FOREST HEALTH PROBLEMS
IMPACTING
INDIANA FOREST RESOURCES

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INTRODUCTION

Forest health problems are part of the management of forest resources. They range from localized impacts within one forest stand to region wide impacts across a large forest landscape. Forest health problems can be acute producing severe short-term impacts that may also have long-term effects, such as defoliation epidemics, bark beetle outbreaks and drought. Or they may be chronic producing low level impacts over long periods of time that accumulate and produce severe impacts, such as ash yellows, Dutch Elm Disease, oak decline and air pollution.

To aid in understanding forest health problems, they are organized into different groups. Four common groups, or agents, of forest health problems are 1.) Insects, 2.) Diseases, 3.) Weather and 4.) Declines. These groups (agents) are further organized to the part of the tree damaged – 1.) Leaves, 2.) Stem, 3.) Roots and 4.) Fruit. Using the part of the tree damaged aids in understanding the agent's potential impact to the tree and thus the entire forest.

Another organization to forest health problems is Native or Exotic. Native indicates a forest health problem that naturally occurs in the United States and has evolved with the environment to have balance through parasites and predators. Although native forest health problems periodically have epidemics, they usually return to a low level of occurrence and impact. However, during the epidemic the impact occurs immediately and may also have long-term effects.

Exotic indicates a forest health problem that is not known to occur naturally in the United States. Exotic's have not evolved with the environment and do not have the natural balance from parasites and predators (Executive Order 13112). Thus, they have the ability to impact the forest resources without any impediment. Exotics are one of the four risks recognized by the USDA Forest Service to the health of the nation's forests. (Bosworth, 2004)

The impacts of forest health problems are direct or indirect. Direct impacts refer to the tree or forest and occur in a short-term event. Indirect impacts are the associated impacts resulting from the direct impact and develop over a long period of time. Examples of direct impacts to the forest resource are tree mortality, growth loss, and reduction in lumber quality. Indirect impacts include changes in tree species composition, watershed quality, recreation opportunity, wildlife populations and others.

This report presents the Current and Future forest health problems of Indiana's forest resources. The report will present native and exotic insects, diseases, weather and declines giving their current and future status and impacts and suggested management.

CURRENT FOREST HEALTH PROBLEMS AND THEIR IMPACTS

INSECTS:

There are many insects impacting the forest resources each year. Much of this impact is minimal and not noticed by foresters, landowners or the general public. However, the small annual impact may accumulate over time and result in noticeable impacts to the forest resource. It is the obvious presence of the insect, such as the 17-year locust in 2004, which draws attention and concern of landowners and the general public.

The native insects that currently draw the attention of foresters, landowners and the general public and impact the forest resource are the looper epidemic, Forest Tent Caterpillar and pine bark beetles. There are other native insects that have or are impacting the forest resource on a small scale and with less impact and notice than the above.

<u>Looper Epidemic</u>

The Looper Epidemic involves two species – Linden Looper, *Erannis tiliaria*, and Half Wing Geometer – *Phaglia titea*. The epidemic began in 2002 with very light defoliation observed in Clark State Forest. The loopers were also present that year in Jackson-Washington and Harrison Crawford State Forests and the Tell City Ranger District of the Hoosier National Forest. In 2003, the epidemic developed over a multi county area of south central Indiana that included these forests. Light to heavy defoliation occurred in the forests and the associated private lands totaling 89,252 acres. The heaviest defoliation occurred in Clark and Jackson-Washington State Forests.

Linden Looper caterpillar

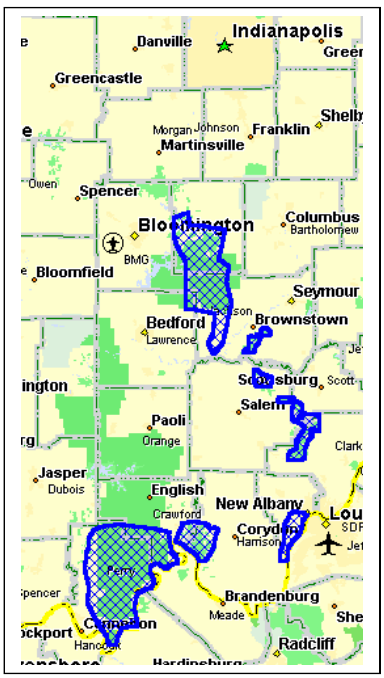


Figure 1. Looper epidemic areas that were defoliated in 2003 and 2004.

The epidemic continued through 2004 in these areas and expanded to Yellowwood State Forest, Brown County State Park, the Deam Wilderness and surrounding area on the Hoosier National Forest. Light to heavy defoliation totaled 131,943 acres. Again, Clark and Jackson-Washington State Forests sustained some of the heaviest defoliation. But the severest defoliation occurred in 2004 in Brown County State Park and the Nebo Ridge and Houston area of the Hoosier National Forest in Jackson County.

The epidemic collapsed by the spring of 2005 and aerial surveys did not detect noticeable defoliation in any area previously defoliated. One reason for the collapse was the presence of a parasitic fly that attacks the caterpillar, which was reported in Brown County State Park (personal communications from state park staff and entomologists). Other agents, such as fungus, virus, wasps, beetles and other parasites, that attack the life stages of the loopers are believed to be involved, however no surveys were conducted to detect and monitor their impact on the looper population.

The last looper epidemic occurred from 1979 to 1983 over the same area as the present epidemic. Comparing the two epidemic's, the current epidemic did not defoliate the Tell City District of the Hoosier National Forest as heavily and as widespread. Yellowwood State Forest and Brown County State Park only had one year of defoliation during the current epidemic compared to 2-3 years for the prior epidemic. Morgan-Monroe State Forest had one year of defoliation on part of the forest during this epidemic compared to 2-3 years of light to heavy defoliation over the entire forest in the prior epidemic. Jackson-Washington and Clark State Forests experienced similar amounts of defoliation for the two epidemics.

During the 1979 to1983 epidemic, tree mortality occurred throughout the epidemic areas. Jackson-Washington State Forest experienced the most mortality and salvaged dead timber from eight tracts from this epidemic. Surveys of mortality on Jackson-Washington State Forest found the following (Forest Pest Informer January 1983, Forest Pest Informer January 1984):

a. 12% of the total stand volume was killed;
b. the predominant mortality was to black and red oak;
c. other oak species and hickories also died;
d. 2-57% of the total volume of individual oak species were killed within tracts;
e. the average tree killed was 20" DBH and had 1.5 logs;
f. that dead trees lost 35% of their volume from decay of the sapwood;
g. hickories decay quickly and must be salvaged with one year of death;
h. oaks can be salvaged 2-3 years after death as heartwood does not rot quickly; and
i. mortality continued for 2-3 years after the defoliation stopped.

Although the defoliation has stopped for the current epidemic, the impact – tree mortality - from consecutive years of defoliation has begun. Jackson-Washington State Forest has marked two tracts during their normal harvesting schedule during the winter of 2004/05 and reported oak mortality at 45% of the volume marked for removal of which was predominately black oak (personal communication Eric Johnson, Property Manager). Although not surveyed, growth loss and timber quality impacts are present and progressing in the forests defoliated by the loopers.

From survey information on the current epidemic and in comparison to the prior epidemic, both epidemics occurred over the same forested area of the state. However the intensity and duration of defoliation over the area is less for this epidemic than the prior epidemic. An exception to this is Jackson-Washington and Clark State Forests where defoliation and impact appear to be similar for the two epidemics.

From the mortality data of the early 1980's looper epidemic, average mortality was 12% of total stand volume on Jackson-Washington State Forest. Dead trees lost 35% of their volume to sapwood decay. The average dead tree was 20" DBH and 1.5 logs, which is equal to 180 Bd.Ft. (Doyle Tree Scale, 16' log).

Assuming the average total volume per acre is 5,000 bd.ft. and average stumpage price of $.30/bd. ft. (Personal communication Don Stump, District Forester) then average mortality is 600 bd.ft./acre with a value of $180/acre. And reducing this amount by 35% for decay to sapwood, the average mortality from loopers is $117/acre. This estimate may be conservative when compared to $358/acre loss reported for the looper epidemic of the early 1980's in West Virginia (Hicks et.al, 1989).

Applying $117/acre to the forest acres of Jackson-Washington (16,500) and Clark (24,000) and assuming every acre of ownership is forested and receives mortality, the looper caused timber mortality would equal $4,680,000. Reducing to a more conservative estimate because not all forested acres will have mortality, assume that only 10-20% of the acres on the forest have mortality. Then total loss is estimated to be $468,000 to $936,000.

Using current defoliation survey information and experience from the first epidemic, forest management plans for these state forests are being revisited and adjusted to address the impact of the loopers. At the preparation of this report, aerial photo surveys are planned to capture mortality and use the photos to guide ground survey work. In addition, digitized defoliation maps have been prepared for each state forest to locate the most heavily defoliated tracts. With this information foresters can research stand inventory data and identify tracts likely to have extensive timber mortality. The goal is locate the tracts with heavy mortality and amend harvesting and management plans to salvage the timber and begin the process to restore the health of the forest tract.

It is recommended that management activities be conducted within one year and no longer than two years (by end of winter of 2006/2007) to optimize salvage of timber value. Research on the degradation of trees following death from gypsy moth defoliation recommends salvage operations for most timber uses should be completed within 2 years after tree death (Karasevicz 1989).

It is also recommended that management activities be conducted in a manner to prepare the future stand for gypsy moth by using the Gottschalk's Silvicultural Guidelines for Forest Stands Thinned by Gypsy Moth.

