Native and Exotic Insects and Diseases in Forest Ecosystems in the Hoosier-Shawnee Ecological Assessment Area

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ABSTRACT

Various native and exotic insects and diseases affect the forest ecosystems of the Hoosier-Shawnee Ecological Assessment Area. Defoliating insects have had the greatest effects in forests where oak species predominate. Increases in oak decline are expected with the imminent establishment of the European gypsy moth. Insects and pathogens of the pine forests are artifacts of stand origin and age. Chestnut blight and Dutch elm disease have had the greatest broad-ranging and historical effects on the non-oak, broad-leaved forests.

Various native and exotic insects and diseases affect the forest ecosystems of the Hoosier-Shawnee Ecological Assessment Area, specifically the Hoosier and Shawnee National Forests. For this analysis, the relative importance of each insect and disease was determined based on the extent and condition of the susceptible resource as well as historical accounts of insect or disease occurrence and potential for future effects.

DISEASES AND INSECTS OF OAK

Oak-hickory and other oak-type forests predominate in the Hoosier-Shawnee Ecological Assessment Area, accounting for 55 to 70 percent of the total forest cover (USDA Forest Service 2001). These forests include several species of both the red (subgenus *Lobatae*) and white oak (subgenus *Quercus*) groups of oak (*Quercus* spp.). Several pathogens and numerous insects can significantly affect forest ecosystems where oak is an important component (table 1).

Diseases

Oak decline

Oak decline, native to the U.S., affects oaks over broad forest areas of the eastern part of the country (Wargo et al. 1983). Oak decline has been reported for over 130 years and its occurrence is episodic. Currently, large numbers of northern red (*Q. rubra*), southern red (*Q. falcata*), black (*Q. velutina*), and scarlet (*Q. coccinea*) oaks are declining and dying in southern Missouri and northern Arkansas, including oaks in the Mark Twain, Ozark, and Ouachita National Forests in these States (Lawrence et al. 2002). An estimated 100,000 acres of severe decline have occurred in the Mark Twain based on recent surveys (Lawrence et al. 2002). Oak decline and mortality were associated with defoliation of looper complex outbreaks between 1978 and 1981 in the assessment area. In southern Indiana, mortality levels exceeded 10 percent in oak-hickory stands (P. Marshall, personal communication).

Scattered oak decline and mortality also occurred following a severe drought in 1987-88.

Oak decline is a debilitating progression of physical and biological stressors. Initially, environmental, stand, and site factors induce long-term to short-term stress, and then various insects and pathogens may move in. The latter may include borers such as twolined chestnut borer (*Agrilus bilineatus*) and red oak borer (*Enaphalodes rufulus*); defoliators such as European gypsy moth (*Lymantria dispar*); and pathogenic fungi such as *Hypoxylon atropunctatum* and *Armillaria* species. The interaction of these factors results in a slow-acting, yet progressive, disease complex that often leads to tree death. Red oaks are more severely affected by oak decline than white oaks. The occurrence and severity of oak decline are closely associated with the time and location of the triggering factors, such as drought or heavy defoliation by insects. The imminent spread of the European gypsy moth (fig. 1) to the assessment area could therefore trigger more frequent and severe episodes of oak decline.

Declining trees present a safety hazard along roads and trails, and in recreation areas (Lawrence et al. 2002). Often the insects and fungi associated with decline degrade timber because of such factors as sapwood stain and loss of structural integrity. Over larger areas, decline and death of oaks leads to fuel-loading because of increased amounts of coarse woody debris. The disease may increase habitat for some wildlife species but decrease it for others. The quality of recreational experiences such as hiking, camping, and hunting may be reduced by oak decline in oak-hickory forests.

Current oak decline management strategies include harvest of oak stands before they become physiologically overmature. Reproduction in young and middle-aged stands

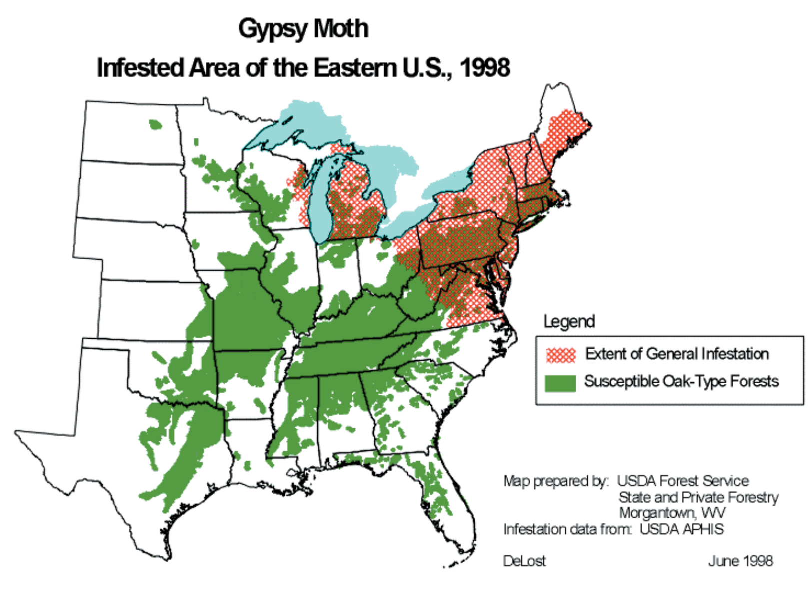

Figure 1. European gypsy moth general infestation area and range of potential host species in the Eastern U.S., 1998. (source: http://na.fs.fed.us/wv/gmdigest/maps_charts/maps/gmoak.htm).

