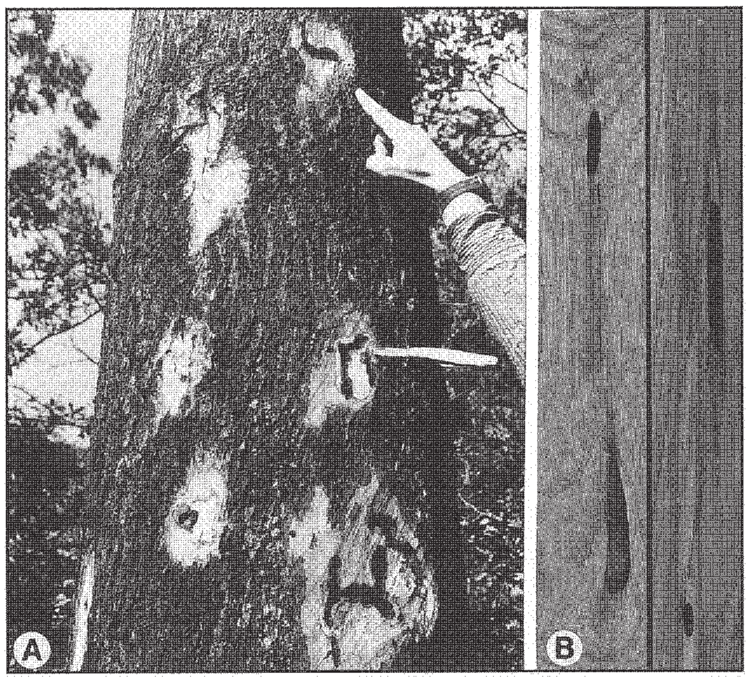

Figure 44—*Damage caused by* Prionoxystus robiniae, *carpenterworm: A, numerous attacks on bole of large red oak; B, wormhole defects in oak lumber.*

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-

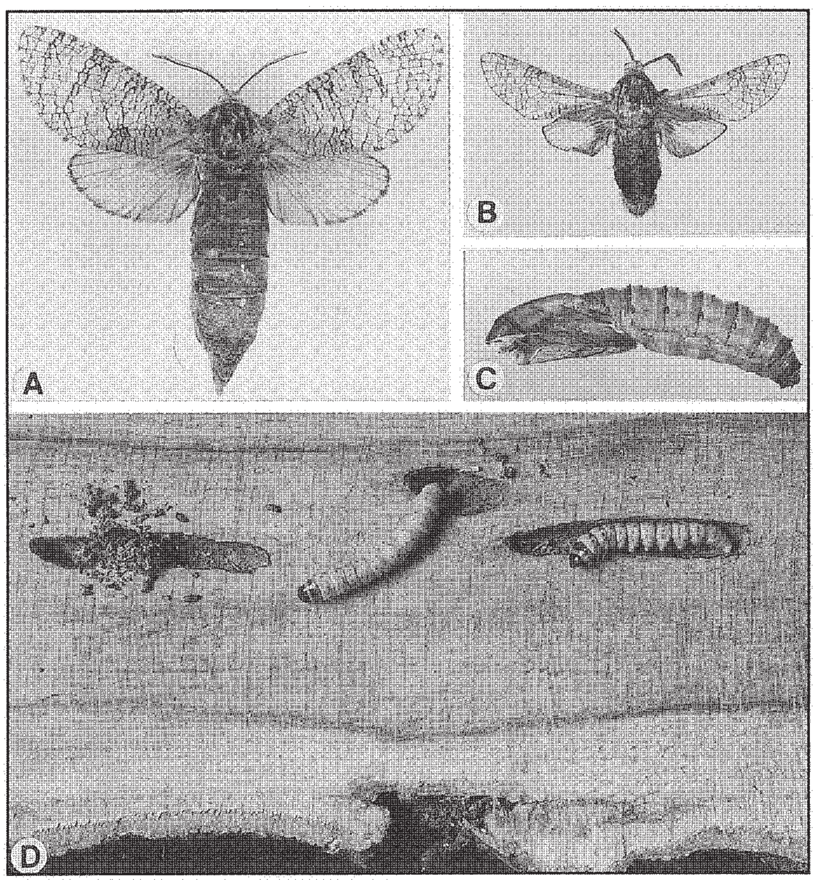

Figure 45—Prionoxystus macmurtrei, *little carpenterworm: A, adult female; B, adult male; C, pupal case; D, larvae with tunnels in red oak (specimens A & B, courtesy R. Hodges).*

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

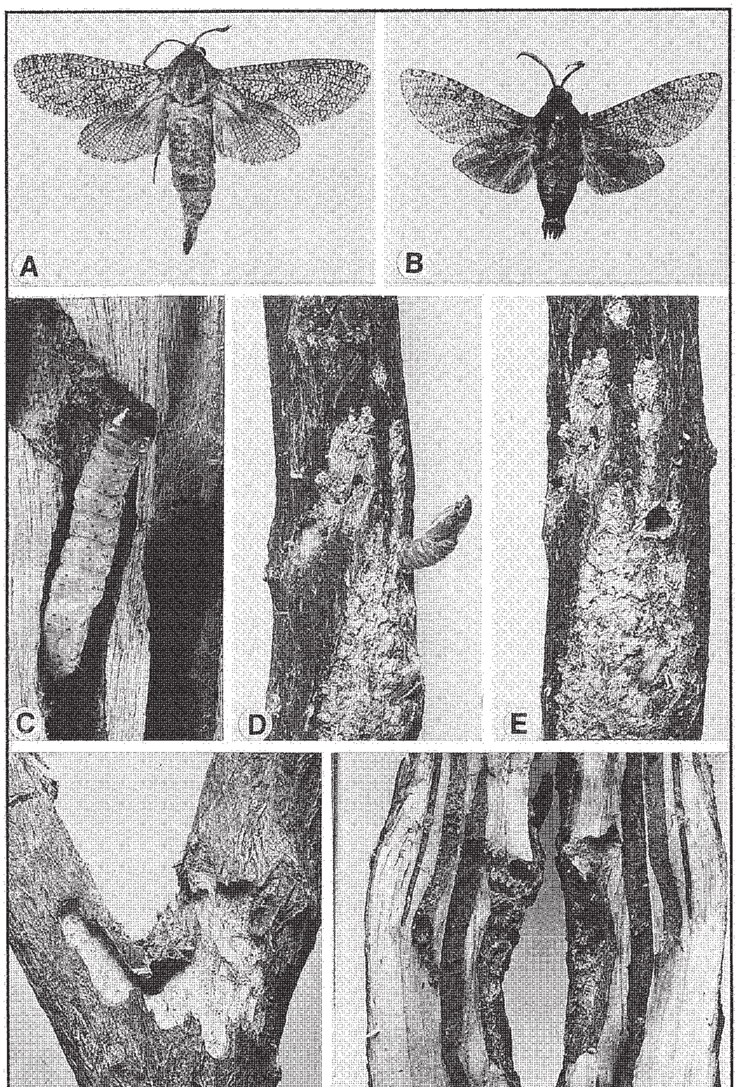

Figure 46—Prionoxystus piger, *[baccharis carpenterworm]: A, adult female; B, adult male; C, larva in gallery; D, pupal case in exit hole; E, entrance hole and frass; F, cambial burrow; G, larval galleries (specimens A & B, courtesy R. Hodges; specimens C-G, courtesy W. Palmer).*