<u>Forest Tent Caterpillar</u>

The Forest Tent Caterpillar, *Malacosoma disstria*, epidemic also began in 2002 but did not produce noticeable defoliation until 2003. This epidemic occurs in a more confined area of the state than the looper epidemic. It is in Jefferson, Ohio and Switzerland Counties. The majority of defoliation from Forest Tent Caterpillar is on the forested slopes immediately north of the Ohio River. The state property defoliated is Splinter Ridge F&W Area, Clifty Falls State Park and Lanier Home. This epidemic is the northern extent of a large epidemic that resides in Kentucky.

Forest Tent Caterpillar

Comparing the defoliation of Forest Tent Caterpillar to the looper epidemic finds that Forest Tent Caterpillar caused higher levels of defoliation over three years and occurred over a smaller area of Indiana forests. The looper epidemic caused repeat defoliation for two years and occurred over a wider area of Indiana forests.

Some areas in the Forest Tent Caterpillar epidemic experienced three years of heavy defoliation. This creates tremendous stress on the trees, which are now responding by dying. Preliminary estimates from one reconnaissance survey found some forests have 20-30% mortality. The same survey also found that 75% of the pupae were parasitized and a majority of the new eggmases was poorly formed and smaller than average. This indicates the Forest Tent Caterpillar population is collapsing and defoliation should decrease or stop in 2006.

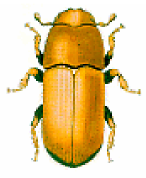
Figure 2. Forest Tent Caterpillar epidemic area 2003-2005.

The prior experience with a Forest Tent Caterpillar epidemic occurred from 1975 to 1977 in the Lawrence, Martin and Greene Counties. This epidemic defoliated less forest acres than the current epidemic, 16,032 vs. 28,705 acres, and collapsed after two years (Marshall & Hoffard, 1977). Pupal parasitism just prior to the population collapse in the 1975-1977 epidemic was 26% (Marshall & Hoffard, 1977.), which is much less than current parasitism, further suggesting that the current epidemic should collapse and the defoliation should decrease or stop in 2006.

Surveys during the 1975 to 1977 epidemic reported average basal area growth loss of 31.5 % and 2.2 trees dead/acre, which was equal to 192.5 bd.ft.dead/acre. The survey also found that 89% of the trees killed were in the red and black oak group (Marshall & Hoffard, 1977.). Using this information as a guide and the current defoliation history, growth loss and mortality in the current epidemic is expected to be at similar or greater levels allowing for variation between the forest habitats of the two areas. Using the above mortality estimate and an average stumpage price of $.30/bd.ft., the estimated timber mortality is $1,657,713.

Currently, aerial photo surveys are planned to map the mortality. This survey information will be paired with the annual defoliation maps to aid in identifying mortality areas that should be considered for silvicultural treatment using salvage or regeneration harvests to begin restoration of forest health. Since Forest Tent Caterpillar defoliates at the same phonological time and to the same preferred hosts as gypsy moth, the silvicultural guides developed for gypsy moth (Gottschalk, 1993) can be used to aid in Forest Tent Caterpillar management. Once information is collected and analyzed, it will be shared with foresters and landowners to aid them in making management decisions to restore the health of the forest.

Pine Bark Beetles



Southern Pine Beetle

The pine forests of Indiana are common on state and national forests in southern Indiana. These forests are reaching maturity and in many situations have increased in density from a lack of management activity. As the density increase, the trees are exposed to stress from competition with each other. Add increasing age and the trees are exposed to more stress because older trees have reduced capacity to respond to stressors such as drought and defoliation (Belanger & Malac, 1980).

There are several Pine Bark Beetle species in Indiana that are starting to realize the stressed status of the pine forest and are taking advantage of the tree stress to attack trees. From this attack, the beetles build a population that will grow in capacity to attack pines not in a weakened state. Bark beetles involved include Ips bark beetles, *Ips pini* or *Ips grandicollis*, and turpentine beetles, *Dendroctonus tenebrans and D. valens*.

The management of this forest health problem is best achieved using surveys to monitor the status of pine stands and quickly apply salvage harvests in infested stands and other silvicultural treatments in stands that are at risk to attack by bark beetles. The reason to act quickly is that stressed trees attacked by Pine Bark Beetles die quickly, usually within one growing season. And, Pine Bark Beetles are able to produce 2-3 generations in one growing season. Thus Pine Bark Beetles are able to expand their populations quickly and attack stronger trees, as they are the only food source remaining after the stressed trees are killed.

One limiting factor to the silvicultural management of pine is the limited, or lacking, market for pine lumber or pulpwood. Merely cutting the Pine Bark Beetle infested trees and leaving them in the stand does not remove the Pine Bark Beetle problem. The beetles can complete their life cycle in the cut tree and emerge to attack remaining trees. The utilization process removes the bark and cambium, which is the home and food supply for the bark beetles. Utilizing pines trees in a timely manner helps to manage the population levels of bark beetles. Removing infested and uninfested trees, also alters the tree-to-tree stress level from competition. This aids in restoring and maintaining a healthy pine forest.

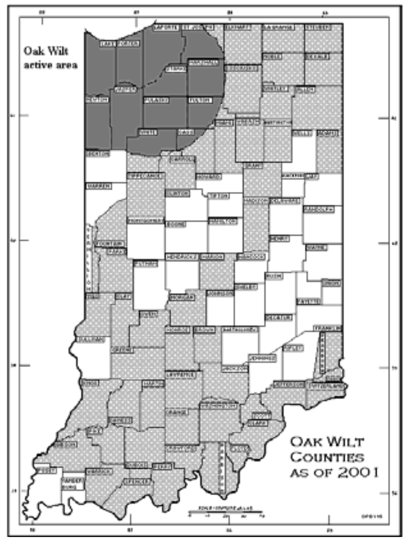
The future for pine stands across Indiana is the increased presence of Pine Bark Beetles and the death of pines in groups or scattered individual trees. Forest management activities that reduce stand density and promote radial growth are measures that can manage the impact of Pine Bark Beetles. (Belanger & Malac, 1983)

DISEASES:

Oak Wilt

Oak wilt, *Ceratocystis fagaecarum*, is a serious vascular disease that can infect all oaks but is more deadly to the red oak group than to trees in the white oak group. Present since the 1940's, this disease has been detected in all major forested counties across Indiana (Figure 3) and other midwest states (Figure 4). As recently as 2001, the distribution of Oak Wilt expanded in Indiana when Grant County was added to the list of infected counties. In this incidence, infected black oak in the forest served as the source for spread of the disease to the landowner's wooded home lot.

Figure 3. Oak wilt infected counties and the area of active oak wilt symptoms and mortality as of 2001.



Although the disease can be detected across the state, oak wilt's active area of impacting the forest resource is counties of northwestern Indiana. In northwestern Indiana, the symptoms and mortality from this disease are easy to see in both the rural and urban forests.

In the other forested areas of the state, oak wilt symptoms and mortality are not as easily identified from two other forest health problems – Armillaria Root Rot and Two-Lined Chestnut Borer. When dead oaks are encountered in southern Indiana, oak wilt may have infected and severely weakened the tree. In this weakened state, the tree is attacked by Armillaria Root Rot and Two-Lined Chestnut Borer to complete the mortality. Then when the trees are examined, the evidence of oak wilt is masked by symptoms of Armillaria Root Rot and Two-Lined Chestnut Borer.

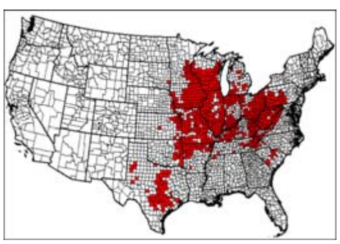


Figure 4. Distribution of oak wilt in the U.S.

Although a serious disease that annually kills oaks in the rural and urban forest, management guidelines are available for foresters, arborists, and landowners to use (Cummings-Carlson & Martin 1994). Developed through research in other forested regions of the Lake States, the guidelines are adaptable to Indiana's forests. Using detection/monitoring surveys to identify oak wilt infections, foresters can incorporate the guidelines into forest management plans and recommendations for both the rural and urban forest to minimize and manage the impact of this disease. (O'Brien, J.G. et.al. 2000). One management guide is to avoid pruning oaks during mid April to late July/August.

Comment [PM1]: Add information on success of using oak wilt guidelines. There is economic information on usefulness of this practice. Info on cost per foot of line.

Besides the mortality from this disease, another impact to Indiana's forest is the economic impact related to the exportation of oak logs and lumber. Oak wilt is not present in Europe and to prevent spread to Europe, international plant regulatory rules require certification that oak logs and lumber are free of oak wilt. One method used is to gain certification is removing bark and kiln drying the lumber. For oak logs, fumigation and the county of origin are used to gain certification. For the future, Oak Wilt will continue to be a serious problem in northwestern Indiana. Elsewhere in the state, conversion of oak forests to home sites and subdivisions will increase the risk that oak trees will be infected by this disease because of the disturbance to the sites.

Dutch Elm Disease

Dutch Elm Disease, *Ophiostoma ulmi & O. novo-ulmi* (*Ceratocystis ulmi)* was first detected in Indiana in 1934 (Holmes, 1962). An exotic invasive disease, Dutch Elm Disease is present across the state and is the limiting factor to presence of elm in the forest and urban environment. American elm is more susceptible than red elm to the disease and as such American elm is not as common as red elm in the forest. Reviewing the statewide forest inventories from the 1950's to the most recent in 2000 finds that the elm component of the forest has decreased, which is attributed to this disease (Schmidt et.al, 2000).