Table 1. Insects and diseases affecting or with future potential to affect oak forest cover types in the assessment area.

Pest type	Common name	Scientific name	Status in U.S. native/exotic	Effect of insect or disease on forest resource* Past	Present	Future potential
Disease complex	Oak decline	numerous biological and physical factors	native	XX	X	XX
Disease	Oak wilt	*Ceratocystis fagacearum*	native	X	X	X
Disease	Sudden Oak Death	*Phytophthora ramorum*	exotic	0	0	XX
Insect	Forest tent caterpillar	*Malacosoma disstria*	native	X	X	X
Insect	Wood borers	*Agrilus bilineatus* *Enaphalodes rufulus*	native	X	X	X
Insect	Jumping oak gall	*Neuroterus saltorius*	native	XX	XX	X
Insect	Looper complex	*Erannis tiliaria* *Phigalia titea*	native	XX	XX	XX
Insect	Walkingstick	*Diapheromera femorata*	native	X	?	?
Insect	European gypsy moth	*Lymantria dispar*	exotic	0	0	XX

* Degree or severity of effect: 0 = not established, X = minor, XX = moderate to major, ? = uncertain.

is promoted to ensure regeneration following the harvest. When timber products are of interest, dead and declining trees are removed early and used before the wood degrades.

Oak wilt

Oak wilt, caused by the fungus *Ceratocystis fagacearum*, is a native tree disease in the Eastern U.S. (Tainter and Baker 1996). Thousands of oaks die every year from infection by the pathogen. Oak wilt has been reported in or near all the counties of the assessment area (O'Brien et al. 2000). Although oak wilt is a serious problem in the more northern areas of Indiana and Illinois, it is considered only a minor problem in the southern areas because infection centers there usually do not become very large (P. Marshall, personal communication). Red oak species are most susceptible to the disease and usually die within the same year they were infected. Infected white oaks, however, die from 2 to 15 or more years later depending on the species. The pathogen is spread in two ways: 1) belowground through grafted roots between diseased and healthy trees, and 2) aboveground by insect vectors.

Sudden Oak Death

The causal organism of Sudden Oak Death, *Phytophthora ramorum*, is a recent discovery and a newly described species (O'Brien et al. 2002). As of fall 2003, the fungus-like organism (an oomycete) has been found on ornamental and nursery plants on the west coast of North America and in England and a number of European countries, as well as on numerous shrubs and trees in forest and wildland-urban forest ecosytems of California, in a small forest area of southwest Oregon, and on forest trees adjacent to public gardens in England and the Netherlands. The pathogen has caused a serious disease epidemic in oak and tanoak (*Lithocarpus densiflora*) forests of California. Widespread dying of tanoaks was first reported in 1995, but the causal agent was not identified until 2000 (Rizzo et al. 2002). The pathogen causes multiple cankers on the stems and branches of oaks and tanoaks and has killed large numbers of trees in 12 counties of California, increasing fire risk and degrading forest ecosystems.

Eastern oak species including chestnut oak (*Q. prinus*), white oak, and northern red oak have been found to be susceptible to *P. ramorum* based on seedling inoculation tests (Tooley et al. 2003). One possible means of pathogen spread is via infected nursery stock, such as rhododendrons. The pathogen can potentially be spread to the assessment area. Quarantines have been imposed in the U.S. to restrict the movement of lumber, logs, mulch, woodchips, firewood, nursery-related materials, and other items from infested to uninfested areas (USDA Animal and Plant Health Inspection Service 2003). If the disease is detected, affected trees and surrounding buffer trees will likely have to be eradicated.

Insects

Forest tent caterpillar

Forest tent caterpillar (*Malacosoma disstria*) is a native defoliator of several hardwood species, but oaks are the main species group affected in the Central States (USDA Forest Service 1989). Other host species fed upon include aspen (*Populus tremuloides*), birch (*Betula* spp.), cherry (*Prunus* spp.), basswood (*Tilia americana*), and ash (*Fraxinus* spp.). The forest tent caterpillar has been considered an important pest of forest trees for many years (Batzer and Morris 1978). Losses in reduced growth following defoliation may be great but tree mortality is generally not common. The pest has historically been a problem in the Oakwood Bottoms Greentree Reservoir of the Shawnee National Forest, particularly on the overmature pin oak resource (D. Haugen, personal communication). Serious defoliation occurred in Lawrence and Martin Counties in Indiana (including the Hoosier National Forest) from 1976 to 1979 (P. Marshall, personal communication).