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

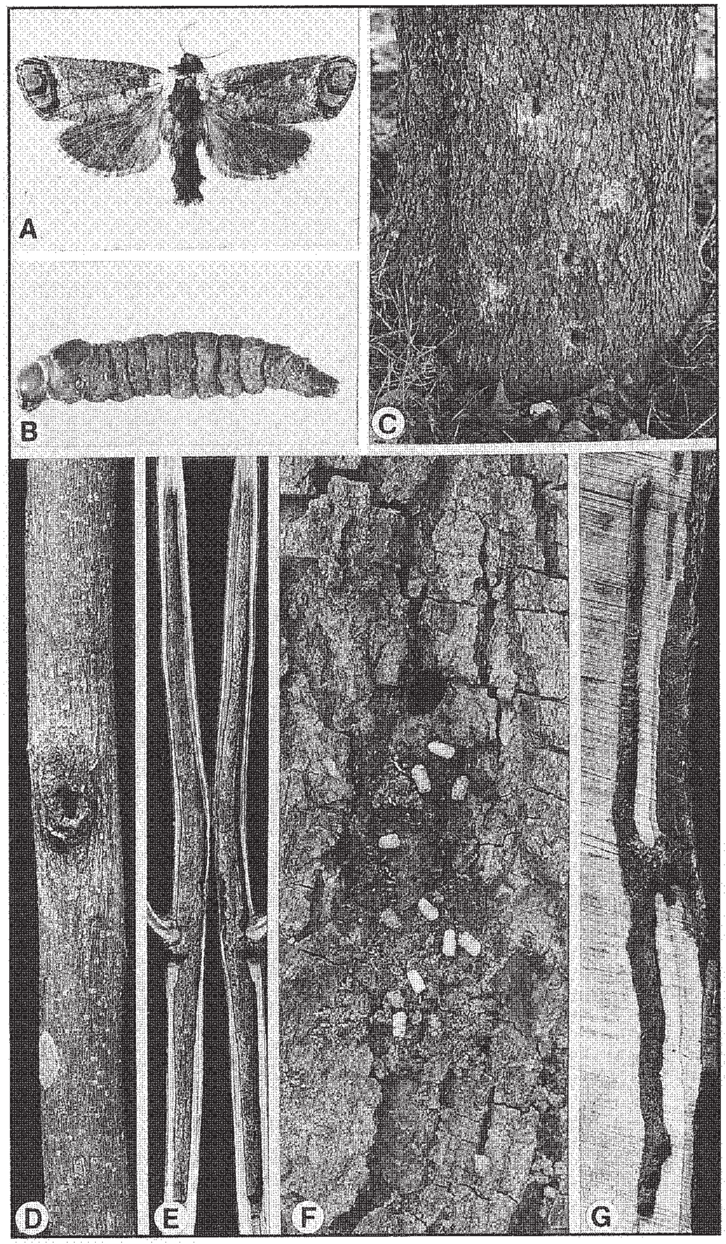

Figure 47—Cossula magnifica, *pecan carpenterworm: A, adult male; B, larva; C, holes and bark scars on trunk; D, entrance hole in branch; E, branch gallery; F, entrance hole, frass, and stained bark on trunk; G, completed gallery in trunk (specimens A & B, courtesy D. Habeck).*

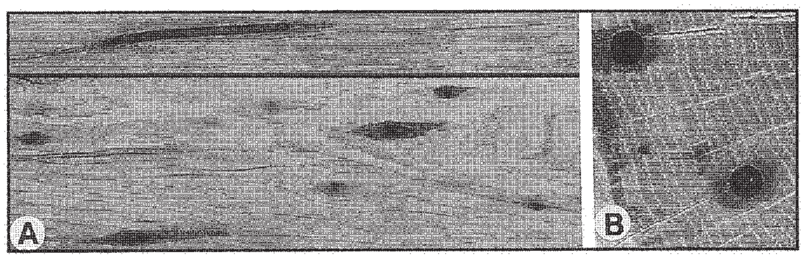

Figure 48—*Damage caused by* Cossula magnifica, *pecan carpenterworm: A, wormhole defects in lumber; B, round holes in log end.*

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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-

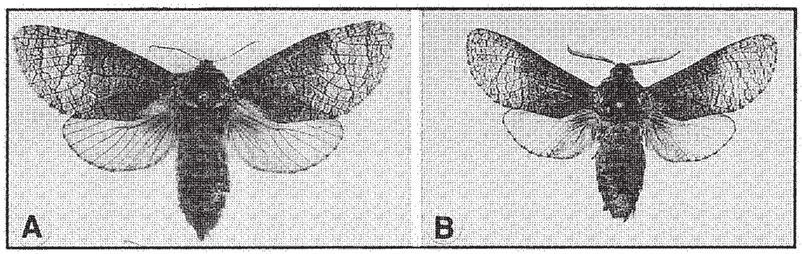

Figure 49—Acossus centerensis, *[poplar carpenterworm]: A, adult female; B, adult male (specimens courtesy R. Hodges).*

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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

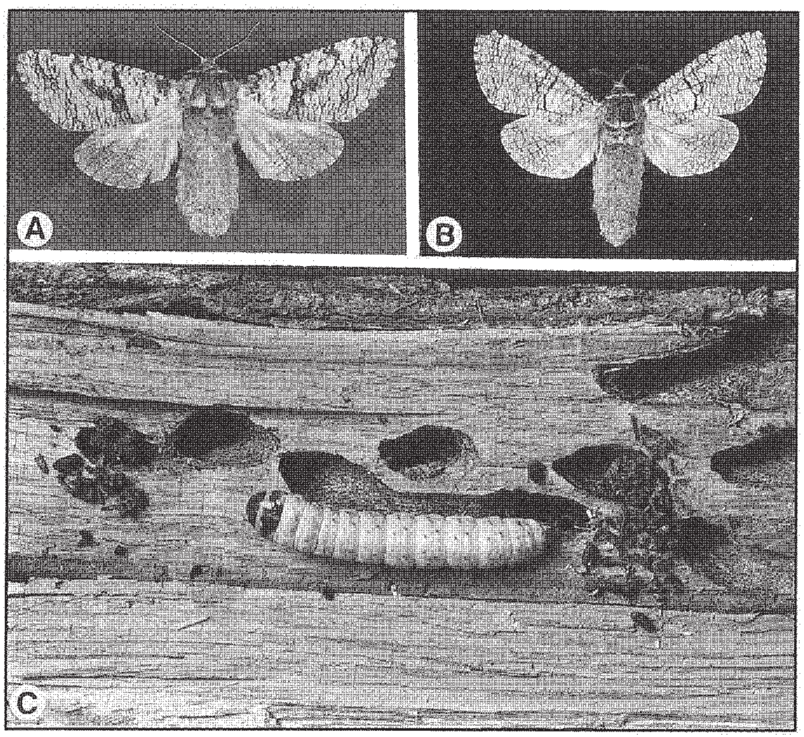

Figure 50—Acossus populi *[aspen carpenterworm]: A, adult female; B, adult male; C, larva and galleries in aspen (specimens courtesy R. Hodges).*

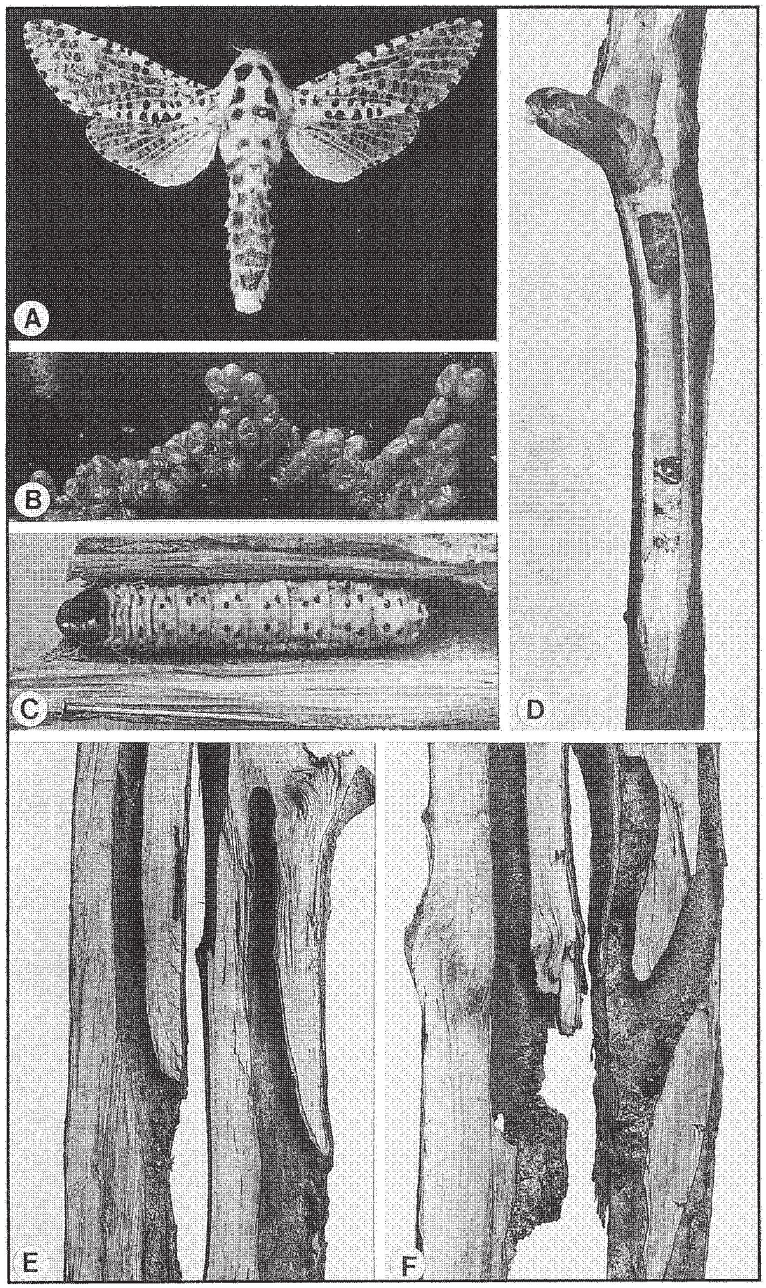

Figure 51—Zeuzera pyrina, *leopard moth: A, adult male; B, eggs; C, mature larva; D, tunneled twig with pupal skin protruding; E, single galleries in branches; F, multiple galleries in stem (B & C, courtesy of W. Johnson).*

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

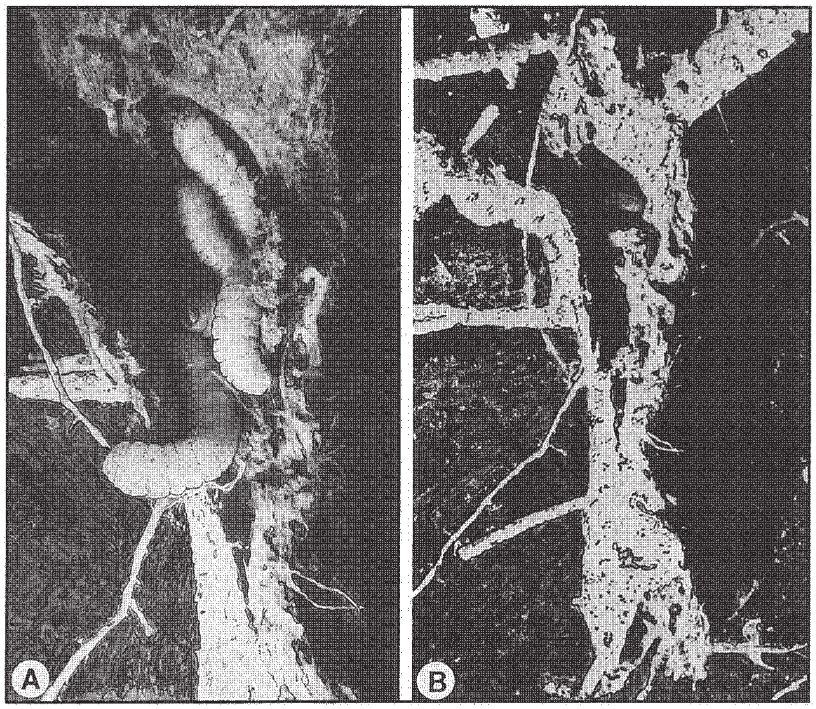

Figure 52—Comadia suaedivora, *[alkali blite borer]: A, cluster of larvae feeding in alkali blite; B, crown and root broken open to expose feeding cavity (courtesy R. M. Brown).*

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.

Lepidoptera

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

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

Genus and Species

Gypsonoma haimbachiana (Kearfott)

cottonwood twig borer (figure 53)

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

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

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

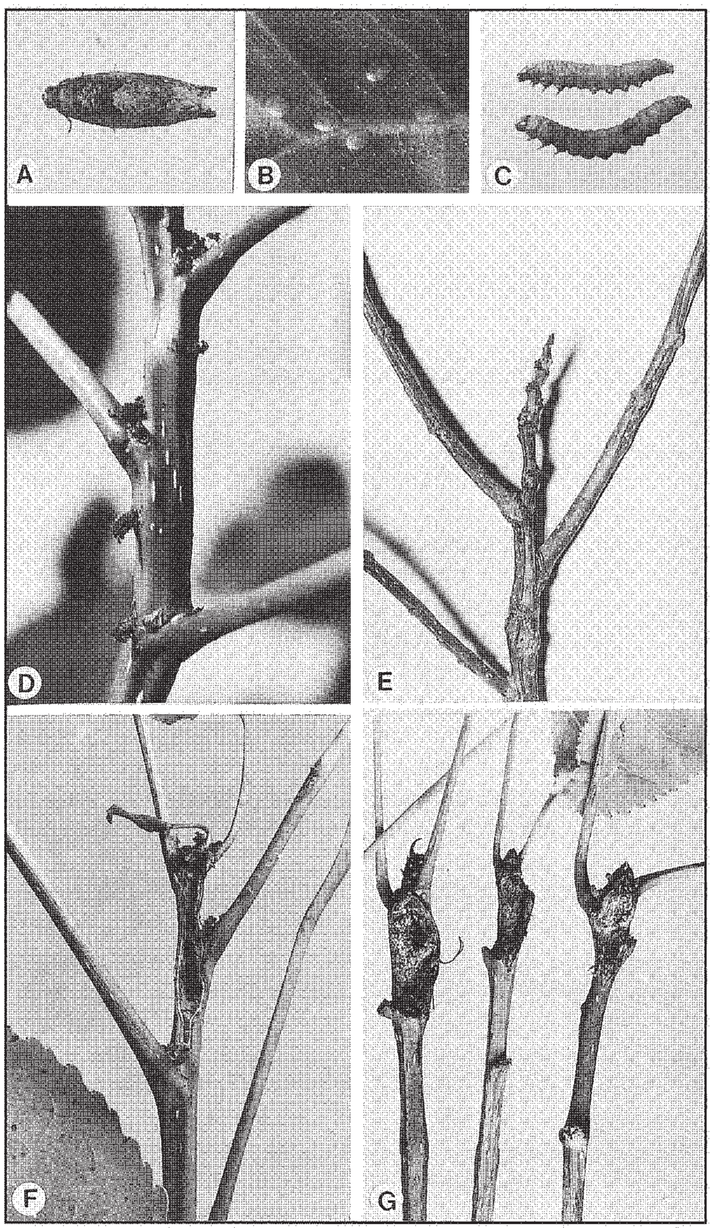

Figure 53—Gypsonoma haimbachiana, *cottonwood twig borer: A, adult; B, eggs; C, larvae; D, frass tubes at entrance holes; E, killed terminal; F, larval tunnel in terminal; G, Terminals flared open by potter wasp predation.*

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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-

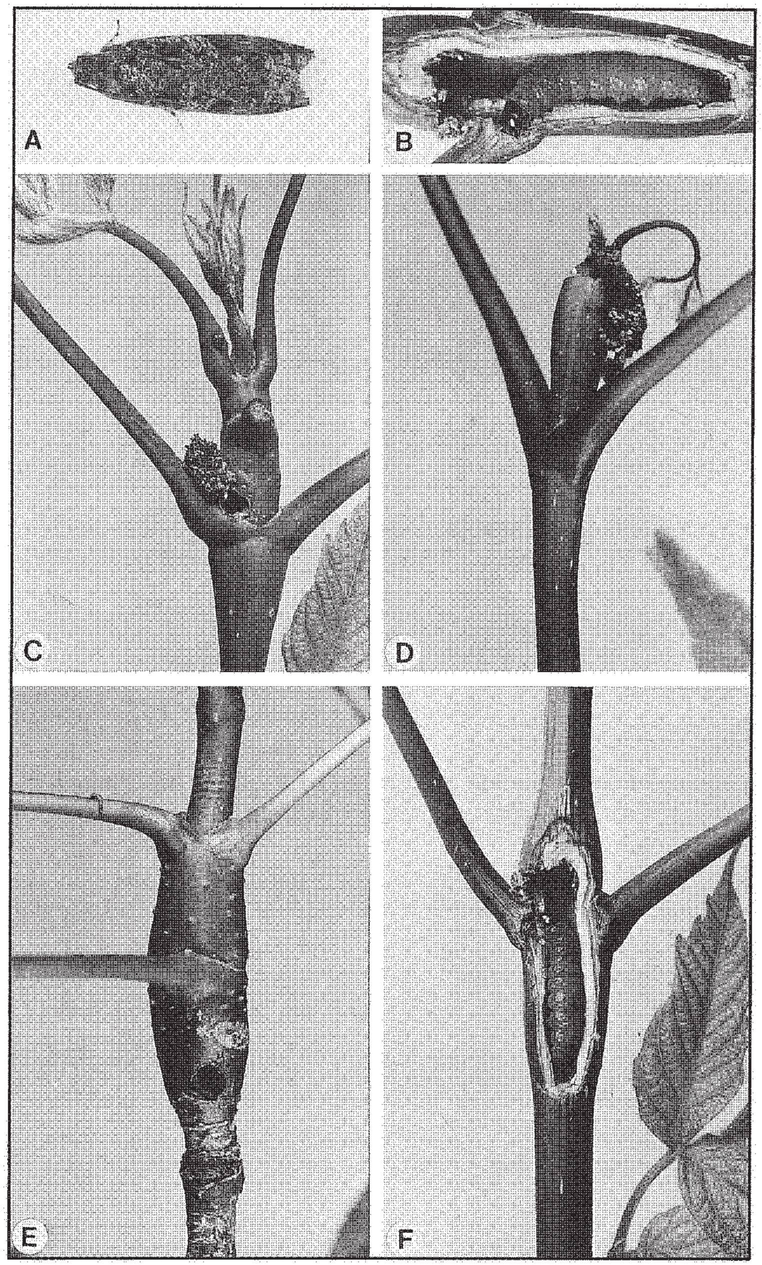

Figure 54—Proteoteras willingana, *boxelder twig borer: A, adult; B, larva; C, frass protruding from entrance at petiole juncture; D, dead terminal with frass at apex; E, gall-like swelling with entrance hole; F, gallery exposed.*

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

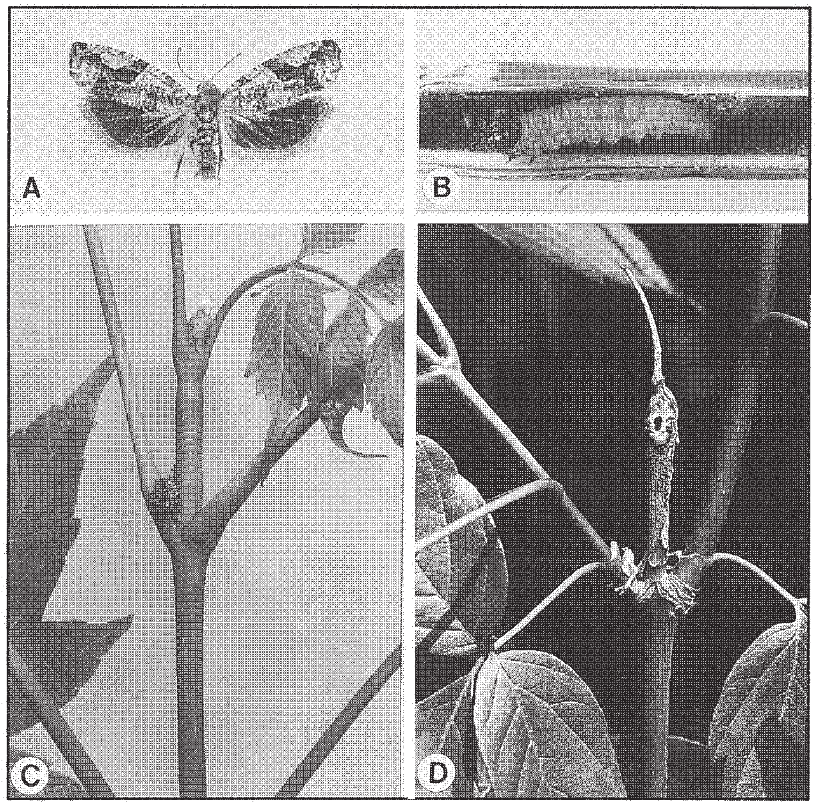

Figure 55—Proteoteras arizonae, *[California boxelder twig borer]: A, adult; B, larva; C, frass clump at larval entrance; D, dead terminal with entrance hole (A, specimen courtesy R. Hodges).*

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

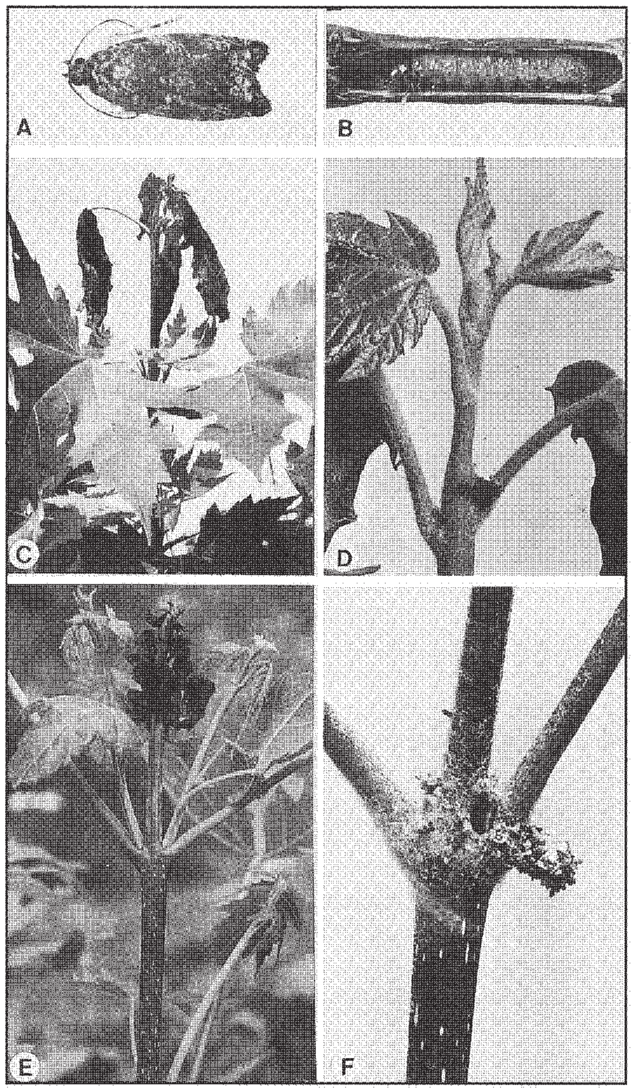

Figure 56—Proteoteras aesculana, *[maple twig borer]: A, adult; B, larva; C, dead terminal; D, frass at juncture of petiole; E, laterals elongating after terminal being killed; F, larval entrance hole.*

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

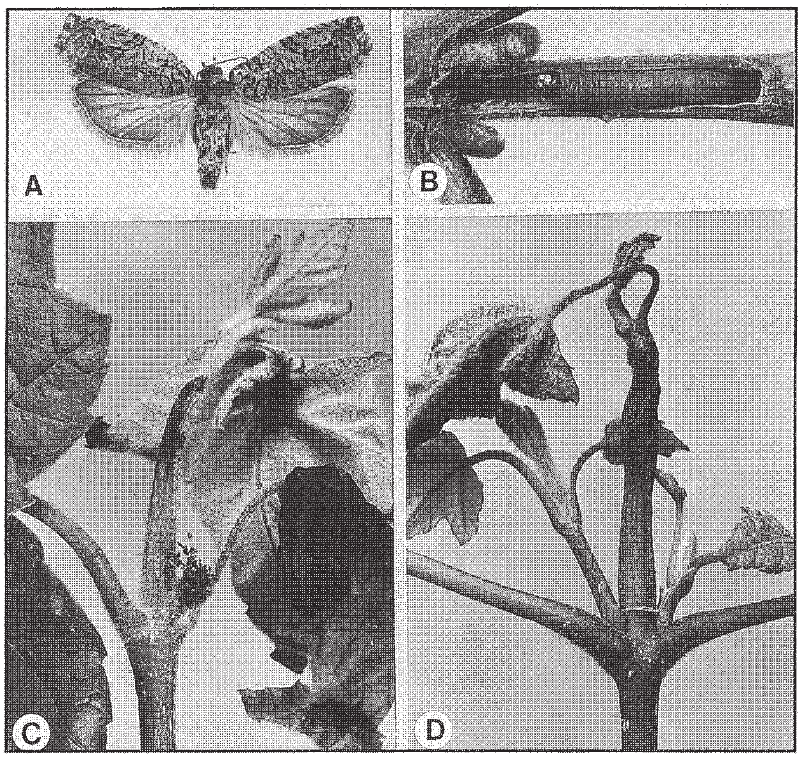

Figure 57—Proteoteras moffatiana, *[maple bud borer]: A, adult; B, larva; C, frass clump at base of dead petiole; D, terminal and one lateral dead allowing opposite lateral to elongate (A, specimen courtesy R. Hodges).*

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

Lepidoptera

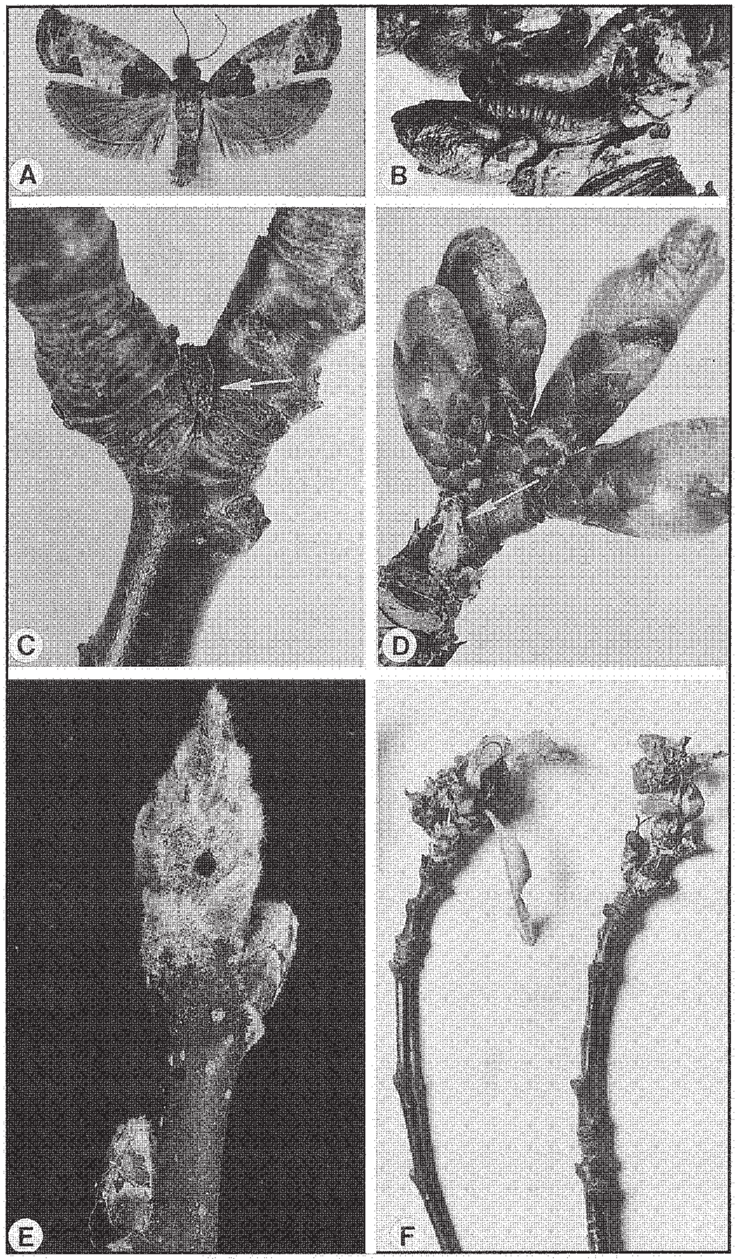

Figure 58—Spilonota ocellana, *eyespotted bud moth: A, adult; B, larvae; C, hibernaculum in twig crotch; D, hibernaculum opened to expose silken interior; E, larval entrance in bud; F, crumpled leaves at twig tip (B–F, courtesy E. Oatman).*

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

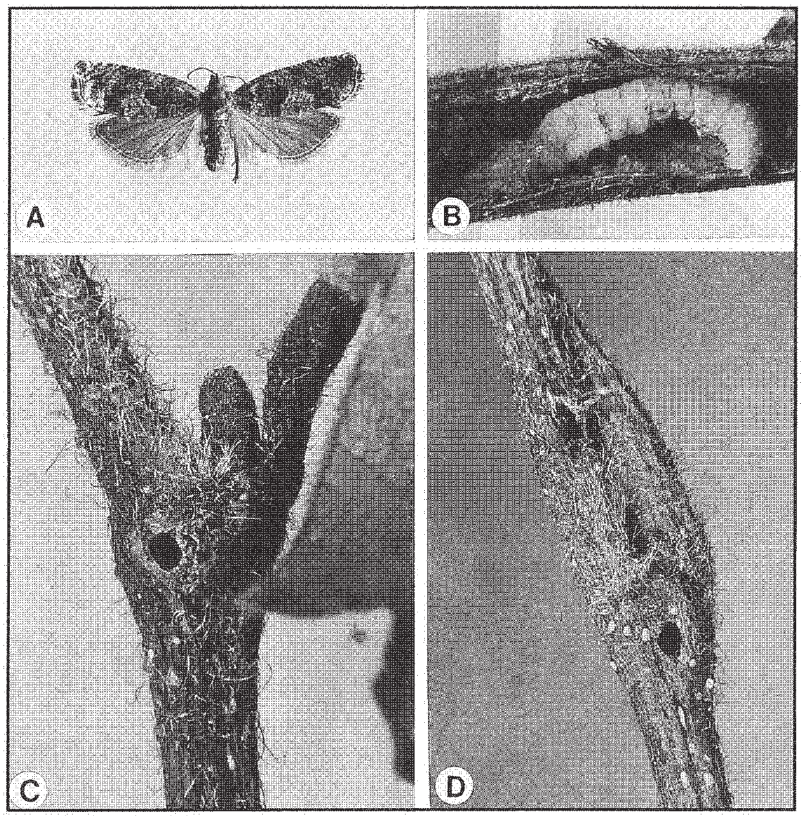

Figure 59—Epinotia solicitana, *[birch shoot borer]: A, adult; B, larva; C, infested swollen shoot; D, entrance hole near juncture of petiole and bud (A, specimen courtesy R. L. Brown).*

(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

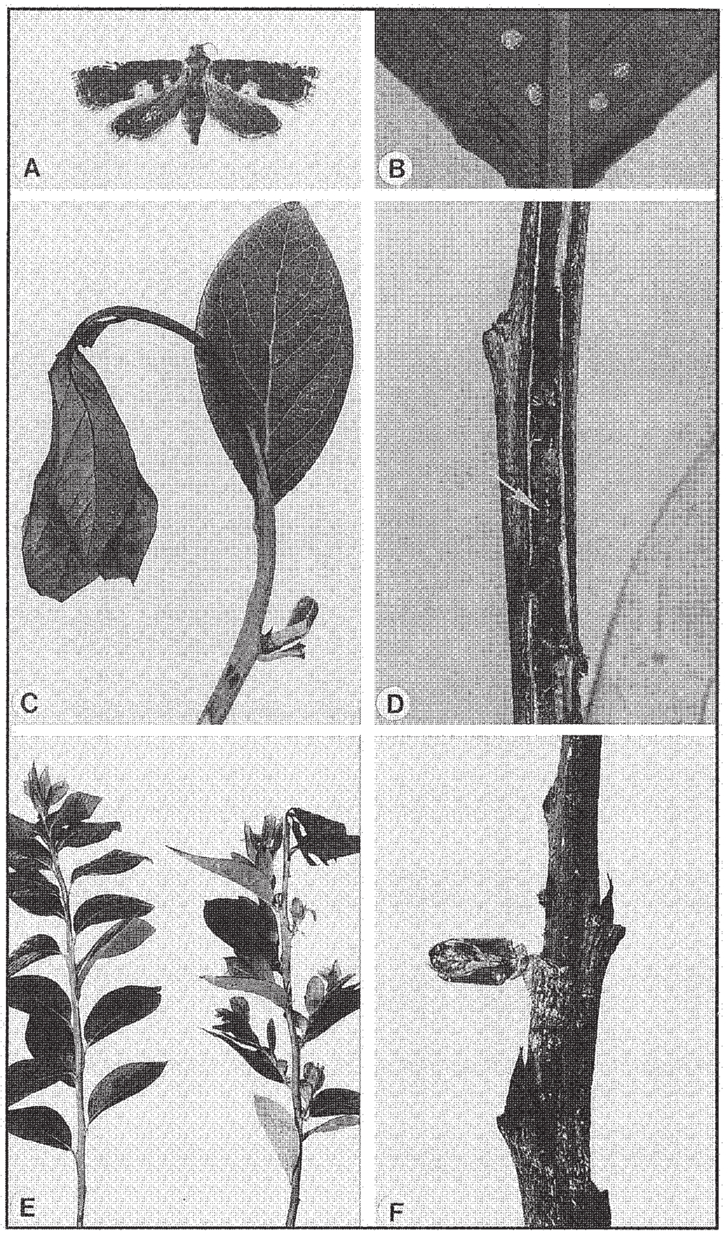

Figure 60—Hendecaneura shawiana, *[blueberry tip borer]: A, adult; B, eggs on underside of leaf; C, wilting shoot; D, burrow and larva; E, healthy shoot on left, infested shoot at right with dead tip and laterals beginning growth; F, pupal skin protruding from shoot (courtesy G. Schaefers).*

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).

Lepidoptera

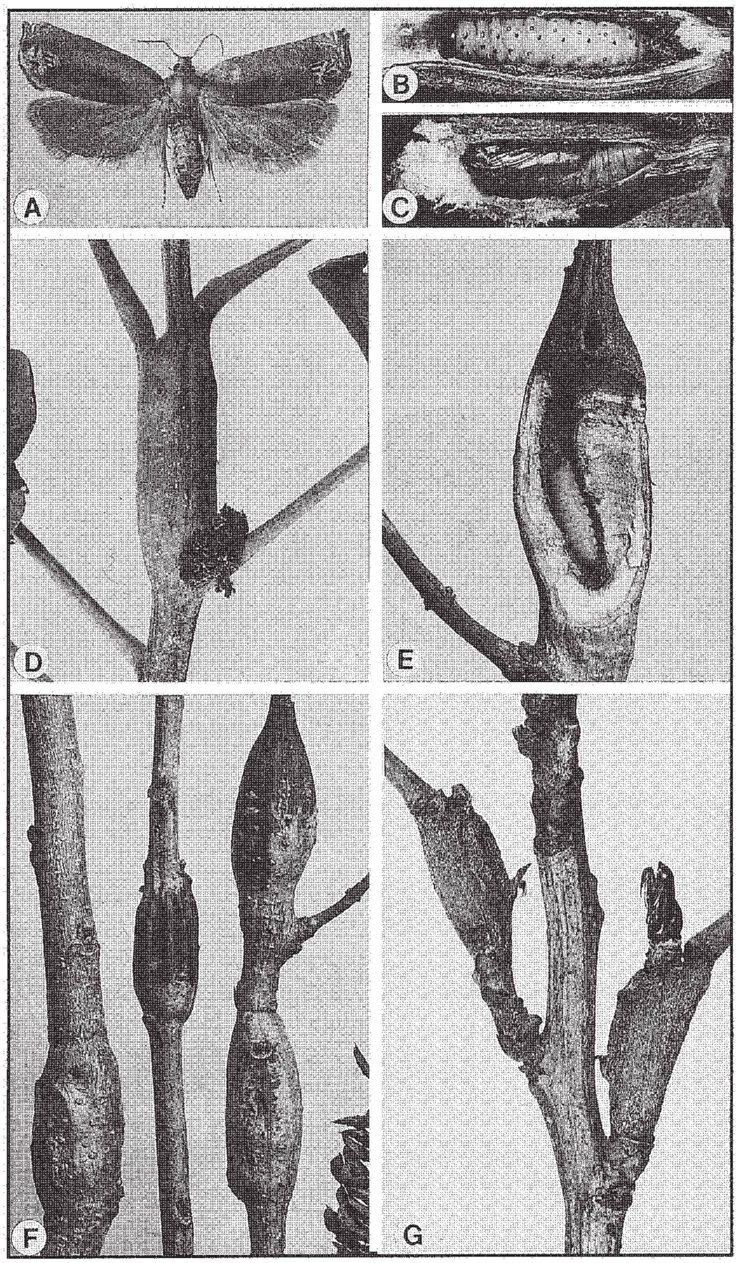

Figure 61—Hystricophora taleana, *[indigobush twig borer]: A, adult; B, larva; C, pupa; D, frass clump at base of petiole; E, larval burrow; F, gall-like swellings on stems; G, pupal skin protruding from enlarged stem.*

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

Lepidoptera

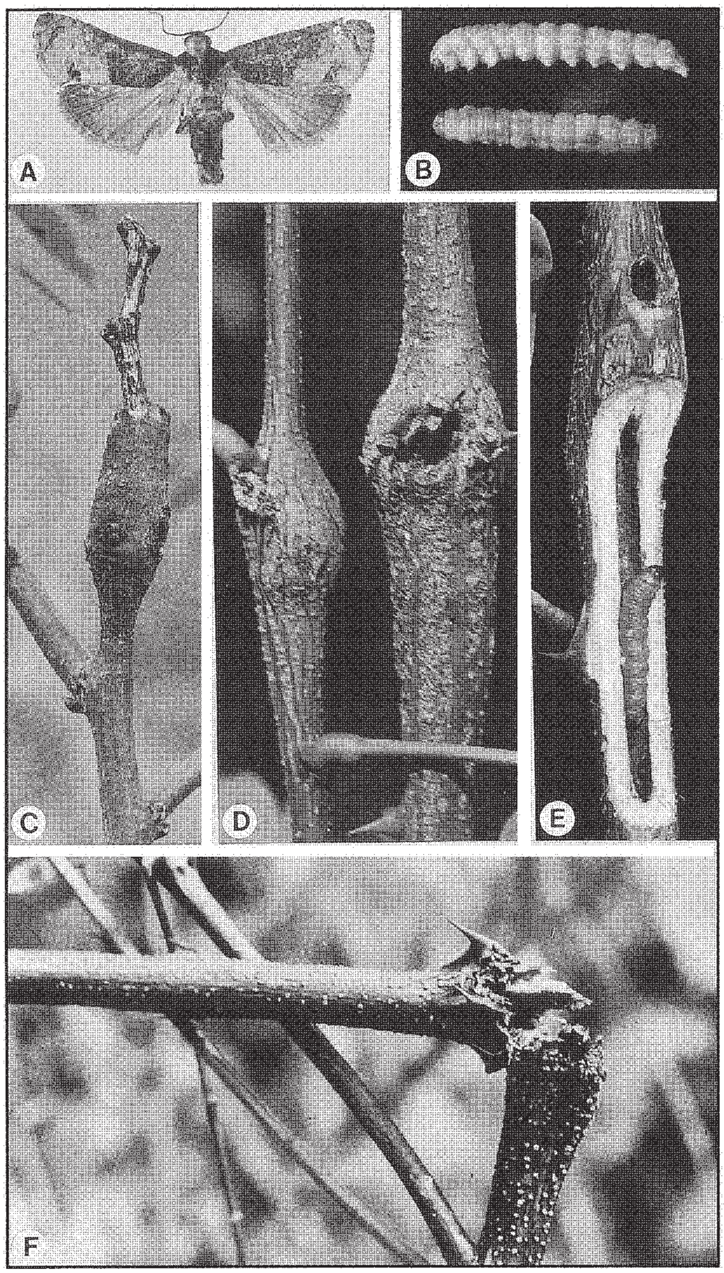

Figure 62—Ecdytolopha insiticiana, *locust twig borer: A, adult; B, larvae; C, gall-like swelling on terminal; D, swollen stems with entrance hole and frass; E, stem split to expose gallery; F, broken stem.*

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

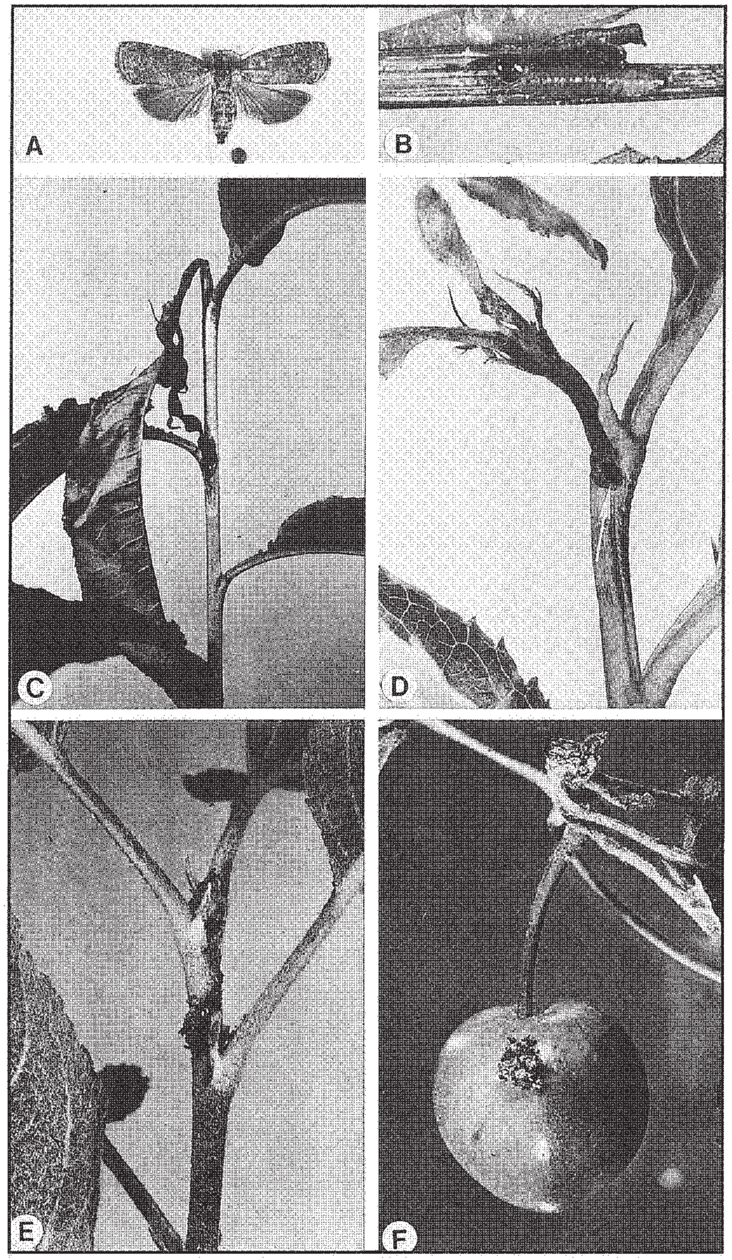

Figure 63—Grapholita molesta, *oriental fruit moth: A, adult; B, larva; C, wilting shoot tip; D, entrance hole in shoot; E, frass at entrance site; F, frass clump on infested fruit (A, specimen courtesy R. Hodges; B, E, & F, courtesy NY Agricultural Experiment Station).*

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.