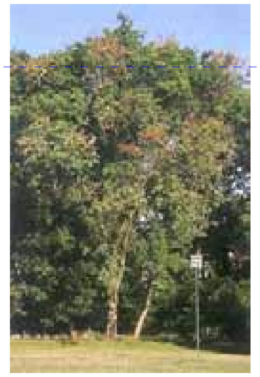


Figure 5. Early Dutch Elm Disease symptoms – red color branches.

Starting in the early 1990's, a new 'wave' of elm death started across the state and has continued to this time (Marshall, 1992). It is common to see the symptoms of this disease beginning in the crown of elms starting in July and continuing through the summer. This new 'wave' is attributed to a new aggressive strain of the fungus, *O. novo-ulmi*, and the regeneration of elms in the forests, fencerows and yards. Since the first killing 'wave' of Dutch Elm Disease, the young trees not killed and trees regenerating from seed have grown to a size that will support the bark beetle vectors of the disease. With an expanding bark beetle population spreading a new aggressive strain, the disease spreads from forest or fencerow to the next. Once infected, the disease spreads by root graft from elm to elm, leaving the dead skeleton to stand and fall apart in the forest or fencerow.

Management of this disease is based on survey to detect the disease followed by quickly applied sanitation measures to destroy infected trees while the bark beetle vectors are still in the tree and the severing of roots to prevent root graft transmission between tree to tree.

It is the research on and economic analysis of Dutch Elm Disease management in urban environments that serves as the premise for Indiana's Gypsy Moth Management Program. The research on Dutch Elm Disease management demonstrated that cities who actively surveyed for infected trees and quickly followed with sanitation management measures prolonged the life of the urban elm by 20 years when compared to a city that did not survey and apply management measures (Cannon & Worley, 1976). This principle applies to managing elms in the forest. Thus, forest management applied in a timely manner can help to manage and retain the elm component of the forest.

Elm Yellows (Elm Phloem Necrosis) is a disease symptomatically similar to Dutch Elm Disease and is present in Indiana. The distribution of the disease is probably widespread across the state

Comment [PM2]: Reference is Holmes, F.W. 1962. Recorded Dutch Elm Disease Distribution in North Amercian as of 1961. Plant Disease Reporter 46:10 715-718 p.

Comment [PM3]: Marshall, P.T. 1992. Forest Pest Informer, June/July. Indiana Dept. Natural Resources, Division of Forestry. 8 p.

Comment [PM4]: Cannon, W. N, Jr. and D.P. Worley. 1976. Dutch elm disease control: performance and costs. Northeastern Forest Experiment Station, Upper Darby, PA. 7 p.

but is not presently defined because surveys have not been performed and elm yellows infected trees may be determined to be Dutch Elm Disease because of the similarity in symptoms.

Dutch Elm Disease will continue to annually kill elms across the state. Over the next 10 years, the symptoms of the disease may be less noticeable as the elm tree population is reduced to a point where it is difficult for the beetles to sustain populations. As the beetle population decreases so should the spread and incidence of the disease. When this occurs, the elm tree population will slowly increase and trees will ultimately grow to a size to support beetle populations. When and if this happens, the next wave of Dutch Elm Disease will go across the state.

Ash Yellows

Ash Yellows is a chronic disease that is present across the forests of Indiana. Caused by a phytoplasma organism that works in the phloem tissue of the tree, Ash Yellows slowly causes dieback, growth loss and death of all ash species, especially white ash (Sinclair & Griffiths, 1994). With the introduction and threat of Emerald Ash Borer (see below), Ash Yellows is now the number two threat to the health of the ash resource.

Figure 6. Tufted foliage at tips of twigs and crown thinning of ash yellows infected tree.

Ash Yellows impacts are more noticeable across the northern forests of Indiana. Surveys from 1983-1994 determined that Ash Yellows is present in any forest of northern Indiana. In southern Indiana, Ash Yellows incidence is reduced compared to northern Indiana. Although present in all northern forests, the incidence and impact ranges from very low to very high. In southern forests, the disease incidence is lower than northern Indiana and works at a slower pace and lower impact. (Personal observations of author)

The impacts of this disease are growth loss and mortality. Quality impact to the value of the log has been reported by the industry, however no studies have been done to verify a relationship between ash yellows and log quality. The threat of Emerald Ash Borer over rides the concern for this disease.

Ash Yellows is a disease that is manageable through silvicultural treatments because of the slow pace of the disease and the ability to recognize symptoms early. As such, forest management practices can minimize the impact of growth loss and mortality, and still retain an ash component to the forest (Pokorny & Sinclair, 1994). The Ash Yellows monitoring surveys conducted in northern Indiana developed guides that aid the forester in the decision process to remove or retain the ash tree should the tree have Ash Yellows (Marshall, 1990).

Comment [PTM5]: Marshall, P.T. 1990. Draft Report: Observations on ash decline/ash yellows over a 10 year period in Indiana. (Unpublished), 6 p.

WEATHER:

Weather is an important component of the health of the forest. This is taught in the basic forest pathology courses through the disease triangle (Figure 7) (Francl, 2001). In the disease triangle, three elements are needed for a forest health problem – host, pathogen and environment (weather). However, weather can create a forest health problem by itself and then lead to a forest health problem by pathogens. The weather events creating forest health problems in recent years are tornado, flooding and drought.

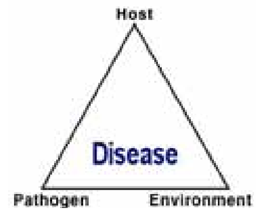


Figure 7. Disease Triangle

Tornado Damage

Tornado damage is an event that foresters must react to immediately versus an event that we prepare to prevent or suppress (such as gypsy moth epidemics). Although, we know the time of year tornados are likely to occur, the forester does not know where they will occur. The last tornado damage to state forests and private land was in 2004 to Clark, Harrison-Crawford and Ferdinand State Forests.

To manage the impacted forests aerial surveys are conducted to identify and map the extent of the damage (Barry, et.al. 1998). The identified tracts are surveyed by ground to prepare harvest and regeneration plans. Finally, the tracts have the trees sold and harvested.

When the tornado occurs, foresters need to salvage the trees as quickly as possible to recover as much timber value and to start the restoration of the forest. Quick response to salvage trees reduces the impact of wood boring insects and fungi that cause stain and decay. Removal of tornado damaged trees also reduces the build up and spread of insect populations, such as two lined chestnut borer in oaks and Ips bark beetles in pines, that have the potential to spread from tornado damaged trees to nearby healthy trees. Two line chestnut borer and Ips bark beetles attack weakened trees to start their epidemic and than can spread to healthy trees resulting in additional mortality that could be prevented by timely salvage of tornado damaged trees.

The optimum time to conduct the salvage to prevent additional value loss and insect population build up is within one year of the tornado. For pines, the optimum time frame is shorter. They need to be salvaged within six months (Barry, et.al. 1998 and Karasevicz & Merrill, 1989).

Flooding


Figure 8. Flooding on the Wabash River near Huntington in July 2003.

The last flood to affect the forests was in 2003 in northern Indiana. This occurred in the headwaters of the Wabash, Mississinewa, Salamonie, Eel, Tippecanoe and St. Mary's rivers (Figure 8). During this flood, rural and urban forests areas that normally do not experience flooding or experience short term intermittent covering of the soil, experienced continuous flooding that began to cover entirely or partially (depending on tree height) the foliage of the tree. It is the continuous flooding at greater depths that produce the impacts to the forest. Where intermittent low level flooding occurs, the forest has adapted through selection of species that are tolerant to flooding and impacts are minimal in these forests.

The impact from flooding to trees is physical removal, reduction in growth, mortality and loss of and reduction in economic value. The impact can occur immediately or take 3-5 years to occur as flooding puts the tree in a 'stress' condition. When in a 'stress' condition, trees are open to attack by other pathogens such as root rot fungi (*Armillaria, Phytophthora* and *Pythium*), canker fungi (*Nectria, Cytospora* and others), and bark beetles (*Agrilus, Ips* and others). It is the death of trees 3-5 years after the flood that is difficult to explain to the landowner, as they do not understand how a flood that occurred 3-5 years ago could still be killing their trees (Bratkovich, et.al. 1994).

The forest management implication from flooding is dependent on the duration, depth, and season of the flood and the species involved. Tree species vary in their susceptibility to flooding both from depth and duration. Species such as silver maple, red maple, green ash, sweetgum, sycamore, cottonwood, pin oak, swamp white oak, willow, elm and bald cypress are tolerant of flooding. They can survive flooding that lasts greater than 50 days or more. Other species such as shagbark hickory, black walnut, pine, black cherry, white oak, black oak, and red oak cannot tolerant flooding for more than a few days. Trees can also tolerate a flood in the dormant season better than they can during the growing season. A late spring flood, just after first flush of leaves is a time when trees are more susceptible to impacts from flooding (Bratkovich, et.al. 1994).

For the urban forest or tree, the impact of flooding is magnified because many of the trees in the urban area are already under stress. Flooding adds to this stress and creates impacts during a shorter period of time when compared to the rural forest.

Reports of tree mortality from the 2003 flood have been low with the majority of the mortality occurring to trees closer to the river that sustained a longer duration of flood.