The forest tent caterpillar has one generation per year. Extensive feeding in tree crowns by the caterpillars (larvae) leads to defoliation. The larvae emerge in spring and begin feeding immediately. They form silken mats on the branches and main stems. Approximately 6 weeks after they emerge, the larvae spin cocoons and pupate. Adult moths emerge about 10 days later and live only a few days. Females lay large numbers of eggs mostly on upper crown branches, and the insect overwinters in the egg stage. Strong winds can carry the moths many miles.

Outbreaks of the pest usually subside after 3 or 4 consecutive years of defoliation (USDA Forest Service 1996). Several adverse environmental factors and natural biological controls are responsible for population decline. Regionwide outbreaks have occurred at intervals varying from 6 to 16 years in northern areas.

The effects of the forest tent caterpillar on the forest ecosystem are both biological and sociological. Besides reducing tree growth and survival, the migrating caterpillars can be a nuisance to recreational forest users. The appearance of defoliated trees during late spring and early summer can also reduce tourism.

Borers

The twolined chestnut borer (*Agrilus bilineatus*) is a native pest that attacks various hardwoods, but especially several species of oaks in the Central States (Haack and Acciavatti 1992). Trees weakened by drought or defoliation are most susceptible to attack, and the insect is often implicated in oak decline (previously discussed). The larvae tunnel in the phloem and outer sapwood, such that a heavy infestation may girdle and kill the tree (USDA Forest Service 1989).

The red oak borer (*Enaphalodes rufulus*), a longhorned beetle native to North America, is responsible for large annual losses in the hardwood timber industry (Donley and Acciavatti 1980, USDA Forest Service 1989). The loss in lumber grade can amount to 40 percent of the current tree value and is caused by tunneling of the larvae. About 38 percent of the oak wood used for lumber, cooperage, and veneer in the Eastern U.S. is affected by this pest. Species of the red oak group are the preferred host. The pest is an important component of the current oak decline outbreak in Missouri.

Jumping oak gall

The light-tan, globular galls associated with jumping oak gall are caused by the native cynipid wasp, *Neuroterus saltatorius* (USDA Forest Service 1979). The gall is about the size of a sesame seed and hangs from the underside of the leaf. When the galls mature, they drop from the leaves and carry the wasp to the ground. Larval activity inside the gall causes the gall to jump around on the ground, hence, the name "jumping oak gall." Outbreaks of this pest occurred in Missouri in 1998, and over 1 million acres were affected in Indiana in 1999. Significant levels of infestation were also observed in 2003 (P. Marshall, personal communication).

This small wasp has two generations per year (USDA Forest Service 1989). The first generation emerges in the spring from galls on the ground. This female-only generation lays its eggs on buds and new foliage. Several weeks later, small blister-like galls form on affected leaves as the larvae develop. The male and female wasps that develop from these larvae mate, and the second-generation females lay their eggs on the mature leaves of host trees. The more conspicuous galls created by this second generation then fall to the ground where they overwinter and complete the cycle.

Looper complex

The linden looper (*Erannis tiliaria*) and half-wing geometer (*Phigalia titea*) feed on and defoliate many hardwood species (USDA Forest Service 1979, 1989). The favored hosts include such trees as red oaks, basswood, maples (*Acer* spp.), and hickories (*Carya* spp.). Although looper-affected stands usually recover, repeated defoliations by either insect can contribute to tree mortality. In general, mortality is confined to trees weakened by drought, disease, or other stresses. Considerable defoliation of oaks and other hardwoods occurred in southern Indiana in 2003 (Sadof and Marshall 2003). This infestation was similar in distribution to that reported in 1979-81. In the earlier epidemic, the defoliation led to 10 percent oak mortality in the area from Morgan-Monroe State Forest south through the Hoosier National Forest to the Ohio River.

Both insect species have one generation per year. The eggs hatch in the spring, and larvae feed on leaves between late April and late June. Entire leaves are consumed except for major veins. Some dispersal of the half-wing geometer occurs when the larvae spin silken threads and are wind-borne to other locations. Both species pupate in the soil. Following emergence and mating by adult moths, eggs are laid. Linden loopers overwinter as eggs, while pupae are the overwintering stage for the geometer. The loopers are managed in forests by selective harvesting of defoliated stands, based on the extent and intensity of the recent defoliation.

Walkingstick

Walkingsticks (*Diapheromera femorata*) are common defoliators of deciduous trees in North America (USDA Forest Service 1989). Nymphs and adults consume entire leaves, except for parts of major veins. Defoliation may occur twice in one season, and trees over large areas may be defoliated during walkingstick outbreaks. Three or four infestations of individual trees can kill some branches. At times in mixed stands, the insect's selective feeding on black oaks may favor the growth of white oaks or conifers (Wilson 1971). Young nymphs feed on low-growing plants (e.g., beaked hazel, *Cordus corylus*; juneberry, *Amelanchier* spp.), while older nymphs and adult prefer black oak, basswood, and wild cherry.