Lepidoptera

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.

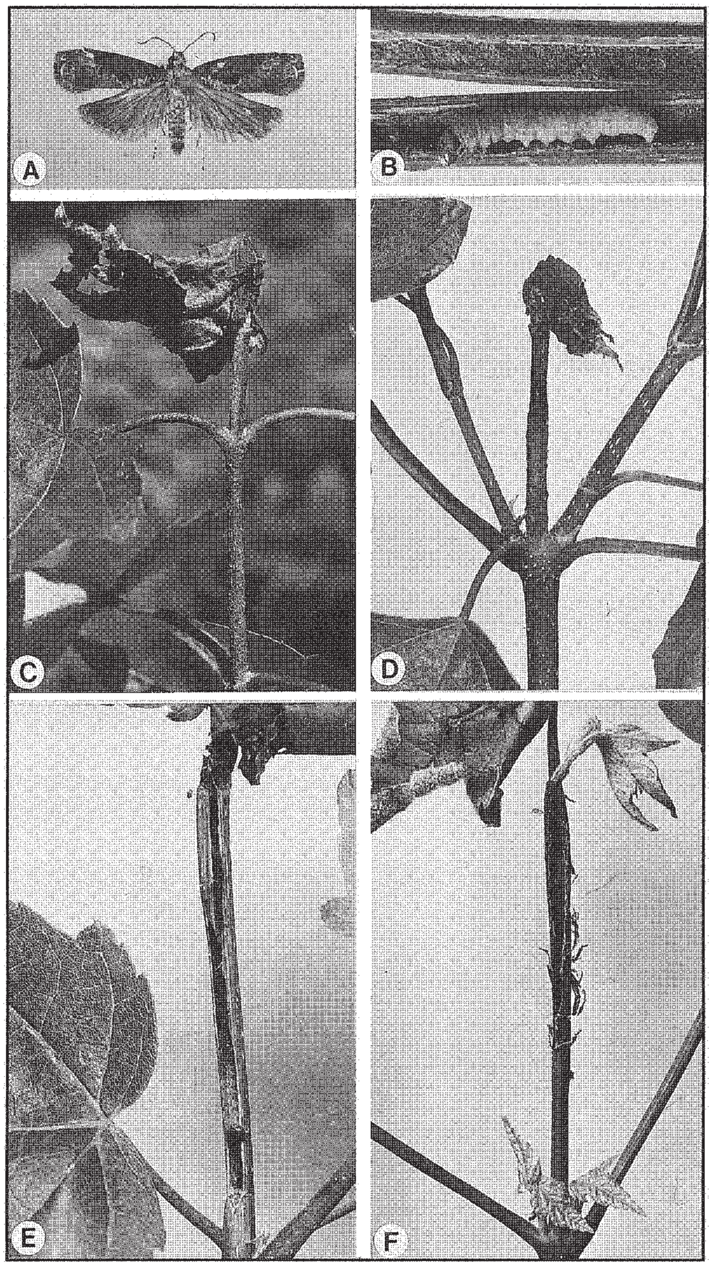

Figure 64—Episimus tyrius, *[maple tip borer]: A, adult; B, larva; C, withering shoot tip; D, silk-tied leaves around dead terminal; E, gallery exposed; F, stem shredded by predator, exposing gallery.*

Lepidoptera

Family Pyralidae—Snout Moths

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

Genus and Species

Euzophera ostricolorella Hulst

[root collar borer] (figure 65)

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

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

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

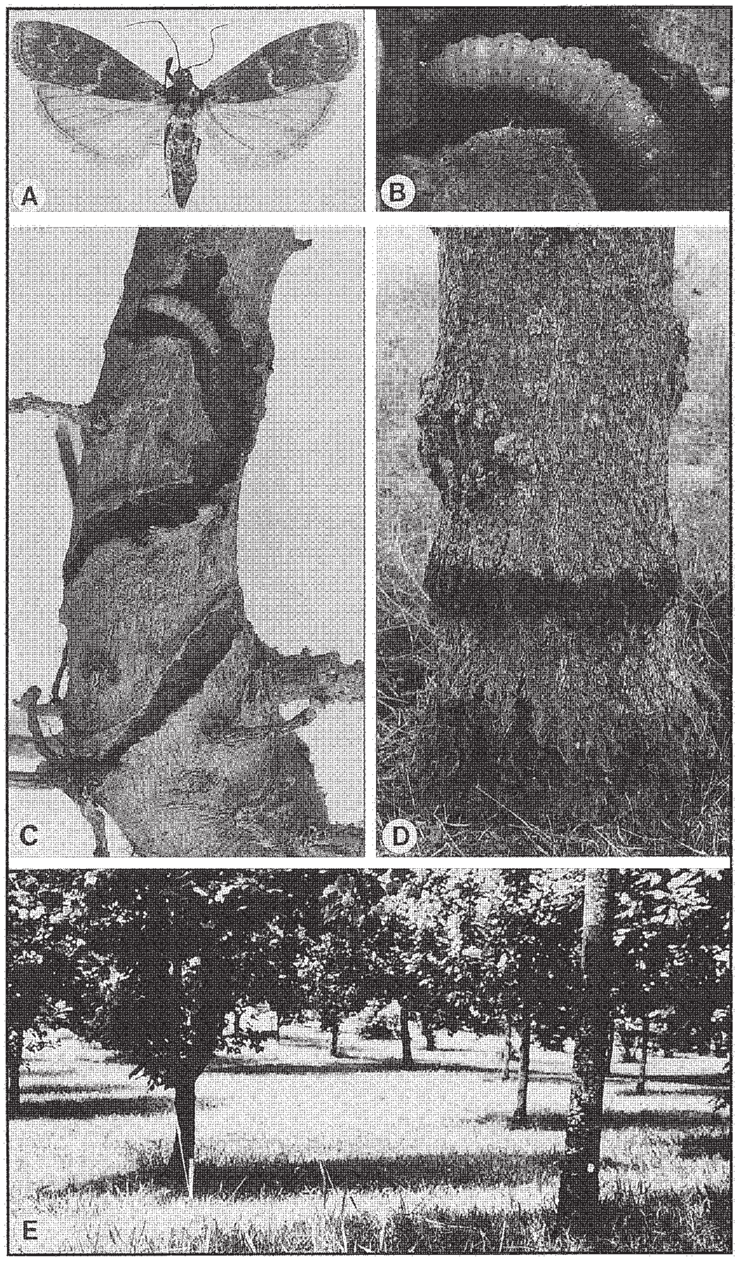

Figure 65—Euzophera ostricolorella, *[root collar borer]: A, adult; B, larva; C, spiral burrow in sapling; D, tree heavily infested at root collar; E, heavily infested yellow-poplar seed orchard (E, courtesy C. Pless).*

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

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

Injury and damage. Injury is often difficult to detect because most attacks are in a relatively narrow zone at the tree base, from about 16 cm above ground to about 7 cm below (figure 65C, D, and E). Trees from about 3 cm diameter at root collar to sawlog size may be attacked. Burrows in seedlings and saplings often spiral around the root collars (figure 65C). Recent larval attacks on vigorous trees may be accompanied by black ooze and frass from entrance holes (Hay 1958) and on heavily infested trees, bark just above the soil line may be loose, cracked, and appear fire scorched (figure 65D) (Schuder and Giese 1962). Because larval burrows are entirely in the succulent inner bark and cambium, they can be observed easily by cutting away the outer bark. White, loosely spun cocoons may also be observed in larval burrows. Numerous small exit holes, made by pre-pupal larvae for the adults' emergence, can be found at the bases of infested trees, but no empty pupal cases (skins) protrude from the holes, as they do with some wood-infesting moths. Another symptom of heavy infestation is a gradual yellowing of foliage and crown dieback. Open-grown trees, such as those in seed orchards, are particularly susceptible (figure 65E). This borer was not recognized as an economic pest until 1954, when it was reported killing yellow-poplars, particularly trees larger than 25 cm in diameter, on a 2,228-ha timber tract in Kentucky (Hay 1958). Considerable dieback and mortality of yellow-poplars has been reported in northern Indiana woodlots (Schuder and Giese 1962). Also, extensive borer damage was found in 2.5-cm-diameter yellow-poplar grafting stock in seed orchards; as many as 10 larvae were observed in some trees (Churchwell 1966). A canker disease—*Fusarium solani* (Martins, [Appel and Wollenweber])—associated with borer damage killed 19, 22, and 50% of the high-value trees in three west Tennessee seed orchards (figure 65E) (Hope and Pless 1979). When attacks occur on the bole, callus tissue and ingrown bark produce small defects in the wood (Hay 1958). However, because few attacks occur above stump height, degrade is not a serious problem. Moreover, most defects in logs can be slabbed off or peeled away in veneer, and the result is minor value loss in wood products.

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

Euzophera semifuneralis (Walker)

American plum borer (figure 66)

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

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

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

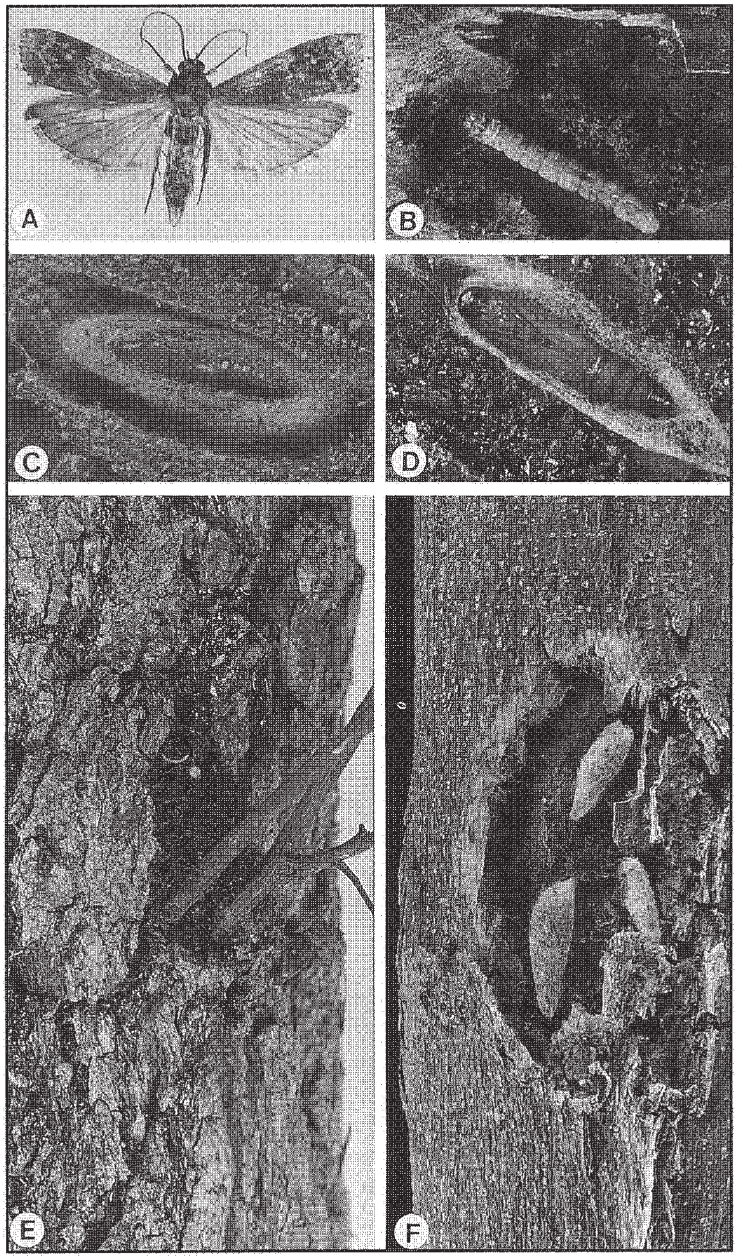

Figure 66—Euzophera semifuneralis, *American plum borer: A, adult; B, larva in burrow; C, cocoon with pupa inside; D, pupa; E, clump of dark frass on bark; F, white silken cocoons in burrows under bark.*

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

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

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

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

Euzophera magnolialis Capps

[magnolia borer] (figure 67)

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

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

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

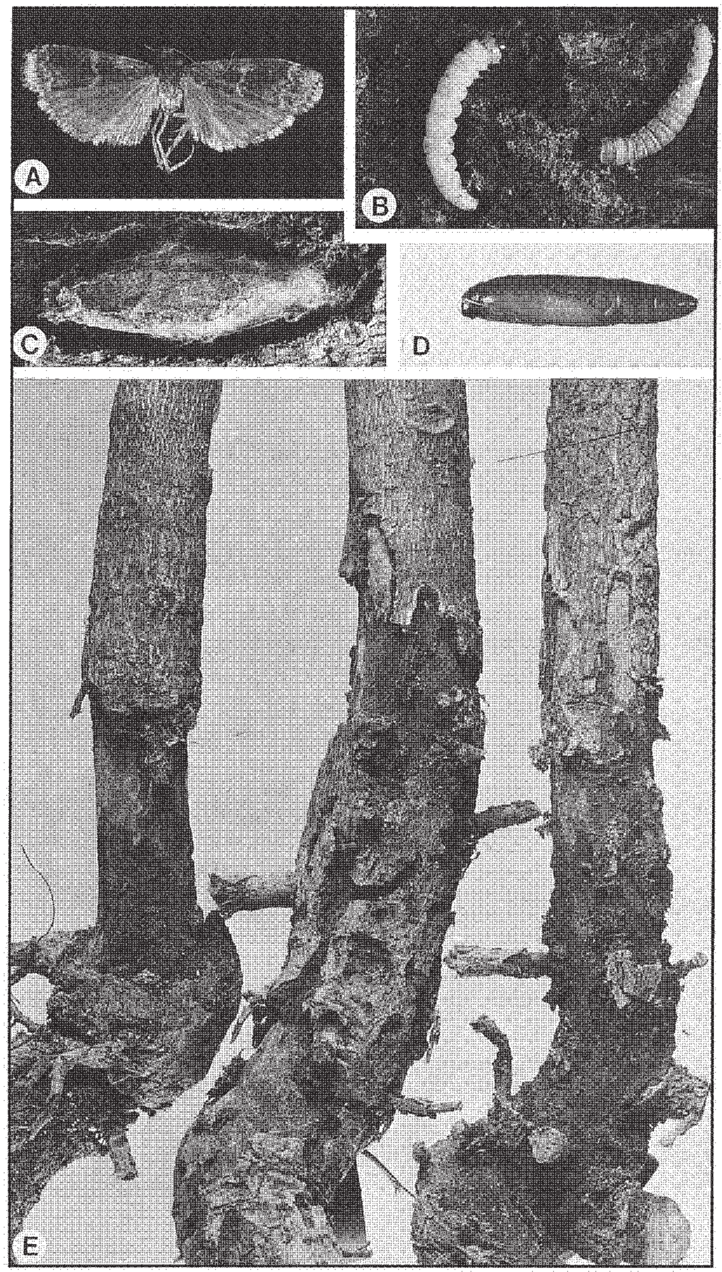

Figure 67—Euzophera magnolialis, *[magnolia borer]: A, adult; B, larvae in burrows; C, white silken cocoon in pupal cell; D, pupa; E, extensive injury at root collar of nursery-grown magnolias (A, specimen courtesy R. Hodges; B-E, specimens courtesy R. Mizell).*

moth with wingspan about 25 mm (figure 67A) (Capps 1964). Forewings purplish brown with grayish dusting predominating over basal half and from outer margin inward almost to postmedial line. Transverse postmedial line dull white and sinuate; an antemedial line of similar color. Hindwings pale, smoky black with fine dark lines along terminal margins. Head, thorax, and abdomen brownish black tinged with purple. ***Larva.*** White to dull white and about 28 mm long when mature (figure 67B). Brown body slightly flattened and tapers gradually posteriorly. Brown head with broad, dark black, lateral band from stemmata to hind margin. Thoracic and anal shields and pinacula brownish to amber. Three pairs of jointed legs on thorax. Fleshy prolegs on abdominal segments 3 to 6 bear complete ring of triordinal crochets. ***Pupa.*** Brown, hooked spines on last abdominal segment, measuring about 12 mm long and enclosed in white silken cocoon (figure 67C and D).

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

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

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

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

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

Acrobasis demotella Grote

walnut shoot moth (figure 68)

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

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

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

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

Lepidoptera