<u>Drought</u>

The northern 2/3rd of the state and especially the northern 1/3rd and northwestern area of the state are in a drought. The southern 1/3rd of the state experienced drought conditions but they were not as intensive and were relieved by rains in July from hurricane Dennis.

For the northern areas, the National Weather Service Forecasting Office website as of August 23, 2005 reports drought conditions are improving (http://www.crh.noaa.gov/lot/climate/drought.php).

"The August 18th release of the drought monitor indicates an improvement to drought conditions over portions of northern Illinois and Indiana. The drought ratings were based on declining short-term conditions as well as below normal rainfall dating back from 6 months to 2 years. ….. Moderate drought conditions (D1) continue for Kankakee and Ford counties in Illinois and Newton and Jasper counties in Indiana. Abnormally dry conditions (D0) now covers Iroquois in Illinois and Lake and Porter counties in Indiana. Newton...Jasper...and Benton counties in Indiana are no longer suffering from dry conditions. "

The last drought events to impact the forests were in 1999 and 1988. These droughts resulted in timber mortality that occurred during the year of the drought and for 1-5 years after the event. In addition to mortality, radial growth loss is another impact of drought. The loss of radial growth varies with the species and the site conditions (mesic vs. xeric) (Orwig & Abrams, 1997).

The forest management implication from drought is the stress that trees experience. This stress exposes trees to attack by other organisms, such as two lined chestnut borer, Armillaria root rot, hypoxylon canker, ips bark beetles, red oak borers and other insects and diseases. Thus, drought becomes an inciting factor that can lead to tree decline and mortality (Starkey, et.al. 1989).

With the drought in the northern areas of the state, tree decline and mortality in the rural and urban forest should increase and be evident during the next 2-3 years. Also for northwestern Indiana, the incidence of Oak Wilt make increase as more oaks are stressed and more likely to die quickly when infected.

<u>Declines – Yellow Poplar and Hickory</u>

Tree decline is a complex disease with no single cause (Manion 1981). Declines are named for the genus/species of tree involved in the decline – oak decline, maple decline, ash decline (Ash Yellows). Over the past 4-5 years, foresters in south central and southeast Indiana report the increased decline and death of yellow poplar and bitternut hickory at a level that is above the average amount anticipated (Figure 9).

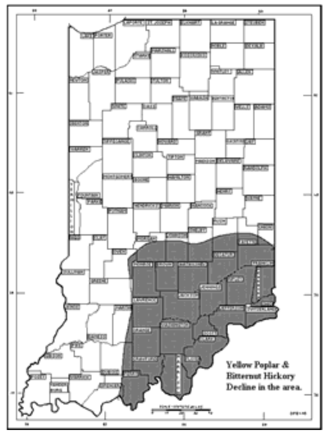


Figure 9. Yellow Poplar and Bitternut Hickory decline in this area of the state.

In addition, they report the pattern of decline and death is unusual. For yellow poplar, they observe and report trees show dieback and decline symptoms at any age and size of tree, the bark splits open and peels off the main stem starting in the lower part of the tree crown and the splits continue to root collar killing the tree.

For bitternut hickory, the trees decline and suddenly die, but it is only bitternut hickory and other smooth bark hickory species that decline and die. Shagbark and other loose bark hickory, even associated with bitternut hickory in the same forest do not decline and die.

From the observations and concerns of the foresters, surveys are underway to collect information from forests experiencing the declines. This information will be used for analysis and comparison with statewide inventory data to assess the impact of the decline and to provide an understanding of the factors involved in the declines. Factors that may be involved are drought/climatic trends, soil depth/texture, topography, tree age, defoliating insects, boring insects, root disease and stand disturbance.

With an understanding of the decline, information and forest management options for the declines can be developed and transferred to foresters. One important understanding of each decline is the future for each impacted species. The common question of landowners and foresters is 'Will all the yellow poplar/hickory continue to die or will the decline stop?'(Elliott & Swank, 1994) (Orwig & Abrams, 1997).

FUTURE FOREST HEALTH PROBLEMS AND THEIR POTENTIAL IMPACTS

INSECTS:

There are many exotic invasive forest insects impacting the forest resources of the U.S. each year (Exotic Forest Pest Information System for North America - http://www.spfnic.fs.fed.us/exfor/). Much of this impact occurs in other areas of the country and is limited in Indiana at this time. However, the impact of exotic invasive species can be as great or greater than the impact of native species. The increased impact results from the lack of natural balance between the exotic invasive species and the forest habitat attacked.

The exotic invasive forest insects that are currently of concern and/or impacting Indiana's forest resource are Gypsy Moth, Emerald Ash Borer, Asian Longhorn Beetles, and Exotic Bark Beetles.

Gypsy Moth

Gypsy Moth was first detected in Indiana by the capture of one male moth in 1973. A second moth was caught in 1977. Since 1980, Gypsy Moth has been detected each year in the state. In 2004, 9,014 male moths were detected with the majority in the northeastern corner of the state (Figure 9). The first treatment against Gypsy Moth occurred in Vigo County in 1982 and the second was in Elkhart County in 1983. The next treatment occurred in 1992 and since 1994, treatments have been made every year against Gypsy Moth populations detected primarily in the counties adjacent to Michigan. However there have also been treatments in the Indianapolis area and in southern Indiana.

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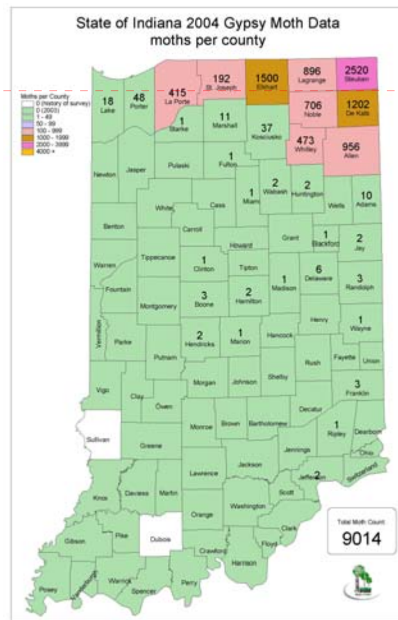


Figure 10. Gypsy Moth survey results for 2004 – number of male moths per county. Counties in white have never had Gypsy Moth detected.

To manage Gypsy Moth, the Forestry and Entomology & Plant Pathology Divisions developed the Cooperative Gypsy Moth Management Program. Other partners in this program include the USDA Forest Service, USDA Aphis, Purdue University and the Slow-The-Spread Foundation.

The primary basis of the Program is the cooperative statewide detection survey. Although Gypsy Moth surveys have been conducted across the state since 1972, the survey changed in 1988 to a statewide survey every year using defined detection survey grids to determine the location and level of Gypsy Moth populations. In 1999, Indiana adopted the survey protocol of the USDA Forest Service Slow-The-Spread Program (USFS-STS), which simply involved changing from a mile-based to a kilometer-based survey grid. By doing this, Indiana gained the computer technology and analytical resources of USFS-STS to analyze the status of Gypsy Moth and determine the treatment options to eradicate, slow-the-spread and slow-the-development of Gypsy Moth in Indiana.

The technology from USFS-STS that has benefited Indiana includes GIS software and support, GPS equipment and support, the mating disruption treatment option, decision algorithms for data analysis and data management.

In addition to technology, Indiana gained financial support from the USFS-STS that is administered through the Slow-The-Spread Foundation. For 2005, the two Divisions are receiving $204,708.54 from the Foundation (Indiana is a member of the Foundation and Bob Waltz is on the board of directors) to conduct the survey and support the Btk treatments (biological insecticide – *Bacillus thuringiensis var. kuristaki)*. The USFS-STS also provides financial support for the mating disruption treatments, data management and analysis and administrative support. For 2005, USFS-STS financial support for Indiana totals $284,531.00. Thus, total Slow-The-Spread financial support that benefits Indiana for 2005 is $486,609.54. (Table 1)

Table 1. Summary of financial support from USDA Forest Service Slow The Spread Program from 1999 through 2005 including state financial support.

	STS Foundation Grant				USFS STS Funds used in IN	Total STS Funds that benefit IN	Total STS & State Funds	Total Match %	
	Funds		Match %						
Year	STS	State	STS	State				STS	State
2005	$ 204,078.54	$ 282,050.00	42.0	58.0	$ 282,531.00	$ 486,609.54	$ 768,659.54	63.3	36.7
2004	$ 193,144.49	$ 199,698.05	49.2	50.8	$ 524,784.89	$ 717,929.38	$ 917,627.43	78.2	21.8
2003	$ 159,806.07	$ 157,644.53	50.3	49.7	$ 243,876.77	$ 403,682.84	$ 561,327.37	71.9	28.1
2002	$ 169,021.48	$ 150,419.68	52.9	47.1	$ 250,912.50	$ 419,933.98	$ 570,353.66	73.6	26.4
2001	$ 163,893.00	$ 158,621.00	50.8	49.2	$ 43,170.00	$ 207,063.00	$ 365,684.00	56.6	43.4
2000	$ 170,999.00	$ 146,019.00	53.9	46.1	$ 261,644.00	$ 432,643.00	$ 578,662.00	74.8	25.2
1999	$ 105,250.00	$ 33,750.00	75.7	24.3	$ -	$ 105,250.00	$ 139,000.00	75.7	24.3
Total	$ 1,166,192.58	$ 1,128,202.26	50.8	49.2	$ 1,606,919.16	$ 2,773,111.74	$ 3,901,314.00	71.1	28.9

Since 1999, the USFS-STS has provided $2,773,111.74 to Indiana. During the seven years, Indiana has provided matching funds of $1,606,919.16. Since joining USFS-STS, $3,901,314.00 of federal and state funds has been available to manage Gypsy Moth. For every 28.9 cents provided by the state, USFS-STS has provided 71.1 cents.

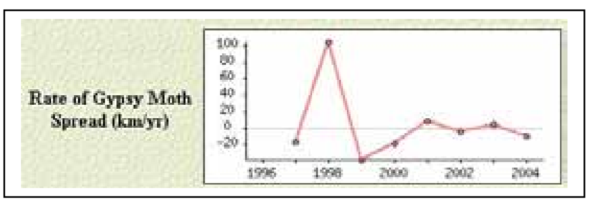


Figure 11. Spread rate (Km/yr) of Gypsy Moth in Indiana from 1997 to 2004.

Using USFS-STS technology and financial support, the Gypsy Moth management program has achieved a negative spread rate of 6.0 miles per year (-9.7 Km/year) at the end of 2004 and a negative spread rate average of 0.42 miles per year over the last four years (Figure 11) (Marshall, 2005).

To achieve the negative spread rate, 117 sites totaling 115,138 acres were treated since involvement with USFS-STS in 1999. The treatment methods of Btk and mating disruption were shared equally as 58 sites received Btk and 59 sites received mating disruption. However, the

Btk sites are smaller than the mating disruption sites – 17,735 versus 137,783 acres, respectively. (Table 2).

Table 2. Number of sites and acres treated for gypsy moth using Btk or mating disruption from 1999 to 2005.

	Btk		Mating Disruption		ALL	
Year	# sites	acres	# sites	acres	# sites	acres
2005	15	8231	9	31393	24	39624
2004	22	3969	17	56858	39	60827
2003	9	690	9	16901	18	17591
2002	3	1016	7	15654	10	16670
2001	1	39	4	1828	5	1867
2000	3	917	11	11215	14	12132
1999	5	2493	2	3934	7	6427
All	58	17355	59	137783	117	155138

Because of the combined and cooperative efforts of Indiana's Gypsy Moth Management Program and the USFS-STS, there has been only two years of noticeable defoliation by Gypsy Moth in Indiana. In 2003 noticeable defoliation occurred on 2 acres at Park View Hospital, Fort Wayne, IN (Allen County). The defoliation occurred because hospital staff was concerned about odors from treatment materials entering the air intakes for the surgerical area of the hospital. To work with hospital staff, alternative methods (burlap banding and increased trapping density) were utilized. This effort failed to manage Gypsy Moth and resulted in the defoliation. For 2004, hospital staff was receptive to treatment, which stopped the defoliation.

The second year for noticeable defoliation is 2005 at two locations. Approximately 1 acre on the Pine Valley Golf Course in Allen County and 1 acre in northern Scott County. At Pine Valley Golf Course, a group of oaks outside of the 2004 Btk treatment boundary, but within a mating disruption treatment boundary, continued to support a Gypsy Moth population that resulted in the noticeable defoliation. A similar situation occurred in Scott County, as several large white oak trees in a 2004 mating disruption treatment site served as the reservoir to support Gypsy Moth, which resulted in the noticeable defoliation and failure of the mating disruption treatment.

From these noticeable defoliation sites and prior treatments, we have learned that large oaks, especially in isolated situations such as, fence rows, pastured woodlots, small park areas and other isolated settings, are ideal places for Gypsy Moth to start a defoliating population. With this knowledge, we now have our employees look for the large oak trees when they encounter traps with a high moth catch (>10).

The future of Gypsy Moth in Indiana is dependent on activities outside of the state and inside the state (Figures 12 & 13). Outside of Indiana, the advance of Gypsy Moth across Ohio is being monitored. Monitoring the progression through Ohio provides early warning as to when the generally infested area will reach Indiana. We also monitor the Gypsy Moth situation in Michigan, as this is the source for Gypsy Moth's entrance into northern Indiana. The USFS-STS is in southern Michigan and provides the data to monitor the spread and development of Gypsy Moth into northern Indiana.

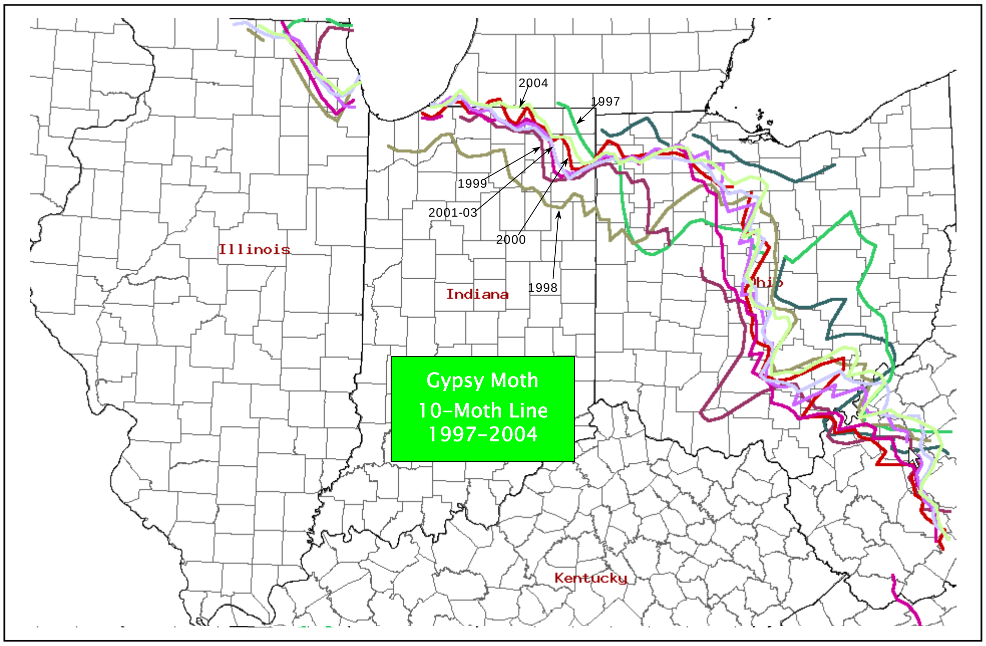


Figure 12. Location of the Gypsy Moth 10-moth line from 1997-2004. This line is used to indicate front edge of Gypsy Moth advance. Note that advance is backward in Indiana.

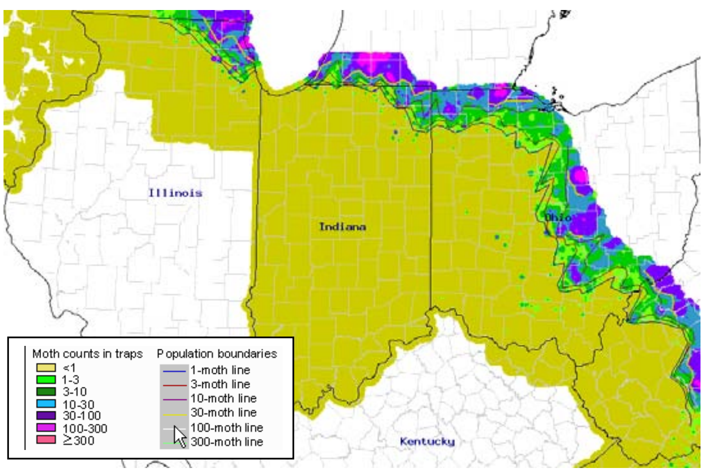


Figure 13. Gypsy Moth population advance at the end of the 2004 survey in Illinois, Indiana and Ohio.

Ohio also implements USFS-STS, which provides the data that we use to monitor progression. We also communicate via meetings and other avenues with Ohio Gypsy Moth personnel to understand their management effort and other administrative issues that may impact how they manage Gypsy Moth and thus could impact how fast it spreads to east and southeast Indiana.

Our current detection survey in recent years has started to record male moth catches in southeast and south central Indiana in a pattern that is similar to the moth catch pattern found in northeast Indiana in the mid 1980's when Gypsy Moth first invaded that area of the state from Michigan.

The activities in the state that impact the future of Gypsy Moth are our ability to operate the Gypsy Moth Management program from a financial and administrative standpoint. Having financial and administrative resources to perform the work for USFS-STS are critical to maintaining the slow spread rates. In the future, hopefully 20 years, but perhaps in 10 years, the advancing front of Gypsy Moth will be one continuous line from the Ohio River north along the Ohio/Indiana border to northern Indiana where the advancing front will turn west towards Illinois.

By the time this occurs, Gypsy Moth management will have three main activities.

1. Eradicating sites in front of the USFS-STS action zone.
2. Treating sites in the USFS-STS action zone to Slow-The-Spread of Gypsy Moth.
3. Suppression programs behind and in the USFS-STS evaluation zone to suppress defoliation and the associated public nuisance of the caterpillars.

Presently, Indiana only performs 1 and 2. However, a suppression program is under development and can be ready within a year, if needed. When this need arises, state financial resources, as well as financial resources from the county and affected citizens, will be needed to conduct the program. In other states that have experienced Gypsy Moth and utilized suppression programs, the programs generally are multi-million dollar programs annually cost shared between landowners, the state and the USDA Forest Service.

Because the Gypsy Moth survey changed in 1988 to essentially a state operated early version of USFS-STS, the need for a suppression program has been delayed by 10-20 years. Thus, initially investing only state funds in the state version of USFS-STS and then adopting the USFS-STS Program and gaining the use of its' resources, the need for multi-million dollar suppression programs has been delayed. Another benefit to this strategy of Slow-The-Spread has been the advance in survey and treatment technology. Through USFS-STS we have improved and safer tools that are used to make decisions and implement management activities.

It is recommended that Indiana remain in the Slow The Spread program and receive the benefits of this federal program.

It is also recommended that preparation continue for a suppression program and that funding is developed to operate a suppression program.

It is also recommended that the funding needs of Emerald Ash Borer not impact the funding of Slow The Spread.

Emerald Ash Borer

Arriving in Indiana prior to 2004, but detected in April 2004 in Steuben County, Emerald Ash Borer is the most recent exotic invasive species to impact and threaten the forest resources of Indiana and the U.S (Figure 14). Only attacking ash trees, the 147 million ash trees across the forests of Indiana and the 1.5 million ash trees in the urban environment are at risk to Emerald Ash Borer.

D. Cappaert, Michigan State University

Figure 14. Adult Emerald Ash Borer

First found in Detroit, Michigan and then in northwestern Ohio in 2003, finding Emerald Ash Borer in Indiana was anticipated. Continuing to be found across Michigan and in other locations in northwestern Ohio, additional detections of Emerald Ash Borer in Steuben and LaGrange counties were also expected.

The four Emerald Ash Borer infestations in Indiana are the result of people moving infested logs and firewood (Figure 16 & 17). Three infestations (Table 3) are the result of firewood movement and the fourth is a combination of introduction through logs and local spread by firewood movement and natural spread.

Each new Emerald Ash Borer detection in the three states is related to artificial movement by man. Prior to detection and identification in the Detroit area, man unknowingly spread Emerald Ash Borer through infested firewood, logs and nursery trees. After 2003, information on Emerald Ash Borer has increased throughout the three state area. Because of this information, quarantines and destruction of ash nursery trees, the movement through infested nursery trees has essentially stopped. However, the movement through firewood and logs is still occurring, but awareness is growing about infested firewood and logs and these avenues are beginning to slow.

D. Cappaert, Michigan State University

Figure 15. Emerald Ash Borer Larva

But we still need to take strong measures to limit or stop the spread of Emerald Ash Borer through firewood and logs (Figure 15). For example, it is against Michigan and federal quarantines to move ash logs and any hardwood firewood outside of Michigan. To protect state resources, a ban on visitors bringing firewood into state campgrounds is under consideration. During July and August 2005, four visitors from Michigan carried ash firewood with Emerald Ash Borer galleries into the campground at Pokagon State Park. State campgrounds receive thousands of visitors each year from Emerald Ash Borer infested areas of Michigan, Ohio and now Indiana.

Table 3. Emerald Ash Borer infestations in Indiana through August, 2005

Infestation name	Township(s)	County	Introduction method	Date detected	Approximate size (sq. mi).
Jellystone	Jamestown	Steuben	Firewood	April, 2004	1.5
Shipshewana	Clay, Van Buren, Newbury	LaGrange	Logs & Firewood	June, 2004	10.0
Manapogo	Millgrove	Steuben	Firewood	October, 2004	1.0
Grand View Bend	Lima	LaGrange	Firewood	July, 2005	1.5

As of August 2005, the status of Emerald Ash Borer eradication work is

1. All ash trees at Jellystone and Manapogo have been cut and burned. Trap trees are in place to monitor the sites.
2. All ash trees identified prior to April 15, 2005 at Shipshewana have been cut and burned. This work occurred in Clay and van Buren Townships. Trap trees are in place to monitor the site.
3. All ash trees identified after April 15, 2005 at Shipshewana have been marked and will be cut and burned prior to May 2006. This includes trees in Clay, Van Buren, and

Newbury Townships. (Note: April 15 is the date when cutting of ash trees stops because the threatened and endangered Indiana Bat may be in the ash trees or woods during their maternity period.)

4. The ash trees at Grand View Bend are in the process of being marked for removal and will be cut and burned prior to May 2006.

The ash tree eradication work to date has removed 118,414 ash trees in the approximately 1,300 acres of forest in the 12 sq.mi. of eradication zones (Jellystone, Shipshewana, & Manapogo). Of this total, 85,372 seedlings (<3/4" DBH) were killed with a herbicide (Garlon). The ash trees >3/4" DBH removed included 263 landscape trees and 32,799 woods trees. Of the woods trees, foresters tallied 2,540 logs in 12-16" DBH trees and 1,455 logs in 18+" DBH trees (12' log length), which totals an estimated 490,000 bd.ft. of timber (Doyle log scale).

The ash tree removal expense totals $2,252,341 to date ($87,211 for initiate removal at Jellystone and $2,165,130 for removal to complete Jellystone and do Manapogo and Shipshewana). An estimated $250,000 in administrative costs to manage the eradication project brings the total to an estimated $2,502,341.

The future of Emerald Ash Borer in Indiana is an expensive and damaging prospect both economically and ecologically. The expenses to date of Emerald Ash Borer management have been paid by the USDA, Aphis. However, beginning is April 2005, USDA Aphis is only able to provide 80% of the management cost and the state has to provide the remaining 20%. Assuming the current eradication sites develop to the same level and expense as in the 2004/2005 project, Indiana's cost to manage Emerald Ash Borer could approach $500,000 over the next year.

To manage Emerald Ash Borer in Indiana, the same cooperative agencies involved in Gypsy Moth management have directed their efforts to manage this new exotic invasive insect. Current management work involves

- the eradication projects in LaGrange and Steuben Counties,
- a statewide survey focusing on the likely points of introduction – campgrounds, sawmills and nurseries,
- a trap tree survey in a 25-50 mile wide band south of the Michigan border across the state,
- information and education projects
- serving as a member of the Emerald Ash Borer science advisory panel,
- and forest management assistance through the Forest Stewardship Program focused on counties adjacent to Michigan and northwest Ohio.

A point of comparison – during one year, the same amount of funds were spent on Emerald Ash Borer eradication as spent in the prior four years (2001-2004) by the Slow The Spread program against Gypsy Moth ($2,414,992, Table 1 above). Assuming the current Emerald Ash Borer eradication work in 2005/2006 grows to the same level as in 2004/2005, then more funds will have been spent on Emerald Ash Borer eradication in two years than on Gypsy Moth from 1999-2005 ($5,000,000 vs. $3,901,314 (table 1).

In comparison to Gypsy Moth, Emerald Ash Borer currently does not have the same science, technology and management methods. This difference is due to the recent presence of Emerald Ash Borer in the U.S., while Gypsy Moth has been present in the U.S. for over 100 years and has the benefit of research and technology development over the past 25-30 years that has brought us to the current management level of Slow The Spread.

Thus, given time, resources, and political/administrative support to develop the science, technology and management methods for Emerald Ash Borer, the ash resource can be spared the threat of elimination.

It is recommended to continue the eradication protocol recommended by the Emerald Ash Borer Science panel and eradicate any infestation detected.

It is recommended that surveys continue annually to detect Emerald Ash Borer.

It is recommended that cooperative management between state and federal agencies continue. (Agencies involved – Division of Forestry, Division of Entomology & Plant Pathology, USDA Forest Service, USDA Aphis and Purdue University).

It is recommended that silvicultural guidance and forest management activities reduce the amount of ash in the forests within and closest to quarantine townships.

It is recommended that state funding sources for Emerald Ash Borer be developed so that they do not interfere with Gypsy Moth funding needs. It is recommended $1-2 million of state funds be made available to match federal funds for Emerald Ash Borer management.

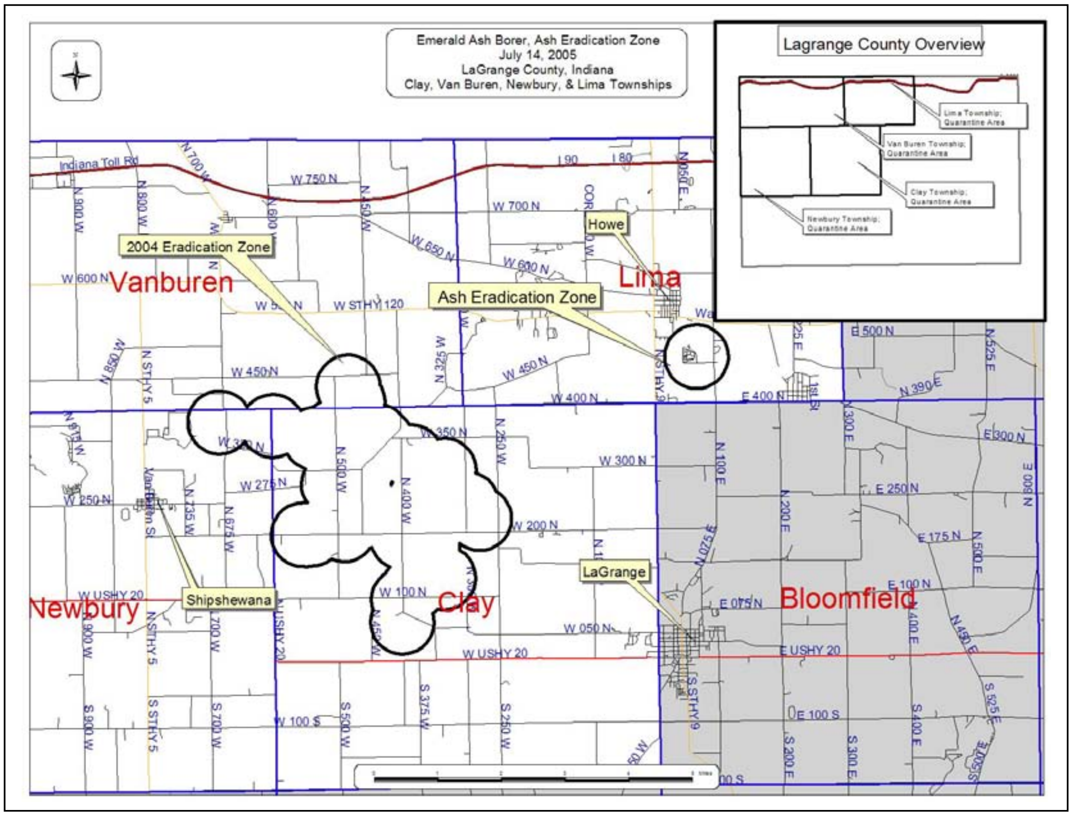
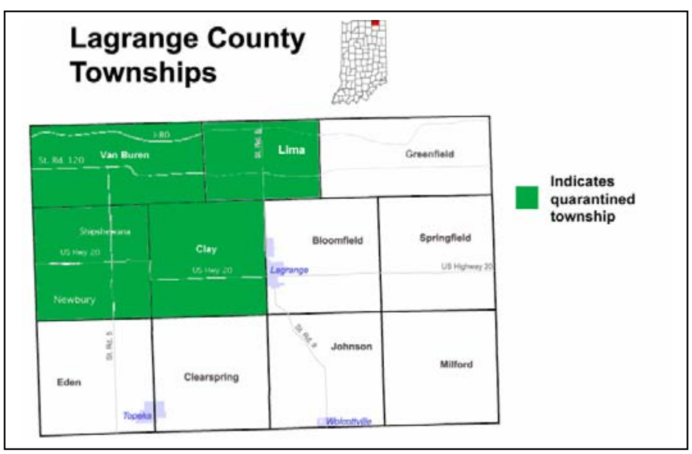


Figure 16. Shipshewana eradication area and the Grand View Bend site SE of Howe in Lima Township as of July 14, 2005. Clay, Lima, Newbury and Vanburen Townships are quarantined.



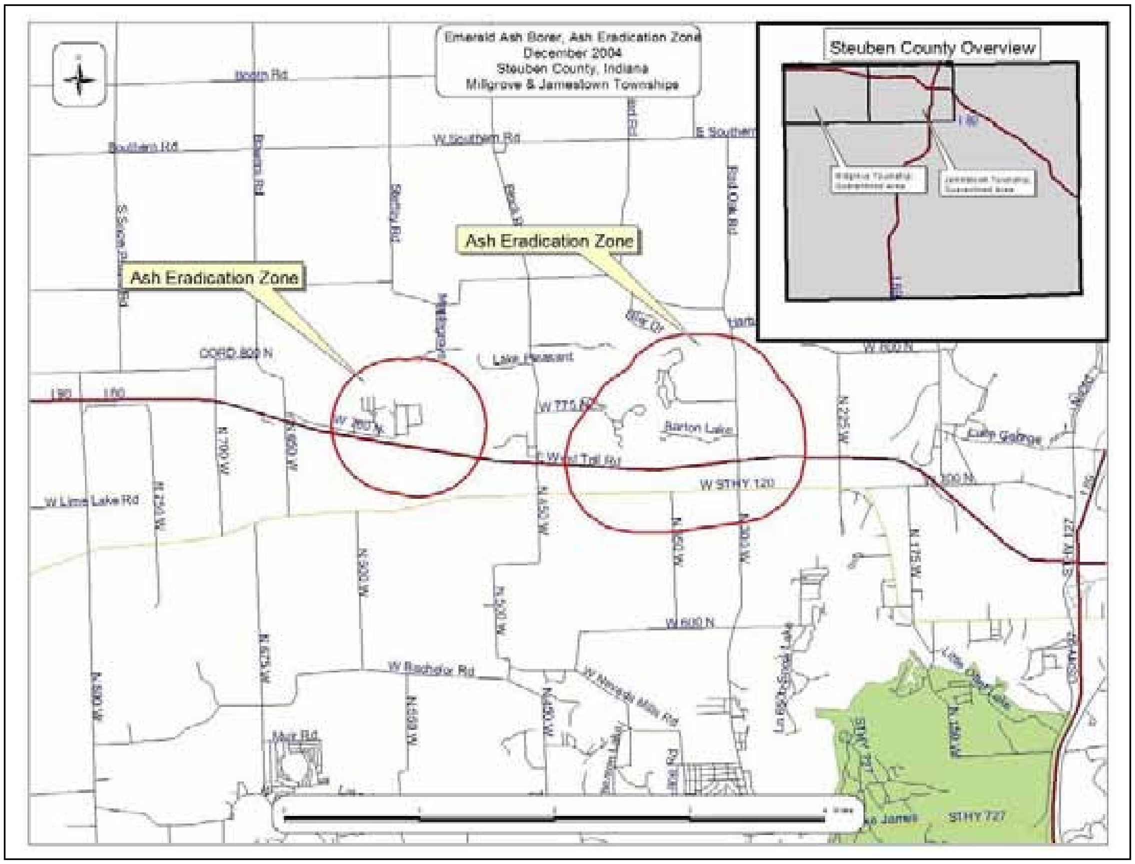
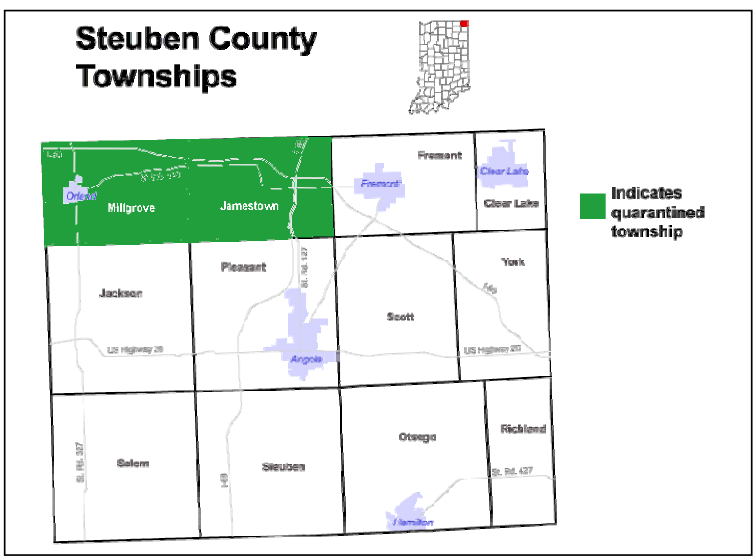


Figure 17. Manapogo, Millgrove township (on left) and Jellystone, Jamestown township (on right) eradication areas in Steuben County.



Asian Longhorned Beetle

Asian Longhorned Beetle is a wood-boring beetle that prefers to attack maple species but has been found on horse chestnut, willow, American elm, birches and Populus spp (Figure 18). It was first found on Long Island in New York City in 1996 and in Chicago in 1998.

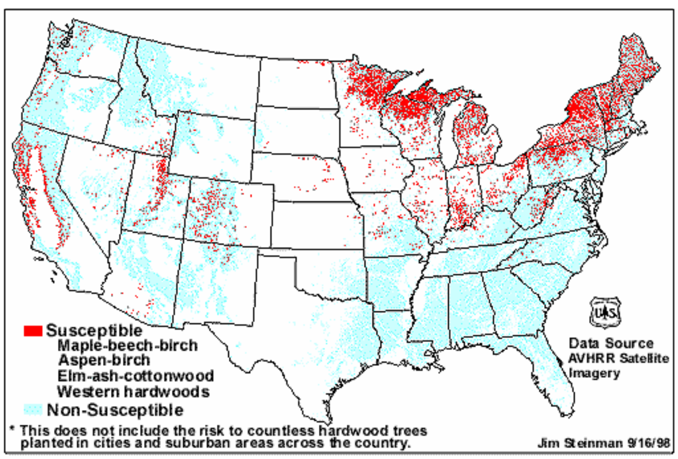
Figure 18. Adult Asian Longhorned Beetle.

Eradication programs began in each city after detection. The eradication effort in New York City is still ongoing. It is believed that the recent detections in Jersey City and Carteret, New Jersey, 2002 and 2004 respectively, are associated with the New York City infestations.

The eradication effort in Chicago has been more successful than New York City. The last detected infestation in the Chicago area was in 2003. In 2005, all prior infestation areas, except the 2003 location, had their quarantine removed because monitoring surveys had not detected life stages in three consecutive years. Should all sites have negative monitoring surveys over the next three years, it is expected that the Chicago infestations will be declared eradicated.

Asian Longhorned Beetle has not been detected in Indiana. The success in Chicago is good news for Indiana as this reduces the risk to maples in northwestern Indiana adjacent to Chicago. However, we need to remain aware that Asian Longhorned Beetle can still be introduced or detected in Indiana. In 2003, Asian Longhorned Beetle was detected in Toronto, Ontario Canada. And following the infestation history in the New York City area, Indiana is still at risk to detecting Asian Longhorned Beetle that may have escaped from the Chicago infestations.

Figure 19. Forest Types potentially at risk to Asian Longhorned Beetle.



Maple is a major forest resource and component of the urban forest. Of the four survey units utilized to inventory Indiana's forests, three of the units have the Maple-Beech forest type as the predominant forest type (Tormoehlen et.al. 2000). Thus a large area of Indiana's forest is at risk to Asian Longhorned Beetle (Figure 19).

Thus, we need to remain aware of Asian Longhorned Beetle and continue to monitor the forest resources for infested trees. As with its original introduction in urban areas, it is more likely to detect Asian Longhorned Beetle in urban areas than in rural forests. But the movement of infested maple firewood, like movement of ash firewood infested with Emerald Ash Borer, is a method to introduce Asian Longhorned Beetle into the forests of Indiana.

Exotic Bark Beetles

This group of beetles works under the bark making tunnels (galleries) in the cambium and sapwood surface. Because of working in this area of the tree, they usually have short life cycles that allow 1 or more generations per year. Thus, they have the ability to build epidemics quickly that can lead to tree death.

They also have association with fungi, such as stain causing fungi, which may also aid the death of the tree. An example of one exotic bark beetle that has aided in the removal of one tree species from the urban forest and a reduction of the species in the rural forest is Smaller European Elm Bark Beetle, *Scolytus multistriatus*, a vector of Dutch Elm Disease.

The Exotic Forest Pest Information System for North America lists 102 insects of concern for introduction and damage to the forests of North America. Of the bark beetles in the list, all received risk levels of high to very high. Thus, with the understanding of how native and established exotic bark beetles already impact the forest resources, any species from this group that can enter and establish populations in Indiana's forest resources is of great concern.

The Asian Ambrosia Beetle, *Xylosandrus crassiusculus*, is present in Indiana forests and nurseries. Commonly attacking black cherry in nurseries it will attack other hardwood species. Recently, it was found attacking yellow poplar that was under stress. Although it attacks trees under stress, attacks of small trees could lead to death but attacks of larger trees may only result in defect to lumber.

A recent find in the U.S. and in 2004 in Indiana is the Banded Elm Bark Beetle, *Scolytus schevyrewi*. The concern with this bark beetle is its potential roll with Dutch Elm Disease. The question is, could this bark beetle function in areas that are not ideal for the Smaller European Elm Bark Beetle and aid in the spread of Dutch Elm Disease? Currently, there are enough problems with Dutch Elm Disease killing elms that Indiana's forests do not need another vector to support the death this disease causes (Exotic Forest Pest Information System for North America **-** http://www.spfnic.fs.fed.us/exfor/).

The oak bark beetle, *Scolytus intricatus*, is another bark beetle that is a risk to Indiana and the central hardwood region. As its name indicates, oaks are the primary host. Like the Banded Elm Bark Beetle, the concern for the oak bark beetle is that it could be an efficient vector of Oak Wilt. Another concern is that it could develop a role with Armillaria root rot and Two Lined Chestnut Borer and increase the death of oaks through Oak Decline events (Exotic Forest Pest Information System for North America **-** http://www.spfnic.fs.fed.us/exfor/).

Bark beetles such as Pine Shoot Beetle, *Tomicus piniperda,* that attack conifers are also of concern. The conifer forests of North America have enough damage from Southern Pine Beetle, Dendroctonus frontalis, Mountain Pine Beetle, Dendroctonus ponderosae, Douglas Fir Beetle, Dendroctonus pseudotsugae, and others that they do not need an exotic bark beetle.

The future impact of exotic bark beetles to Indiana forests could be high. To prevent and manage this risk, surveys serve as the tool to provide this protection. Currently, the USDA, Aphis conducts an exotic bark beetle trapping survey in southern Indiana. The Forestry and Entomology & Plant Pathology Divisions provide assistance with survey locations and other support as needed. In the future, the Divisions should consider increasing the level of involvement and intensity of the survey.

DISEASES:

The greatest exotic disease to impact the North American forest is Chestnut Blight. This canker disease introduced 100 years ago removed one species from the forest and altered the forest to oaks. Some may feel the oaks that replaced the American chestnut tree recovered much of the impact from the loss of chestnut from the forest. But others will argue that the oaks have not replaced the versatility and value that the chestnut provided through its lumber and fruit.

Regardless of this argument, Chestnut blight awakened foresters that canker diseases are a deadly threat to the forest.

For Indiana's forest, two canker diseases of concern are Sudden Oak Death and Beech Bark Disease.

<u>Sudden Oak Death</u>

Sudden Oak Death, *Phytophthora ramorum*, was discovered in California in 2000 and has spread to Oregon. In recent years, *P. ramorum* has been found in nursery stock in 17 states and in nurseries and public gardens in Europe. Indiana is not immune to the possible spread of infected nursery stock into the state.

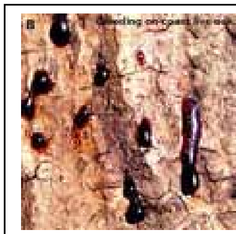


Figure 20. Bleeding symptom caused by *P. ramorum*.

As the name indicates, oak is a host of this disease. However, the host range is broad and growing.   Currently the USDA regulates 75 tree and plant species that are hosts for this disease. Besides Coast live oak, California black oak, southern red oak, northern red oak and other oak species, rhododendrons, azaleas, lilacs, viburnums, yews, and spicebush are hosts and regulated by USDA. Some species of witch hazel, maple, beech, buckeye and ash are hosts and regulated.

Inoculation trials found red, white, chestnut and cherrybark oaks susceptible. All of these species are present in Indiana rural and urban forests. Knowing that these species are susceptible, it is likely that the other oak species in Indiana forests are also susceptible.

The Indiana forests have moderate to low risk for Sudden Oak Death establishment based on the environmental needs of *P. ramorum* and the host range of oak (Figure 21).

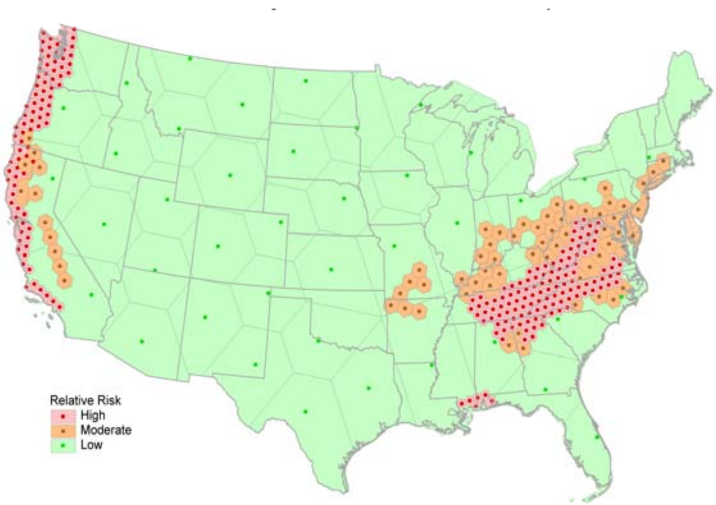


Figure 21. Sudden Oak Death risk map for areas of the U.S. forests that can support the disease.

Although given a moderate or low risk, the presence of Sudden Oak Death in Indiana forests is a major threat to the oak resource and associated timber industry. The Oak-Hickory forest type is the dominant timber type in the area of the state shown with moderate risk for Sudden Oak Death (Tormoehlen et.al. 2000). And, with the oak forest growing bigger and older, especially on public land and in the Knobs Survey Unit of south central Indiana, this forest is at great risk to this disease because, as trees grow older and bigger, their ability to respond to any stress decreases (Tormoehlen et.al. 2000 and Starkey et.al. 1989). Thus, introduction of Sudden Oak Death into the forest associated with drought or defoliation events could give the disease the beginning it needs.

Besides the economic and environmental impact to the forests, presence of this disease will have economic impact to the nursery industry through regulatory impacts and associated costs from loss of infected nursery stock.

Current activities to monitor for this disease include collection and testing of nursery stock by the Division of Entomology & Plant Pathology and the surveys of the forest areas surrounding nurseries and forest areas that have declining/dying oaks conducted by the USDA Forest Service.

To date *P. ramorum* has not been detected in Indiana in nurseries or the forest environment.

For the future, detection surveys need to continue both in the nurseries and in the forests. Also, awareness of the disease and training on the symptoms need to continue in the forest and arboriculture communities.

Beech Bark Disease

Beech Bark Disease is a complex of a sap-feeding scale insect and species of the canker fungus *Nectria*. American Beech is the host that is attacked and slowly killed. The first evidence is the white wooly covering of the beech scale, *Cryptococcus fagisuga*, on the bark of the trees. Their feeding in the bark creates minute wounds that are infected by the *Nectria* fungi. *Nectria galligena* is a native fungus that first attacks the tree and then is followed by the exotic fungus, *Nectria coccinea* var. *faginata*. The *Nectria* fungi create cankers that eventually girdle and kill the tree. (Houston & O'Brien 1983)

This disease was introduced 100 years ago in Nova Scotia and by the 1980's had spread south through New England to Pennsylvania and West Virginia. Isolated populations of the scale have been found in Ohio, Tennessee, Virginia and North Carolina (Houston & O'Brien 1983).

In 2000, Beech Bark Disease was detected in Michigan. To date, the disease is present in the eastern Upper Peninsula and in the northwestern Lower Peninsula (McCullough et.al. 2001).

The impact of this disease is the loss of big beech trees and reduction in beech regeneration over time. The additional impact of this loss is to the many species of wildlife that use beech for food and habitat. It is the larger and older beech trees that are killed first and it is these trees that produce the beechnuts and habitat for wildlife. The loss of these trees will, over time produce the impact to wildlife McCullough et.al. 2001).

Again, this is a disease that attacks the older trees and thus the older aging forest is at risk. This disease can spread by man through firewood and logs. