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Planting and Care of Fine Hardwood Seedlings

Hardwood Tree Improvement and Regeneration Center

Northern Research Station
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Department of Forestry and Natural Resources
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Insects Affecting Hardwood Tree Plantings

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Introduction

The Central Hardwood Region (CHR) is one of the largest forested areas in the country, covering more than 100 million acres, and is dominated by oak-hickory and mixed hardwoods. Although large areas of forest have been cleared to make way for agriculture and urban growth, the number of trees in the CHR is increasing as farm and pasture lands are reverting back to forest. In fact, more than 2.6 million acres of forest trees were planted on public and private land in 1999, with nearly half of these acres planted by private landowners (AF and PA 2001). Whether these trees were planted for timber production, wildlife habitat, riparian buffers, woodland protection, watershed restoration, windbreaks, or for conservation, the health of these trees is threatened by a litany of indigenous and invasive insect pests.

This publication is intended to provide landowners with an overview of some of the more important insect pests affecting hardwoods in the CHR. It is by no means comprehensive, but rather serves to highlight the biology and feeding damage caused by some of the more common pests. For a listing of the host associations of selected pests described in this publication please refer to Table 1 on page 2 and 3. To more effectively understand the relationships between the insects and their hosts, we present these according to their feeding and biological habits. For example, many insects use sucking mouthparts to feed on the sap of trees. Defoliators feed on leaves and are among the most economically important group of forest pests. A number of insect groups feed on or within the trunks of hardwoods, while others induce the formation of galls. Damage caused by forest pests can have economic consequences ranging from killing the entire tree, to reducing its growth, grade of timber, or seed production, causing stem deformities, or more subtly affecting recreation, wildlife, esthetics, or potential for fire. Nevertheless, a very small fraction of insects in forests are actually pests. Many insects are beneficial to forest ecosystems, and serve as predators or parasites of other insects or feed on decaying vegetation, thereby suppressing potential pests or recycling nutrients back to trees.

Inner Bark Borers

Of all forest insects, those that feed on the inner bark of trees are among the most economically important. Although there are several different insect orders and families within this guild, two of the more destructive groups are the bark beetles (Family Curculionidae: Subfamily Scolytinae) and metallic wood-boring beetles (Family Buprestidae).

Bark Beetles. Bark beetles routinely cause serious losses of standing timber, particularly in pine forests of the southern and western United States. Several species also damage hardwoods in the CHR. Most bark beetles are only millimeters in length and uniformly brown to black in color. These tiny beetles feed on the nutrient-rich cambium and disrupt nutrient flow within the tree. Some beetles are known to transmit important pathogens such as Dutch elm disease. Some of the more common bark beetles affecting hardwoods in the CHR are discussed below.

European Elm Bark Beetle

Scolytus multistriatus (Order Coleoptera: Family Curculionidae: Subfamily Scolytinae)

Host: Elms (*Ulmus* spp.).

Damage and Signs of Attack: Larvae feed under the bark of elm trees. At low population densities this beetle prefers to colonize dead and dying trees, but

Table 1. *Host association of selected insect pests of hardwoods.*

	Hickory	Pecan	Beech	Ash	Walnut	Butternut	Cherry	Oak	Elm	Chestnut	Maple	Linden	Hackberry
Inner Bark Borers													
Bark Beetles													
Elm bark beetle, *Scolytus multistriatus*									X				
Hickory bark beetle, *Scolytus quadrispinosus*	X	X				X							
Peach bark beetle, *Phloeotribus liminaris*							X						
Metallic Wood-Boring Beetles													
Emerald ash borer, *Agrilus planipennis*				X									
Borers and Girdlers													
Black stem borer, *Xylosandrus germanus*	X	X	X	X	X	X	X	X	X	X	X	X	
Redheaded ash borer, *Neoclytus acuminatus*	X		X	X	X			X	X		X	X	X
Banded ash borer, *Neoclytus caprea*				X				X					
Living hickory borer, *Goes pulcher*	X	X											
Red oak borer, *Enaphalodes rufulus*								X					
Twig girdler, *Oncideres cingulata*	X	X						X	X			X	X
Little carpenterworm, *Prionoxystus macmurtrei*								X					
Lesser peachtree borer, *Synanthedon pictipes*							X						
Greater peachtree borer, *Synanthedon exitosa*							X						
Nut Feeders													
Acorn weevils, *Curculio sp.*								X					
Black walnut curculio, *Conotrachelus retentus*					X								
Butternut curculio, *Conotrachelus juglandis*					X	X							
Pecan weevil, *Curculio caryae*	X	X											
Codling moth, *Cydia pomonella*					X								
Walnut husk fly, *Rhagoletis completa*					X								
Fluid Feeders													
Beech blight aphid, *Grylloprociphilus imbricator*			X										
Giant bark aphid, *Longistigma caryae*	X	X	X		X			X		X		X	
Beech scale, *Cryptococcus fagisuga*			X										
Twig and Petiole Feeders													
Black walnut curculio, *Conotrachelus retentus*					X								
Butternut curculio, *Conotrachelus juglandis*					X	X							
Defoliators													
Pin oak sawfly, *Caliroa lineata*								X					
Elm sawfly, *Cimbex americana*									X		X		
Gypsy moth, *Lymantria dispar*	X		X					X	X		X		
Whitemarked tussock moth, *Orgyia leucostigma*								X	X	X	X	X	
Eastern tent caterpillar, *Malacosoma americanum*				X			X	X			X		
Orangestriped oakworm, *Anisota senatoria*	X							X			X		
Elm leaf beetle, *Xanthogaleruca luteola*									X				
Galls													
Horned oak gall, *Callirhytis cornigera*								X					

Table 1. *(Continued)*

	Redbud	Persimmon	Poplar	Basswood	Black Locust	Honeylocust	Dogwood	Birch	Willow	Sweetgum	Sycamore
Inner Bark Borers											
Bark Beetles											
Elm bark beetle, *Scolytus multistriatus*											
Hickory bark beetle, *Scolytus quadrispinosus*											
Peach bark beetle, *Phloeotribus liminaris*											
Metallic Wood-Boring Beetles											
Emerald ash borer, *Agrilus planipennis*											
Borers and Girdlers											
Black stem borer, *Xylosandrus germanus*			X			X	X	X	X	X	
Redheaded ash borer, *Neoclytus acuminatus*	X				X	X	X	X		X	
Banded ash borer, *Neoclytus caprea*											
Living hickory borer, *Goes pulcher*											
Red oak borer, *Enaphalodes rufulus*											
Twig girdler, *Oncideres cingulata*	X	X	X	X		X	X				
Little carpenterworm, *Prionoxystus macmurtrei*											
Lesser peachtree borer, *Synanthedon pictipes*											
Greater peachtree borer, *Synanthedon exitosa*											
Nut Feeders											
Acorn weevils, *Curculio sp.*											
Black walnut curculio, *Conotrachelus retentus*											
Butternut curculio, *Conotrachelus juglandis*											
Pecan weevil, *Curculio caryae*											
Codling moth, *Cydia pomonella*											
Walnut husk fly, *Rhagoletis completa*											
Fluid Feeders											
Beech blight aphid, *Grylloprociphilus imbricator*											
Giant bark aphid, *Longistigma caryae*								X	X		X
Beech scale, *Cryptococcus fagisuga*											
Twig and Petiole Feeders											
Black walnut curculio, *Conotrachelus retentus*											
Butternut curculio, *Conotrachelus juglandis*											
Defoliators											
Pin oak sawfly, *Caliroa lineata*											
Elm sawfly, *Cimbex americana*			X					X	X		
Gypsy moth, *Lymantria dispar*			X	X					X		
Whitemarked tussock moth, *Orgyia leucostigma*			X					X			X
Eastern tent caterpillar, *Malacosoma americanum*			X					X	X		
Orangestriped oakworm, *Anisota senatoria*								X			
Elm leaf beetle, *Xanthogaleruca luteola*											
Galls											
Horned oak gall, *Callirhytis cornigera*											

during outbreak conditions it can overwhelm healthy trees. This European import vectors the fungus *Ophiostoma ulmi*, the causative agent of Dutch elm disease, to healthy trees.

Life Cycle: Adults emerge in the spring and colonize new host material. After mating, females lay eggs in galleries chewed into the phloem parallel to the wood grain (Fig. 1). After eggs hatch, however, the developing larvae feed perpendicular to the grain, disrupting the flow of nutrients along the trunk. A second generation of adults emerges in August and September. Larvae of subsequent generations overwinter and complete pupation in the spring (Johnson and Lyon 1994).

Hickory Bark Beetle

Scolytus quadrispinosus (Coleoptera: Curculionidae: Scolytinae)

Hosts: Hickory (*Carya* spp.), pecan (*C. illinoinensis*), and butternut (*Juglans cinerea*).

Damage and Signs of Attack: Larvae feed underneath the bark, chewing galleries in the phloem. Signs of an attack can include dead or browning leaves and galleries under the bark. These beetles rarely kill trees, but repeated attacks can significantly weaken hickories.

Life Cycle: Adults emerge in early summer and colonize host trees. Females chew nuptial chambers in the phloem and after mating construct galleries into which they lay eggs (Goeden and Norris 1965). The beetles have two generations per year, with the second one overwintering as larvae. In the spring, these larvae pupate and emerge as adults.

Peach Bark Beetle

Phloeotribus liminaris (Coleoptera: Curculionidae: Scolytinae)

Hosts: Primarily black cherry (*Prunus serotina*), but also attacks other fruit trees such as peach and plum.

Damage and Signs of Attack: Like other bark beetles, this species feeds just under the bark of the host tree. In response to these attacks, the tree attempts to 'pitch out' the colonizing beetles by producing large amounts of gum (a process known as gummosis). This process leaves gum spots which stain and pocket the wood making it unsuitable for veneers.

Life Cycle: Adults overwinter within the bark of live trees. In the spring, beetles emerge and colonize moribund trees. However, under high population densities this beetle is able to successfully colonize stressed or healthy trees. There are two generations per year (Rexrode 1982).

Figure 1. *Elm bark beetle galleries.* (J.R. Baker and S.B. Bambara, North Carolina State University, Reproduced with permission, www.bugwood.org)

Metallic Wood-Boring Beetles. Adult buprestids are often metallic (especially on the ventral surface) and are hard-bodied, compact, and rather boat-shaped. Females lay eggs in bark crevices and the larvae bore exclusively in the cambium of trees. Many buprestids attack either living trees or newly cut branches. The larvae are whitish in color and legless with a broadly flattened thorax (body region directly behind the head). The larval galleries are flattened and winding and usually oval in cross section. Pupation occurs in a cell at the end of the larval mine and these galleries are packed with frass that resembles pellets of fine sawdust. The adult beetles emerge through the bark and leave characteristic oval, elliptical, or (in the case of the emerald ash borer) D-shaped exit holes. The adults are sun-loving and can often be found at logging operations and mills running along the cut logs.

Emerald Ash Borer

Agrilus planipennis (Coleoptera: Buprestidae)

Hosts: Ash (*Fraxinus* spp.).

Damage and Signs of Attack: External symptoms of attack include crown dieback, vertical splits in the bark, and D-shaped exit holes in the bark. Underneath the bark, the feeding larvae create S-shaped galleries. Adult beetles (Fig. 2) are small, metallic green, and their presence is a good sign that a tree is being attacked. The emerald ash borer is an exotic buprestid introduced from Asia,

Figure 2. *Adult emerald ash borer.* (David Cappaert, Michigan State University, Reproduced with permission, www.bugwood.org)

and is currently spreading throughout the Midwest with devastating effects. This beetle is responsible for the loss of an estimated 12 million ash trees in Michigan, Ohio, and Indiana; it has also been found in Illinois, Maryland, Pennsylvania, West Virginia, and Ontario, Canada. If the emerald ash borer is not controlled, over 147 million forest trees are at risk in Indiana alone. For more information, please visit www.entm.purdue.edu/EAB.

Life Cycle: Adults begin to emerge in May and females lay eggs on the bark of ash trees. The larvae bore into the tree and feed on phloem. Winter is spent in the larval stage and pupation takes place the following spring.

Borers and Girdlers

Members of this guild attack the woody parts of trees. The larvae usually bore deep within the wood, although girdlers also feed on the phloem of branches. Although this guild contains a wide variety of taxa, the most damaging and notable are the longhorned beetles. Borers and girdlers not only have the potential to weaken and kill standing trees, but may also damage cut timber. Stressed trees are often more prone to attack by these insects. Stress can be a result of poor soil, poor drainage, drought, or a number of other factors, including damage from insects.

Ambrosia Beetles. Although these beetles superficially resemble true bark beetles, their biology is quite distinct. Adult ambrosia beetles burrow directly from the bark into the xylem where they mate and females lay eggs. These initial burrows are generally uniform in diameter throughout, free of boring dust, and once in the sapwood widen into a number of cave-like chambers where the eggs and larvae develop. The tunnels and chambers are lined with the ambrosia fungus which serves as food for the growing larvae. Adult females carry the ambrosia fungus in specialized sacs called mycangia and then cultivate the fungus after they bore into a suitable host. In fact, when a new tunnel is bored the female smears a mixture of feces and wood fragments over the walls of the tunnel that acts as a substrate for the fungus to grow. The adult female carries the fungus along with her during migration flights and while overwintering. Interestingly, there is a highly evolved relationship between the fungus and beetle, and neither of them are found 'free living' in nature. The fungus also severely stains the wood and makes it unsuitable for sawlogs. The most common ambrosia beetle in the CHR is the black stem borer.

Black Stem Borer

Xylosandrus germanus (Coleoptera: Curculionidae: Scolytinae)

Hosts: Over 200 species (Weber and McPherson 1983), usually attacking small stems or recently dead trees (Fig. 3).

Figure 3. *Damage to pecan by black stem borer.* (Jerry A. Payne, USDA Agricultural Research Service, Reproduced with permission, www.bugwood.org)

Damage and Signs of Attack: Adult females create a feeding gallery in their host, extruding a toothpick-like peg of fungus and sawdust. Branches above the attack site may also begin to die.

Life Cycle: This is an invasive species from southeast Asia and is of particular concern because, unlike most ambrosia beetles, it is known to attack apparently healthy plants. It is a particular threat to the nursery and orchard

industries because of its preference for saplings and small diameter broadleaved trees. It can also attack larger trees, particularly if they are stressed, and cause girdling, stunting, and even death.

Longhorned Beetles. Some species of longhorned beetle are quite host-specific, while others attack a number of closely related trees. A large number of longhorned beetle larvae infest stressed, weakened, and dead trees, and play an important ecological role in disintegrating and recycling slash and other woody material. Other species, however, attack the branches and boles of living trees. Regardless of their feeding habits, these beetles cause serious defects in lumber by tunneling into the wood, thereby reducing its sawlog grade. These injuries may also allow wood rotting fungi to enter the logs. There is also considerable variation in the feeding habits of the larvae. Some species spend their entire larval life under bark, while others are pith feeders, twig girdlers, root feeders, or even gall formers. The majority, however, are phloem feeders and tunnel into the sapwood and even heartwood to pupate.

Adult females lay eggs in branch scars, cracks in the bark, or egg niches chewed into the bark. The larvae first feed on the phloem and living cambium and later bore into the sapwood. Although the tunnels left by these feeding larvae are generally oval-shaped, the adult emergence holes are perfectly round. Depending on the species, the larval frass can be fine and powdery, flaky chips, or even long fibrous shreds. This frass may be tightly packed behind the larvae or pushed completely out of the burrows.

The larvae are elongate, cylindrical, whitish in color, and often legless. They can be distinguished from metallic wood-boring beetle larvae by the lack of a broadened and flattened anterior end of the body. The biology of a number of common longhorned beetles including one twig-girdling cerambycid is discussed below.

Redheaded Ash Borer and Banded Ash Borer

Neoclytusa acuminatus and ***Neoclytus caprea*** (Coleoptera: Cerambycidae)

Hosts: Ash, occasionally hickory, oak (*Quercus* spp.), and other hardwoods.

Damage and Signs of Attack: Larvae of both species of ash borer feed on recently killed or cut hardwoods. Although weakened trees are at risk of attack, these beetles most often cause damage to wood cut for lumber (Craighead 1950). Redheaded-ash borers (Fig. 4) are reddish with yellow markings, while banded ash borers are black with white markings. Signs of damage include small piles of sawdust underneath logs, circular exit holes on the bark surface, or the presence of adult beetles.

Figure 4. *Adult Neoclytus acuminatus.* (Natasha Wright, Florida Department of Agriculture and Consumer Services, Reproduced with permission, www.bugwood.org)

Life Cycle: Adults emerge in early summer and the females lay eggs on suitable host material. The larvae are white, grub-like, and feed on the sapwood. These beetles have a one year life cycle.

Living Hickory Borer

Goes pulcher (Coleoptera: Cerambycidae)

Hosts: Hickories and pecan.

Damage and Signs of Attack: Larvae feed underneath the bark and in the heartwood of hickories. Trees are not defenseless against these attacks and produce large amounts of sap in an effort to expel the feeding larvae. In fact, areas of bark wettened by oozing sap are often an indication that a tree is infested with *Goes pulcher* larvae (Solomon 1974). Fibrous frass and emergence scars are also indications of attack.

Life Cycle: Adults are large (18 to 24 mm) robust beetles with a dark brown body, and yellow and brown bands across their backs. In the CHR adults emerge from May to June, and females lay eggs in niches and cracks in the bark (Solomon 1974). Larvae can take three to five years to mature.

Red Oak Borer

Enaphalodes rufulus (Coleoptera: Cerambycidae)

Hosts: Living oak trees, most commonly red oak (*Q. rubra*) and black oak (*Q. velutina*).

Damage and Signs of Attack: Larvae bore through the sapwood and heartwood of host trees. External signs of attack are generally limited to extruded frass coming from entry holes of the larvae and exit holes of adults. Woodpeckers often feed on red oak borer larvae, and an increase in their activity is often an indication of attack. This beetle has also been implicated as an important contributor to oak decline, a serious disease that has killed thousands of oak trees in Arkansas and Missouri.

Life Cycle: Adults (Fig. 5) emerge from June to August, and mating occurs on the larval host tree. Young larvae feed on the inner bark and sapwood, while older larvae move into the heartwood. Development takes two years, which likely leads to the two-year cycle of adult emergence (Donley and Acciavatti 1980).

Figure 5. *Adult red oak borer.* (Gerald J. Lenhard, Reproduced with permission, www.bugwood.org)

Twig Girdler

Oncideres cingulata (Coleoptera: Cerambycidae)

Hosts: Prefers hickory, elm, persimmon (*Diospyros virginiana*), and poplar (*Populus* spp.), but can infest various hardwoods, including basswood (*Tilia* spp.), locust (*Robinia* spp.), and dogwood (*Cornus* spp.) (Rice 1995).

Life Cycle: Adults (11 to 13 mm in length) emerge in late summer. Females girdle small branches and twigs within which they lay their eggs. Larvae feed within the girdled twigs, which often fall to the ground. This species overwinters in the larval stage, and larvae take one to two years to mature. Significant die-back can occur as a result of their attacks.

Cossid Moths. Cossid larvae seldom kill trees, although heavily infested trees are susceptible to being wind-thrown. The greatest damage inflicted by these insects is the degradation of lumber from infested material. In fact, rough cut lumber may be devalued by as much as 20% as a result of damage by carpenter worms. It appears that open-grown black, red, and scarlet oaks are particularly susceptible to attack, although a number of hardwood species are suitable hosts to this insect. Generally, the larvae first bore into the inner bark and soon continue into the sapwood and heartwood of the main stem. Full-grown caterpillars can grow to be as long as 50 to 70 mm, and overwinter in the galleries.

Little Carpenterworm and Large Carpenterworm

Prionoxystus macmurtrei and ***Prionoxystus robiniae*** (Lepidoptera: Cossidae)

Hosts: The large carpenter worm feeds on a number of hardwood trees, while the little carpenter worm feeds primarily on oaks.

Damage and Signs of Attack: Larvae bore into living trees, creating large tunnels in the sapwood and heartwood. Large amounts of frass ejected from the tunnel are the only external sign of an infestation.

Life Cycle: Adults emerge in June and July, and are quite large grayish moths with speckled forewings. Eggs are laid on the bark of trees, and newly hatched larvae enter the tree via existing wounds left by other wood-boring insects. Young larvae feed on the inner bark and then move into the sapwood as they mature. Three to four years may be required for larvae to mature into an adult (Johnson and Lyon 1994).

Clear-winged Moths. These insects bear a striking resemblance to bees and wasps and are called clear-winged moths because of their transparent scaleless wings. Larvae bore into the roots, branches, and trunks of their hosts, and some are serious pests of landscape and forest trees. A few are gall formers, others feed on the inner bark, and some inhabit only injured areas of a trunk or branch, but the most serious pests bore extensive tunnels in the sapwood. The larvae are often bright white and usually unmarked. As with the cossids, silk is often found; it is associated with the larval galleries of these borers. Some of the more common pests include those in the genera *Podosesia* (e.g., lilac borer) and *Synanthedon* (e.g., peachtree and lesser peachtree borers).

Lesser Peachtree Borer and Greater Peachtree Borer

Synanthedon pictipes and ***Synanthedon exitiosa*** (Lepidoptera: Sesiidae)

Hosts: Primarily black cherry, but also attacks fruit trees such as peach and plum.

Damage and Signs of Attack: Peachtree borer larvae tunnel within the phloem of weakened trees. Large amounts of dust-like frass along with a large wound with oozing sap are a good indication that a tree is infested with these borers. Adults of both species are very similar in appearance, but the larvae feed on different portions of the host. Specifically, the lesser peachtree borer attacks the trunk and branches of trees, often using existing wounds, while the greater peachtree borer usually attacks the tree at its base.

Life Cycle: Adults are wasp-like moths with blue-black bodies. Female lesser peachtree borers typically lay eggs in the upper parts of cherry trees, especially where there is existing damage, while greater peachtree borers lay eggs at ground level. Larvae feed on the inner bark and can grow to be almost 25 mm in length. These species overwinter as larvae and pupate in the spring. Adults emerge in May and June. There may be up to two generations per year. Mating occurs shortly after emergence followed by the female laying up to 400 eggs (Bessin 2004).

Nut Feeders

Weevils are the most important nut-feeding insects affecting hardwood trees. This family (*Curculionidae*) contains over 2,000 North American species, a small number of which attack the fruits of oak, hickory, and pecans. The adults are light tan to reddish-brown and can have a long, slender, curved beak or snout (e.g., *Curculio* spp.) or a short beak (e.g., *Contrachelus* spp.), and usually appear about the time the fruits begin to ripen. Long-snouted females drill a hole through the shell and deposit an egg in the meat of the nut, while the short-snouted females lay eggs in cracks between the acorn shells. Larvae then overwinter either in the nut or in the soil, where they pupate.

Figure 6. *Acorn damage caused by a Curculio weevil.* (Louisiana State University Archive, Louisiana State University, Reproduced with permission, www.bugwood.org)

Figure 7. *Adult Curculio weevil.* (Clemson University -USDA Cooperative Extension Slide Series, Reproduced with permission, www.bugwood.org)

Members of the genera *Curculio* and *Conotrachelus* are the most important weevil pests of hardwood nuts. Oak acorns (Fig. 6) are often infested by species of *Curculio*, and butternuts and black walnuts are commonly affected by *Conotrachelus juglandis* and *C. retentus*, respectively. Damage caused by *C. juglandis* adults may increase the susceptibility of trees to infection by butternut canker fungus. This same genus also contains a number of fruit feeders that can heavily scar fruits of apple, plum, cherry, and peach trees. Hickory and pecan nuts (Ring et al. 1991) are also colonized by the pecan weevil (Fig. 7), *Curculio caryae*, which can cause significant losses. Nut weevils are thought to be a major deterrent of regenerating oak stands in the Midwest.

The codling moth, *Cydia pomonella* (Lepidoptera: Tortricidae), can also affect walnuts and various fruit trees including apple, pear, and cherry. Larvae are creamy pinkish-white, bore directly into developing nuts and fruits, and feed within the developing seeds. Once mature, however, the larvae chew their way out of the nut, fall to the ground, and pupate. This insect is capable of infesting both early- and late-season nuts. The adult moths are rather small (~ 12 mm long) and gray in color with a prominent copper spot on the tip of each forewing. Adults become active and mate around dusk when temperatures are above 12.8 °C (55 °F). Eggs are laid near a developing fruit and usually hatch within two weeks. Larvae bore into the fruit and pass

through five instars before pupating outside of the fruit. One to three generations may occur each year, depending on climate.

Another important pest of walnuts is the walnut husk fly, *Rhagoletis completa* (Diptera: Tephritidae). The adult females are yellow in color, and males are darker, but both sexes have three prominent dark bands on their wings. Females lay eggs in soft husks of nearly mature walnuts, and the larvae feed on husks turning them black and soft. In three to five weeks the larvae mature and pupate in the soil below the host tree. There is one generation per year.

Root Feeders

Root-feeding white grubs of beetles in the genus *Phyllophaga* often sever or even girdle roots, leading to injury or death. The adults, often called June or May beetles, are defoliators of only minor consequence, but the grubs are particularly problematic in nurseries. Most eastern hardwoods and conifers are susceptible, and damage is often first seen in late summer when formerly healthy trees wither and die. These symptoms are often confused for drought injury.

Fluid Feeders

Although some members of this guild cause little damage to their hosts, others can actually kill trees. Some are sap-suckers, others damage twigs while laying eggs, some distort foliage, and others vector various disease organisms. These insects all have highly modified sucking mouthparts that are usually inserted into the functional phloem cells of their hosts. Phloem cells are responsible for transporting nutrients (i.e., photosynthates) in the sap. Many of these insects also undergo gradual metamorphosis. For example, the life cycles of some aphids are very complex and can consist of as many as five life stages. Sometimes adding to this complexity is an alteration of host species within and between generations. Common fluid-feeding insects include aphids, lace bugs, leafhoppers, and scale insects.

Aphids. Aphids (Hemiptera: Aphididae) are among the most common sucking insects, and are sometimes referred to as 'plant lice'. They are colonial and destroy a variety of plants including house and garden plants, shrubs, and trees. Often a particular species of aphid is not only host-specific, but also feeds on a particular part of the plant such as the root, stem, or leaf.

Aphids secrete honeydew from their anus. This sweet and sticky fluid often forms a shiny covering over leaves and a sooty mold may also grow on the honeydew, blackening infested trees and even vegetation below. Honeydew is also rich in sugar and, not too surprisingly, ants, bees, and other insects find it quite attractive.

Aphids are soft-bodied and relatively pear-shaped. Their legs have two-segmented tarsi and are long in relation to the rest of the body. The dorsal surface of the fifth or sixth abdominal segments is equipped with two cornicles, or short tubes that may secrete wax or defensive fluids. A group called the woolly aphids has special glands scattered along their bodies from which they secrete strands of white wax.

The life histories of aphids can be quite complex. There can be as many as 20 generations throughout the summer, and each generation can be a completely different color, with different form, manner of reproduction, and even host preference. Within a single species, individuals of one generation can be green, while another brown; some winged and others wingless; and some reproduce sexually while others reproduce asexually. Many species also have alternate hosts. The life histories of a number of economically important aphids are discussed below.

Beech Blight Aphid

Grylloprociphilus imbricator (Hemiptera: Aphididae)

Hosts: Beech (*Fagus* spp.).

Damage and Signs of Attack: Beech blight aphids (Fig. 8) can feed in large numbers on leaves of beech. These fluid-feeders are white in color with a fuzzy appearance. At high population densities, the sticky excess sugar or honeydew secreted

Figure 8. *Beech blight aphids (nymphs).* (Bob Lepak, Reproduced with permission, www.bugwood.org)

from the feeding colony can even accumulate under infested trees. As this honeydew begins to mold, it can become quite unsightly, but is harmless to the tree (Childs 2002).

Life Cycle: Adults are active throughout the summer, but are most noticeable in August and September. Although populations of these aphids often go unnoticed, during outbreak conditions trees can appear as if they are covered with snow. This aphid is not known to cause any serious injury to trees, although some limbs may die as a result of a heavy infestation.

Giant Bark Aphid

Longistigma caryae (Hemiptera: Aphididae)

Hosts: Hickory, oak, basswood, walnut (*Juglans nigra*), and sycamore (*Platanus occidentalis*).

Damage and Signs of Attack: Adults (Fig. 9) are the largest aphids in North America (up to 6 mm in length) and feed on trunks and branches of their host trees. As they feed, the adults also secrete honeydew which is often noticeable as a

Figure 9. *Giant bark aphids.* (Herbert A. "Joe" Pase III, Texas Forest Service, Reproduced with permission, www.bugwood.org)

result of the sooty mold that grows on it. These aphids have the potential to kill twigs and branches that they feed on, and the resulting buildup of honeydew and mold can reduce the vigor of heavily infested trees by blocking necessary sunlight (Johnson and Lyon 1994).

Life Cycle: Populations grow to their highest levels in late summer and autumn. Females lay eggs under the bark in the fall. These eggs hatch the following year, resulting in reinfestation of the same trees.

Lace Bugs. Lace bugs (Hemiptera: Tingidae) are common pests of hardwoods, and the adults have extremely ornate wings and a hood-like structure that covers the head. The nymphs and adults live on the undersurface of leaves and feed on plant juices through slender piercing mouthparts. This feeding damage results in yellow or white spots on the upper surface of leaves, and as the insect continues to feed, they deposit a hard, varnish-like tar or resin spots. The nymphs are oval-shaped and covered in spines. Common lace bugs in forest ecosystems in Indiana include the oak lace bug (*Corythuca arcuata)*, the walnut lace bug (*C. juglandis*), sycamore lace bug (*C. ciliate*), and hackberry lace bug (*C. celtides*).

Plant Bugs. Feeding by plant bugs (Hemiptera: Miridae) superficially resembles lace bug damage, in that it can cause small white dots on leaves. Plant bug injury, however, can also be quite severe and lead to the distortion or even destruction of leaf tissue. Injury is generally quite light and rather widely distributed. Some plant bugs are quite polyphagous, while others feed on a narrow range of plants or even a single species. Although adults are strong fliers, the nymphs are wingless and usually cause more damage as they mature. Plant bugs important to hardwoods in the CHR include ash plant bug and tarnished plant bug.

Leafhoppers. Some species of leafhoppers (Hemiptera: Cicadellidae) feed beneath the leaves of hardwoods and cause 'hopper burn', damage that appears as a severe mottling of the leaves. Leafhoppers can also vector disease. Elm necrosis, an important disease of elm, is vectored from diseased to healthy trees by a leafhopper.

Cicadas. Adult cicadas suck sap from a number of hardwood trees, but this feeding does little damage. Females, however, cut a series of deep slits in twigs and branches in which to lay eggs and this injury kills the foliage at the end of the branch and is commonly called "flagging". In fact, during periods of particular high infestations, trees can appear as if they have been singed by fire. When the eggs hatch, the nymphs head underground where they feed on roots. The most common cicada, known as the 'dog-day cicada', generally requires one to three years to complete development. The periodic cicada, on the other hand, requires much longer to develop (usually 13 or 17 years), but lives for merely weeks as an adult.

Spider Mites. Spider mites (Tetranychidae) are arachnids generally found on the underside of leaves, where they spin protective silk webs and feed on plant sap. In fact, their common name comes from this habit of spinning webs. Spider mites are very small (~ 1mm in length) and vary greatly in color. Female spider mites originate from

Table 2. *Examples of fluid-feeding arthropods important to the Central Hardwood Region.*

Common name	Family	Example
True aphids	Aphidae	Giant bark aphid, *Longistigma caryae* Beech blight aphid, *Grylloprociphilus imbricator* Honeysuckle aphid, *Hyadaphis tataricae*
Plant bugs	Miridae	Ash plant bug, *Tropidosteptes amoenus* Tarnished plant bug, *Lygus lineolaris*
Lace bugs	Tingidae	Oak lace bug, *Corythuca arcuata* Sycamore lace bug, *Corythuca ciliate* Hackberry lace bug, *Corythuca celtides* Walnut lace bug, *Corythuca juglandis*
Leaf hoppers	Cicadellidae	Japanese maple leafhopper, *Japananus hyalinus*
Cicadas	Cicadidae	Dog-day cicada, *Tibicen* spp.
Spider mites	(Acari: Tetranychidae)	Two spotted spider mite Honey locust spider mite European red mite Oak red mite
Soft scales	Coccoidae	European elm scale, *Eriococcus spuria*
Armored scales	Diaspididae	Oystershell scale, *Lepidosaphes ulmi*

fertilized eggs, while males result from unfertilized eggs. The best known spider mite is the two-spotted spider mite which is a common pest in greenhouses. There are a number of spider mites that are important in forest ecosystems (see Table 2).

Scales and Mealybugs. This group contains minute, highly specialized fluid feeders. Females are wingless, usually legless, and are sessile. Males, on the other hand, have a single pair of wings and lack functional mouthparts. The first stage nymphs, called 'crawlers', are fairly active, but after the first molt their legs are lost and they become sessile. A waxy material is then secreted which covers the body, giving it the appearance of a scale.

The oystershell scale, *Lepidosaphes ulmi* (Hemiptera: Diaspididae), is an armored scale that infests over 100 species of hardwood trees, including ash, beech, elm, and birch. Eggs overwinter on the bark and beneath the protective covering of the female. Females resemble miniature, grey-brown oystershells and 'crawlers' are active from late May until early June.

Other important forest pests include tortoise scales and a number of soft scales. Generally, these insects either overwinter as eggs beneath the mother scale or as partially grown nymphs.

The beech scale, *Cryptococcus fagisuga* (Hemiptera: Eriococcidae), feeds through the thin bark of beech and can build up large populations on the trunks, but causes little lasting damage. Nevertheless, these insects pose a serious threat because their feeding damage increases the susceptibility of beech to attack by a canker-causing *Nectria* fungus which can eventually kill the tree. This complex of scale and *Nectria* is known as beech bark disease (Houston and O'Brien 1983).

Adult beech scales are tiny yellowish insects that cover themselves with a white waxy substance. Females are parthenogenetic and thus do not require fertilization by males. In fact, males are not known for this species. Females lay a number of eggs that develop under the protection of her waxy scale. These eggs then hatch into 'crawlers', the mobile stage of this insect, which seek out new feeding sites where they also overwinter. The following spring, adults eclose and disperse in air currents or move phoretically on other organisms.

Defoliators

Defoliators by and large cause the most damage to hardwoods in the CHR. At low population densities, these insects scarcely affect forest health because enough foliage remains for trees to maintain their vigor. In outbreak conditions, however, these populations escape the normal environmental factors that control their population growth (e.g., natural enemies) and their numbers swell by tremendous proportions. The resultant defoliation may slow the growth rate of trees for a time, reduce their vigor, increase their susceptibility to pathogens and other secondary pests, and even kill trees outright.

Defoliation can come in many different forms. Insects can mine, skeletonize, or even completely defoliate leaves. Larvae of loopers (Geometridae) can even chew holes in the leaves rather than feed on their margins. Some defoliators are exposed while they feed, while others are concealed within a shelter of foliage or silk. Web or tentmakers live in relatively large conspicuous colonies, leaf tiers use silk to bind together a small number of leaves, and leaf rollers make compact uniform shelters, usually from distorting a single leaf.

Most defoliators fall within two diverse orders: the Hymenoptera (e.g., sawflies) and Lepidoptera (e.g., moths and butterflies). Both groups have complete metamorphosis, but sawfly larvae are distinct from lepidopteran forms by having a greater number of prolegs, possessing prolegs on the second abdominal segment, the lack of claw-like crochets on the ventral surface of the prologs, and the presence of a single simple eye on the head.

Sawflies. Two common sawflies affecting hardwoods in the CHR, the pin oak sawfly and the elm sawfly are discussed below.

Pin Oak Sawfly and Others

Caliroa lineata (Hymenoptera: Tenthredinidae)

Hosts: Usually pin oak (*Q. palustris*), but also other oak species.

Damage and Signs of Attack: The larvae (Fig. 10) of this species feed on the bottom of oak leaves, leaving the veins and top layer of the leaves intact. The immature sawflies are greenish caterpillars and superficially resemble immature moths and butterflies.

Figure 10. *Larva of pin oak sawfly.* (Pennsylvania Department of Conservation and Natural Resources-Forestry Archive, Reproduced with permission, www.bugwood.org)

Life Cycle: Adults begin to emerge in May and can be found through September. Larvae generally begin feeding in the crown and move downwards as they grow. When mature, the larvae pupate in the soil. Up to two generations may occur per year. There are seven species of *Caliroa* that feed on various oaks, all having similar life histories (Johnson and Lyon 1994).

Elm Sawfly

Cimbex americana (Hymenoptera: Cimbicidae)

Hosts: Many trees, usually elm or willow (*Salix* spp.).

Damage and Signs of Attack: Larvae (Fig. 11) are yellowish-white with a single black stripe and can reach ~50 mm in length. The larvae feed on foliage during the summer, often wrapping part of their body around a twig for support while it eats.

Figure 11. *Larva of elm sawfly.* (Herbert A. "Joe" Pase III, Texas Forest Service, Reproduced with permission, www.bugwood.org)

Life Cycle: Adults are the largest of the North American sawflies and are wasp-like in appearance with a thick, non-constricted abdomen, and iridescent black coloration. Adults emerge in early summer, mate, and lay eggs. The resulting larvae hatch and feed on the foliage. The larvae overwinter in a cocoon and pupate in the spring. There is only one generation per year (Craighead 1950).

Tussock Moths. Larvae in this family (Lepidoptera: Lymantriidae) are either uniformly hairy or have either brush-like or long hairs arranged in tufts. Two important species in the CHR, the gypsy moth and the whitemarked tussock moth, are discussed below.

Gypsy Moth

Lymantria dispar (Lepidoptera: Lymantriidae)

This European insect was brought to Massachusetts by Leopold Trouvelot in the 1860s in the hope of finding a viable alternative to silkmoths for commercial silk production. Unfortunately, some of the moths escaped and became established in the area. Since then, this destructive insect has slowly spread across the eastern United States. Pest

management techniques such as pheromone disruption and the use of fungal pathogens have slowed, but have not stopped its spread.

Hosts: Many trees, especially oaks, alder (*Alnus* spp.), basswood, and willows.

Damage and Signs of Attack: The larvae begin feeding in the crown of a tree, chewing small holes out of the leaves. Later, instars consume the whole leaf. In fact, a single gypsy moth larva can consume as much as 1 m^2 of foliage in its lifetime. Not surprisingly, large populations of gypsy moth caterpillars (Fig. 12) on a single tree can lead to complete defoliation.

Figure 12. *Gypsy moth caterpillar.* (E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Reproduced with permission, www.bugwood.org)

Life Cycle: Flightless females lay brownish egg masses on the trunks of trees; the eggs then overwinter and hatch in the spring. These newly emerged caterpillars either begin feeding on the tree, or dangle themselves on thin silk strands and allow the wind to disperse them up to 1.6 kilometers, a process known as 'ballooning'. Caterpillars feed on crown foliage at night, moving down the tree to find shelter during the day. At high population densities, however, feeding can occur continuously. Gypsy moth caterpillars mature and pupate in June and July. Because the females are too heavy to fly, they do not disperse to lay their eggs. If these egg masses occur on nursery stock or firewood, they may be easily transported and further the spread of this invasive insect (McManus et al. 1989).

Whitemarked Tussock Moth

Orgyia leucostigma (Lepidoptera: Lymantriidae)

Hosts: At least 60 species of hardwood tree are attacked by this insect, especially maple (*Acer* spp.), elm, birch (*Betula* spp.), sycamore, and poplar.

Figure 13. *Caterpillar of the whitemarked tussock moth.* (A. Steven Munson, USDA Forest Service, Reproduced with permission, www.bugwood.org)

Damage and Signs of Attack: Like all defoliators, this species eats foliage leaving only the veins undamaged. The caterpillar of the whitemarked tussock moth (Fig. 13) has distinctive light-colored clumps of hairs along its back with two large tufts of black hairs extending forward from near the head.

Life Cycle: Females lay hundreds of eggs on their cocoons. The eggs hatch from June to July, and the larvae skeletonize leaves of their host tree. Late instar caterpillars can be 3 cm in length and pupate within a grayish colored cocoon. Depending on conditions, one to three generations of this moth may occur each year (Johnson and Lyon 1994).

Tiger Moths. Tiger moths (Lepidoptera: Arctiidae) are white or brightly colored and can be recognized by their habit of holding their wings roof-like over the abdomen while at rest. The larvae are adorned with dense clusters of hairs of varying length. One of the more economically important tiger moths is the fall webworm (*Hyphantria curea*).

Loppers, Spanworms, and Cankerworms (Lepidoptera: Geometridae).

This group defoliates a number of broadleaved trees, and females of several species (e.g., cankerworms and linden loopers) have stout-bodied, wingless females. Winged adults are more slender-bodied with broad, delicate wings which possess one to three thin, wavy lines. The larvae are hairless and have a reduced number of prolegs (usually two pair). The larvae move by bringing their anal segment of the abdomen forward to the thoracic legs forming a loop with the body. They then move forward by extending their front end.

Important hardwood defoliating members of this family include the fall- and spring-cankerworm, linden looper, winter moth, and elm spanworm. Many of these pests defoliate their hosts in early spring and are, in fact, some of the first caterpillars encountered on expanding buds and young leaves.

Tent Caterpillars. Tent caterpillars (Lepidoptera: Lasicampidae) are generally hairy and many spin conspicuous silken tents, where they reside during inclement weather and while molting. This behavior is not unique, however, as many other lepidopteran families also make tents of silk. An important defoliator in this group is the eastern tent caterpillar (*Malacosoma americanum*), which feeds on a variety of *Prunus* species and other hardwoods. Eastern tent caterpillars (Fig. 14)

Figure 14. *Eastern tent caterpillars.* (Jerry A. Payne, USDA Agricultural Research Service, United States, Reproduced with permission, www.bugwood.org)

spend the daylight hours in silken tents formed in forks of a tree or small branches. These insects feed at night and early morning, and are capable of severely defoliating a tree. In the fall, female moths lay gray-colored egg masses on stems of the host plants where they overwinter and hatch in the spring. These hairy caterpillars have a mottled blue-black color, and can be distinguishable from other species by a solid white line running down their back. After six larval instars, a caterpillar spins a cocoon in which it will develop into an adult moth. After approximately three weeks, a reddish brown moth with a diagonal white stripe running across its front wing emerges from the cocoon. There is only one generation per year (Batzer and Morris 1978).

Microlepidoptera. The microlepidoptera include a number of families of very small moths with a wing span usually less than 20 mm. These moths can be distinguished by a fringe of long hairs on the hind wings that is as wide as the wing itself. A few species in the family Psychidae, such as bagworms (*Thyridopteryx* spp.), construct bags or cases from foliage of their hosts.

Silkmoths. The silkmoths (Lepidoptera: Saturniidae) are among the largest (75 to 150 mm wingspan) and most colorful moths in North America. The brightly colored larvae are quite large and armed with tubercles or spines. The eggs are also relatively large and deposited on the foliage of hosts. Most species overwinter on the host or in leaf litter in large, densely spun silk cocoons. An important defoliator within this group is the orangestriped oakworm (Fig. 15), *Anisota senatoria*, which feeds on oaks, especially red oak. The larvae are black colored with distinctive orange stripes and can grow to a length of ~50 mm. Adult moths emerge and lay eggs on the undersurface of leaves from June to July. Larvae feed for five to six weeks and then pupate in the soil. One generation occurs per year (Craighead 1950).

Figure 15. *Orangestriped oakworm caterpillar.* (Clemson University- USDA Cooperative Extension Slide Series, Reproduced with permission, www.bugwood.org)

Coleopteran Defoliators. A number of beetles are important defoliators of trees, including leaf beetles (Chrysomelidae), chafers and May/June beetles (Scarabaeidae), and some weevils (Curculionidae). The elm leaf beetle, *Xanthogaleruca luteola* (Coleoptera: Chrysomelidae), is an important defoliator of elm. Although adult beetles

Figure 16. *Leaf damage caused by elm leaf beetle.* (Whitney Cranshaw, Colorado State University, Reproduced with permission, www.bugwood.org)

feed on foliage (Fig. 16), the immature stages are by far more destructive. Larvae feed on the underside of the leaf, leaving the upper surface intact. This leads to the death and loss of badly damaged leaves. The larvae are initially entirely black, but as they mature, their color changes to a greenish or yellowish color with a black lateral stripe. Mature larvae move to the base of the tree to pupate. There are often two generations per year, and these insects do not disperse long distances, with successive generations often reinfesting the same tree. Extensive feeding by these beetles over several years can severely weaken or even kill a tree (Johnson and Lyon 1994). Adults overwinter and begin to feed and lay eggs in the spring. Larvae are small, grub-like, and feed on the bottom of leaves.

Both the adult and immature stages (grubs) of the Japanese beetle, *Popillia japonica* (Coleoptera: Scarabaeidae), are destructive pests of a wide range of plants. The adults feed on the foliage and fruits of hundreds of species of hardwood and fruit trees, as well as shrubs, vines, herbaceous plants, and field and vegetable crops. Adults skeletonize the foliage and leave behind large, irregular holes in leaves. The grubs develop in the soil, feed on the roots of various plants, and are common pests of turf grasses, lawns, and pastures.

Gall Forming Insects

Galls are irregular plant growths formed by plant hormones interacting with growth-regulating chemicals produced by some insects and mites. Galls are often caused by the overproduction of the plant hormones auxin and cytokinin. These plant hormones not only stimulate cells to grow abnormally large, but also to divide more rapidly. Feeding by gall-making parasites causes adjacent plant tissues to form the gall. The parasite then

Figure 17. *A horned oak gall on pin oak.* (USDA Forest Service-Northeastern Area Archive, USDA Forest Service, Reproduced with permission, www.bugwood.org)

develops within the gall and receives food and protection from the tissue. Gall formation generally occurs in the later spring when new leaves, shoots, and flowers are growing quickly, and mature plant tissues are seldom affected. Once the galls begin to appear, the organism is protected inside and control measures are usually ineffective. In fact, the physical gall can remain and even continue to grow after the parasite dies. Although gall populations fluctuate from year to year, and can cause significant aesthetic damage, they seldom affect tree vigor.

Members of the insect Orders Hemiptera (e.g., aphids, psyllids, and adelgids), Coleoptera (e.g., Cerambycidae), and the arachnid Order Acari (mites) cause galls on twigs, foliage, fruits, and other plant parts. However, the Orders Hymenoptera (Cynipidae: gall wasps) and Diptera (Cecidomyiidae: gall midges) by and large contain the most gall-formers. These insects commonly attack oaks, a variety of other trees, flowers, and grasses. Many species within these groups are most easily identifiable by the shape and location of the galls they induce.

The horned oak gall, *Callirhytis cornigera* (Hymenoptera: Cynipidae), induces gall formation on woody twigs of oaks (Fig. 17). This species is a serious pest of oaks in the CHR and can be recognized by the sharp, horn-like protrusions on the surface of the gall. Adult wasps are minute (only 2 mm in length) and emerge from the galls in the spring and lay eggs on new growth. Larval feeding causes the tree to form the gall around the developing wasp. It may take two years for development (Johnson and Lyon 1994). The descriptions of common gall-makers and their galls are listed in Table 3.

Table 3. *Description of galls and gallmakers on ash, maple, and oak.*

Host	Gall	Gallmaker, Description
Ash	Ash flower gall	Caused by a mite and results in swollen, distorted flower pedicles. Green at first, then brown. Variable in size.
Maple	Maple bladder gall	Mite. Small (~2.5 mm in diameter), irregular, globular-shaped red or black galls.
	Maple spindle gall	Mite. Leaf gall that is slender and spindle-shaped (~5 mm in diameter).
Oak	Wool sower gall	Wasp. Sphere-shaped, white, wooly mass marked with pink grains (3 to 4 cm in diameter).
	Jumping oak gall	Wasp. Thin-shelled spherical gall. Appears as slightly pointed leaf gall on lower surface of leaf and a blister above.
	Horned oak gall	Wasp. Spherical twig gall. Irregularly shaped and woody with horn-like projections. Each horn contains a larva that will give rise to a parthenogenetic female. These females lay eggs on the midribs, and in mid-summer the adults emerge, mate, and females lay eggs on twigs and new galls form around the larvae.
	Hedgehog gall	Wasp. Look like spine-covered spheres. Usually ~1 cm in diameter, and yellow or red colored.
	Oak bullet gall	Wasp. Globular, hard twig galls (8 to 16 mm in diameter) that may be single or clustered.

Control

Although specific recommendations for controlling these insects are not addressed in this publication, damage by many of these pests can be minimized by maintaining a healthy tree stand. Proper sanitation practices, such as removing dying and diseased trees, and thinning to reduce stress will increase tree vigor and reduce their susceptibility to attack. Landowners are encouraged to consult their local Department of Natural Resources or University Extension personnel to confirm the identity of a suspected insect pest, and for current management tactics and control measures.

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