European gypsy moth

The European gypsy moth (*Lymantria dispar*), a major defoliator of hardwood trees in both forest and urban landscapes, has caused considerable damage to forests in the Northeastern U.S. (McManus et al. 1992). This exotic insect became established in Massachusetts in 1869 and has since become widespread in the northeastern deciduous forests where its favored hosts, oaks, are common (USDA Forest Service 1989). Its range expands each year; the current southern extent of infestation is Virginia and the western extent is Wisconsin (fig. 1). It will likely have a major effect on the oak forests of the assessment area in the near future because the oak forests of southern Indiana and southern Illinois have been rated as highly susceptible to gypsy moth infestation (Liebhold et al. 1995). Several consecutive years of severe defoliation by the larvae can contribute to oak decline.

Gypsy moth larvae prefer hardwoods but may feed on several hundred different species of trees and shrubs (Liebhold et al. 1995). In the East the insect prefers oaks, apple (*Malus* spp.), sweetgum (*Liquidambar styraciflua*), speckled alder (*Alnus rugosa*), basswood, birch, poplar (*Populus* spp.), willow (*Salix* spp.), and hawthorn (*Crategus* spp.). The host list will undoubtedly expand as the insect spreads further south and west (Liebhold et al. 1995). During heavy infestation, gypsy moth larvae feed on almost all vegetation on a site. However, to date, the insect has avoided ash, yellow-poplar (*Liriodendron tulipifera*), sycamore (*Platanus occidentalis*), butternut (*Juglans cinerea*), black walnut (*Juglans nigra*), catalpa (*Catalpa speciosa*), flowering dogwood (*Cornus florida*), balsam fir (*Abies balsamea*), eastern redcedar (*Juniperus virginiana*), American holly (*Ilex opaca*), and several shrub species (Liebhold et al. 1995). Several interrelated factors (e.g., abundance of favored host, site and stand factors, and tree conditions) determine the vulnerability of forest stands to gypsy moth defoliation.

The gypsy moth has one generation per year. Eggs hatch during late April to early May at approximately the same time as budbreak in oaks. The larvae crawl to the tree crowns to feed until early summer. After feeding, the larvae pupate and emerge as adult moths in about 2 weeks. Shortly after the female emerges, she mates and lays a single egg mass (100 to 1,000 eggs per mass) on trees, rocks, or other objects. These egg masses are the overwintering stage of the insect.

Spread rates for the gypsy moth increased from 1.8 miles/year between 1916 and 1965 to 12.4 miles/year between 1966 and 1990 (Liebhold et al. 1992). In addition to the steady dispersal of the first instar larvae by wind, the insect can be transported over long distances during other life states by human activities. Within infested forests, gypsy moth populations periodically increase to outbreak levels and cause widespread defoliation (McManus et al. 1992). The insects are, however, subject to a number of natural controls that limit their growth potential. For example, cool, wet weather during egg hatch can kill many young caterpillars. Epizootics of a naturally occurring virus (nuclear polyhedrosis virus) and a fungus (*Entomophaga maimaiga*) can cause widespread collapses in gypsy moth populations (Reardon and Hajek 1998). Other natural enemies of the pest exist.

The effects of dying and dead trees resulting from repeated gypsy moth defoliation are numerous. Understory plants dependent on the shade of the affected tree are stressed. Animals depending on the affected tree species for shelter or food are affected. Timber loss occurs in certain areas. Hazard trees are created and fire risk may increase. The larvae themselves are a nuisance and may deter visitors from recreation areas. Lastly, visual quality of the landscape is reduced.

Domestic quarantines are maintained to regulate the human-aided, long-distance transport of gypsy moths from infested to uninfested areas (USDA Animal and Plant Health Inspection Service 2002). Detection programs exist outside the generally infested area. When isolated reproducing populations are detected in such locations, eradication efforts are undertaken. Suppression programs are carried out in the generally infested area to mitigate impacts in selected environments. Specific management strategies for *L. dispar* are covered in detail in the Final Environmental Impact Statement for Gypsy Moth Management in the United States (USDA Forest Service 1995). Detection programs within the assessment area and eradication of isolated reproducing populations should extend the time until the pest ultimately becomes established. In addition, implementation of selected forest management strategies before pest establishment in the assessment area would lessen effects that the pest could have in the future (Gottschalk 1993). Other strategies would likely be considered once the pest becomes established and suppression programs are justified.

DISEASES AND INSECTS OF PINE AND REDCEDAR

Forest cover types that include pine (*Pinus* spp.) and eastern redcedar account for <15 percent of forests in the assessment area (USDA Forest Service 2001). Plantations of shortleaf (*P. echinata*), loblolly (*P. taeda)*, red (*P. resinosa*), Virginia (*P. virginiana*), and eastern white pine (*P. strobus*) are found in the assessment area. Except for isolated stands of shortleaf pine in Illinois and Virginia pine in Indiana, none of these species of pine are native to the area. Most of the plantations were established during the 1930s and 1940s and their general health is declining because the trees are now overmature and not well suited for the sites on which they are growing.

Several diseases and numerous insect pests can significantly affect forest ecosystems where pine or redcedar are important components (table 2).

Diseases

Annosum root disease

Annosum root disease, caused by *Heterobasidion annosum*, is one of the most economically important diseases of conifers in the North Temperate Zone of the world and occurs in most forested areas of the U.S. (Tainter and Baker 1996). The pathogen causes a root and butt rot of affected conifers (Robbins 1984). Infected trees grow more slowly and are susceptible to windthrow and bark beetle attack. Mortality commonly results from infection. Although hardwoods are also susceptible, conifers (including *Juniperus, Larix, Picea,* and *Pinus*) are the major hosts.

New root disease centers are established when spores of the fungus land on freshly cut stump surfaces. Spread from a diseased tree to adjacent healthy trees can occur through root contact. This spread leads to a slowly expanding, somewhat circular disease center. The fungus may survive in infected stumps for 5 to 25 years and produces fruiting bodies and spores. Although quantitative impacts of the disease in the assessment area are not known, the risk of new infection centers developing in pine plantations is high especially following stand thinning (Froelich et al. 1977). Annosum root disease was associated with large pockets of mortality in two red pine stands in the Hoosier National Forest in 1993 (D. Haugen and J. O'Brien 1993).

Clusters of dead trees in pine stands are the most visible effect of the disease. Such openings may be beneficial for wildlife. The disturbed site also may be colonized by invasive plants and the dying trees heavily infested with bark beetles. The primary means of disease control is to prevent infection of freshly cut stumps during thinning.

Armillaria root disease

In North America, Armillaria root disease is caused by at least 10 different biological species of the fungal genus *Armillaria* (Shaw and Kile 1991). More than 600 woody plant species are hosts for *Armillaria* species. *Armillaria ostoyae* is one of the most important root pathogens of conifers in the Eastern United States (Williams et al. 1986) and is presumed to be the species present in pine stands in the assessment area. *Armillaria* (presumably *ostoyae*) can cause substantial losses in red pine sites originally occupied by oaks and possibly other species such as aspen in the North Central States (Tainter and Baker 1996). Red pine on sites not well suited for its growth is also predisposed to infection. The susceptibility of shortleaf, Virginia, and eastern white pine growing in the assessment area to *A. ostoyae* is not known.

The fungus generally produces clusters of honey-colored mushrooms in the fall. Local spread of the fungus from infected trees, stumps, or other residue occurs through shoe-string like structures called rhizomorphs. Infected red pine usually dies in localized areas scattered across a plantation. Large areas of mortality were observed in two red pine stands of the Hoosier National Forest in 1993; Armillaria root rot and two other root diseases as well as several pine bark beetles were present in declining trees (D. Haugen and J. O'Brien 1993).

Armillaria spp. may be beneficial in forested ecosystems by acting as thinning agents in dense stands and coincidently improving stand quality. Small openings created by disease centers may also improve forage for wildlife. The mushrooms of the fungus are eaten by many mammals. The fungus is also considered beneficial as a decomposer of downed and dead timber. The negative effects of Armillaria root disease in pine stands include tree mortality and creation of potential hazard trees in recreational areas.

Table 2. Insects and diseases affecting or with future potential to affect pine and redcedar forest cover types in the assessment area.

Pest type	Common name	Scientific name	Status in U.S. native/exotic	Effect of insect or disease on forest resource* Past	Present	Future potential
Disease	Annosum root disease	*Heterobasidion annosum*	native	X	X	?
Disease	Armillaria root disease	*Armillaria ostoyae*	native	X	X	?
Disease	White pine blister rust	*Cronartium ribicola*	exotic	X	X	X
Insect	Pine bark beetles	*Dendroctonus tenebrans* *Ips grandicollis, I. pini*	native	X	X	?
Insect	Pine root collar weevil	*Hylobius radicis*	native	X	X?	?
Insect	Introduced pine sawfly	*Diprion similis*	exotic	XX	X	?
Insect	Pine shoot beetle	*Tomicus piniperda*	exotic	0	X	XX?

* Degree or severity of effect: 0 = not established, X = minor, XX = moderate to major, ? = uncertain.

White pine blister rust

White pine blister rust is caused by an exotic rust fungus, *Cronartium ribicola* (Nicholls and Anderson 1977, Tainter and Baker 1996)). The fungus causes cankers on the branches and stems of nearly all white pine species, including eastern white pine. The fungus requires an alternate host, *Ribes* species, to complete its life cycle before re-infecting the pine host. The disease is most common in areas where the microclimate favors infections of the foliage by the fungus, i.e., where periods of cool temperature and 100 percent relative humidity for ≥24 hours are common. White pine blister rust is present in the assessment area but does not cause significant damage or mortality.

Insects

Pine bark beetles

The black turpentine beetle (*Dendroctonus tenebrans*), a native pest, prefers trees of reduced vigor (Smith and Lee III 1972). All species of southern pines and red spruce (*Picea rubens*) are attacked, but loblolly and slash pines (*P. elliottii*) seem to have higher risk of beetle damage (USDA Forest Service 1989). The beetles are attracted by terpenes released by fresh stumps and injured trees. Trees damaged or weakened by fire, logging, or drought are also highly susceptible. Large pockets of mortality (3-5 acres) were observed in two red pine stands of the Hoosier National Forest in 1993, associated with black turpentine beetles, *Ips* beetles (see below), and three root (D. Haugen and J. O'Brien 1993). Three years of drought preceded the mortality, and the trees were overmature and not well suited for the sites. The pests were likely beneficial in hastening conversion of the stands from non-native pines to native hardwoods. Two native engraver beetles (*Ips grandicollis* and *I. pini*) occur within the assessment area and may contribute to mortality of conifers (USDA Forest Service 1979). These beetles usually prefer trees that have been weakened by lightning or other damage, or they infest and populations increase on fresh slash after logging. Both species attack all pine species found in the assessment area; *I. pini* attacks several spruce (*Picea*) species as well. Besides contributing to mortality in red pine stands on the Hoosier National Forest, these *Ips* species have been associated with disease centers in a shortleaf pine stand (D. Haugen and J. O'Brien 1993).

Weevils

The ranges of several native weevils that affect regeneration of pines overlap with the assessment area; however, only one of these weevils is considered to be of concern. The pine root collar weevil, *Hylobius radicis*, occurs throughout the north central and northeastern region of the U.S. and in southeastern Canada (USDA Forest Service 1989). It primarily attacks Scotch

(*P. sylvestris*), red, jack (*Pinus banksiana*), Austrian (*Pinus nigra*), and eastern white pine. The insect larvae feed belowground in the root collar, root crown, and on larger roots. Such feeding injury may kill small (<10 cm diameter) trees. Partial girdling of the root collar area in larger trees results in reduced growth rate, increased susceptibility to windthrow, and predisposition to other pests. Pine root collar weevil is scattered through areas of the Hoosier National Forest because of the presence of Scotch pine Christmas tree plantings. Its impact on forest stands is low (P. Marshall, personal communication).

Introduced pine sawfly

Eastern white pine is the preferred host of the introduced pine sawfly (*Diprion similis*), an exotic insect first reported in the U.S. (Connecticut) in 1914 (USDA Forest Service 1989). The larvae consume foliage of infested trees. Branches and sometimes entire trees are killed following early season defoliation by the insect (Wilson 1966). Two distinct, widespread outbreaks have been reported in North Carolina, Tennessee, and Virginia. Defoliation of white pine by this sawfly was observed within the assessment area in 1994 and 1995 (D. Haugen, personal communication).

Common pine shoot beetle

The common pine shoot beetle (*Tomicus piniperda*) is a serious pest of pines in Europe where it is considered the second most destructive shoot-feeding insect. This beetle was first discovered in Ohio during 1992 (Haack and Kucera 1993). The species now occurs in parts of nine States in the United States (including Illinois and Indiana) and in Ontario, Canada (Ciesla 2001, USDA Animal and Plant Health Inspection Service 2003), and it has the potential to spread over much of the U.S. and Canada. In areas of the United States where this insect has become established, Scotch pine is its preferred host, but Austrian pine, eastern white pine, red pine, and jack pine also have been attacked (Ciesla 2001). The most severe damage caused by *T. piniperda* is the destruction of shoots during maturation feeding. Tree height and diameter growth are reduced when shoot feeding by the beetle is severe. The potential for the common pine shoot beetle to damage pine in forests of the assessment area is low. The insect and associated damage have appeared primarily in Christmas tree plantations and pine tree nurseries.

In cooperation with State officials, the USDA Animal and Plant Health Inspection Service (2003) has quarantined counties in portions of 11 States, including Indiana and Illinois. The Federal quarantine regulates pine logs, stumps, and lumber with bark attached in addition to Christmas trees and pine nursery stock. Several counties in and around the northern end of the assessment area in Indiana are either currently under the Federal quarantine, were added to the quarantine in 2001, or have been surveyed for the pest. Specifically, Brown County (includes part of the Hoosier) and Owen County were added. The close proximity of these quarantined counties and the general quarantined area raises some concerns about management on the Hoosier National Forest.

DISEASES AND INSECTS OF NON-OAK, BROAD-LEAVED TREES

Non-oak broad-leaved trees (excluding dogwood) account for 19 to 31 percent of forests in the assessment area (USDA Forest Service 2001). Numerous diseases and insect pests occur on elm, maple, ash, birch, aspen, black cherry, and other tree species in these forests (table 3). Dogwood also occurs in two oak cover type forests in the assessment area.

Diseases

Dutch elm disease

Dutch elm disease (DED), caused by exotic pathogens, became established in the U.S. following introduction of the original pathogen (*Ophiostoma ulmi*) in the early 1930s

Table 3. Insects and diseases affecting or with future potential to affect non-oak, broad-leaved forest cover types in the assessment area.

Pest type	Primary forest tree spp. affected	Common name	Scientific name	Status in U.S. native/exotic	Effect of insect or disease on forest resource*		
					Past	Present	Future potential
Disease	Elms	Dutch elm disease	*Ophiostoma ulmi* *Ophiostoma novo-ulmi* *Scolytus multistriatus***	exotic	XX	XX	X?
Disease	Butternut	Butternut canker	*Sirococcus clavigigenentia-juglandacearum*	exotic	X	X	X
Disease	Ash	Ash yellows	phytoplasma	native	X?	XX	XX
Disease	Dogwood	Dogwood anthracnose	*Discula destructiva*	exotic	X	X	X
Disease	Chestnut	Chestnut blight	*Cryphonectria parasitica*	exotic	XX	XX	?
Insect	Ash	Emerald ash borer	*Agilus planipennis*	exotic	0	0	XX
Insect	Maples	Asian longhorned beetle	*Anoplophora glabripennis*	exotic	0	0	X

* Degree or severity of effect: 0 = not established, X = minor, XX = moderate to major, ? = uncertain.
** Scolytus multistriatus is an exotic insect vector of the Dutch elm disease pathogen.

(Tainter and Baker 1996, Haugen 1998). An insect vector, the smaller European elm bark beetle (*Scolytus multistriatus*), also was accidentally introduced. A second, closely related, and more aggressive species (*Ophiostoma novo-ulmi*) arrived later and resulted in additional waves of mortality. These exotic pathogens and the exotic beetle are responsible for significantly reducing the populations of elms in the U.S.; losses have been particularly devastating in urban areas. The first wave of DED in the assessment area in the late 1960s and 1970s caused widespread mortality in mature elms. The beetles reproduce in dying elms, and the emerging generation of adults leaving DED-infected trees may carry spores of the causal fungus on their bodies. The infested beetles then transmit the fungus to healthy trees when they feed in twig crotches. The recent increase in DED mortality is likely due to a new cohort of American elms reaching susceptible age. The fungus also is spread from diseased to healthy trees through root grafts.

Mortality of American elms from DED in the assessment area will likely continue. The survival of the elm species, however, is not of concern because young trees can produce several seed crops before they are at risk from bark beetle infestation. There is no feasible, effective control for DED in forests.

Butternut canker

Butternut grows on rich loamy soils as a minor component in mixed hardwood forests in the Eastern U.S. including parts of the assessment area. Butternut is being killed by *Sirococcus clavigigenenti-juglandacearum*, a fungus considered exotic to North America (Ostry et al. 1996). Multiple perennial stem and branch cankers caused by fungus infection coalesce and lead to tree death. Since it was first identified in 1967, butternut canker has spread throughout the range of the host species. Overall in the Southern U.S., butternut mortality from this disease is estimated at 77 percent. The losses in the assessment area have not been documented, but disease occurrence has been reported. Butternut trees across the range of the species appear to have no resistance, and no risk factors associated with site have been determined. Therefore, butternut on all sites should be considered at risk for the disease. Butternut is a Regional Forester Sensitive Species (RFSS) in the Forest Service's Eastern Region for 13 of the 16 national forests there, including the Shawnee and the Hoosier. It also is listed as a species of current viability concern for the Northern Hardwoods Ecosystem. Currently, harvest of healthy butternut is restricted on Federal lands, and guidelines for retention of living trees are available (Ostry et al. 1994). The effects of the disease are evident in the loss of wood for specialty uses and products, loss of wildlife food, failure of reproduction by the species (i.e., nuts from declining trees are not viable), and imminent loss of this species from the forest. There is no known control for this disease.

Ash yellows

Ash yellow, a recently discovered (1980s) disease of unknown origin, results in poor growth and gradual decline of ash species (Tainter and Baker 1996, Pokorny and Sinclair 1994). This disease is caused by phytoplasmas (wall-less microbes) that infect and move through the phloem sieve tubes of infected trees. Twelve ash species are reported hosts of the phytoplasma, but white (*F. americana*) and green ash (*F. pennsylvanica*) are the most frequently affected species. The impact of ash yellows on ash populations is not well documented. However, white ash trees that become infected when young do not grow to merchantable size, but merchantable-size trees will survive for 5 to 10 years following infection. Ash yellows may sometimes be a factor in ash decline. In 1995, the State of Indiana reported that approximately 3 percent of the ash population each year showed initial signs of decline due to ash yellows and that tree mortality ranged from 2 to 7 percent annually. The prevalence and long-term effect of the disease on ash in the assessment area, however, is not known. There is no known way to prevent or cure ash yellows.

Dogwood anthracnose

Dogwood anthracnose, caused by the fungus *Discula destructiva*, was first observed in Washington State in the late 1970s. Following its subsequent appearance in New York in 1978, it has apparently spread rapidly south down the Appalachians to Alabama and as far west as Missouri (Kennard 2001). Flowering dogwood is the principal host in the Eastern U.S. and is not resistant to the disease (Mielke and Daughtrey 1990). The pathogen (most likely an exotic) first infects leaves and causes spots; it then moves through petioles to branches and stems where it causes cankers. In forests, flowering dogwood usually dies within several years of initial infection. Cool moist environments favor infection and disease development. Mortality may be extensive in the landscape. As of 1999, the disease had killed 50 percent of native dogwood trees in 24 western counties of North Carolina (Kennard 2001). Although the disease has been reported within the assessment area, it has not yet caused significant mortality.

Effects of the disease on flowering dogwood in the southern Appalachians have been serious. Aesthetic quality and the tourism industry have been harmed. Dogwood fruits for wildlife food have been lost. Dogwood leaves have also been considered important in maintenance of soil properties, and loss of dogwood leads to deterioration in soil health. Similar effects would be likely for the assessment area if dogwood anthracnose increases in incidence and severity. There are currently no known controls for managing dogwood anthracnose in forests.

Chestnut blight

Chestnut blight, caused by *Cryphonectria parasitica*, is the most devastating exotic tree disease known in the U.S.. The pathogen has killed all but a small fraction of the original population of American chestnut (*Castnaea dentata*) in that species' natural range (as well as other *Castanea* spp.) since the pathogen's accidental introduction in the early 1900s. The disease causes rapidly growing cankers on branches and stems of trees; stems usually die within 1 to 2 years as these cankers coalesce. Spores of the fungal pathogen are disseminated by wind and wind-driven rain and infect the trees through cracks or wounds in the bark. There is no natural resistance to this exotic pathogen.

American chestnut once grew in one small portion of the assessment area, but this niche has since been occupied by other species. Resistant varieties resulting from backcrossing studies by the American Chestnut Foundation may be available within the decade for deployment in selected areas of the previous range of the species. The USDA Forest Service is currently exploring a partnership with the foundation concerning potential use of such stock for ecosystem restoration on selected portions of Federal lands such as the assessment area.

Insects

Emerald ash borer

Emerald ash borer (*Agrilus planipennis*), an exotic insect from northeastern China, was first found to be established in the United States (Michigan) in 2002 (McCullough and Roberts 2002). As of 2003, infestations had been confirmed in 13 Michigan counties; one adjoining county in Ontario, Canada; and two counties in northwestern Ohio (D. Haugen, personal communication). The infestation in the Detroit area had apparently been established for at least 5 years before its discovery. The borer has infested and killed trees in both urban areas and native forests. Extensive feeding galleries of the larvae in the phloem and outer sapwood girdle branches and main stems. In Michigan, the borer has been observed only on ash trees. The borer has attacked both vigorously growing and stressed trees.

The adults are strong fliers and flights of >1 km are possible. In addition, the beetle can be transported in wood products with intact bark moving via international trade. Quarantines have been imposed in North America to restrict the movement of ash trees, firewood, branches, and logs from infested to uninfested areas (Michigan Department of Agriculture 2003). If the emerald ash borer were introduced to forest areas in the assessment area with an ash component, the potential for its establishment would be high (Ciesla 2003).

Asian longhorned beetle

The Asian longhorned beetle (*Anoplophora glabripennis*), a recent introduction to the United States, is a serious threat to the millions of acres of hardwood trees in forest lands and urban forests, and has no known natural predator in this country (USDA Forest Service 2002). The insect likely arrived in the United States inside solid wood packing material from China. The beetle has the potential to damage such industries as lumber, maple syrup, nursery, commercial fruit, and tourism. To date within the U.S., infestations have been found in metropolitan areas of New York City and Chicago, Illinois (USDA Forest Service 2003). In these areas, infested trees were removed and the woody material was destroyed by chipping and burning in an attempt to eradicate the insect. There are large areas of forest land with susceptible hosts in and around the southern Indiana portion of the assessment area.

Maples, including boxelder (*A. negundo*), Norway (*A. platanoides*), red (*A. rubrum*), silver (*A. saccharinum*), and sugar (*A. saccharum*), are the preferred host species in the U.S. Other known species include alders, birches, elms, horsechestnut (*Aesculus* spp.), poplars, and willows. Tunneling by beetle larvae girdles tree stems and branches. Repeated attacks lead to dieback of the tree crown and, eventually, death of the tree.

To prevent further spread of the Asian longhorned beetle, Federal quarantines have been established to avoid transporting infested trees and branches from these infested areas (USDA Forest Service 2003). The regulations also attempt to prevent movement of the insect on wood products such as solid wood packing material. The Asian longhorned beetle has not been detected in the year since treatment of the Chicago infestation (Dennis Haugen, personal communication) and, thus, the risk of introducing of the beetle into the assessment area has been greatly reduced.

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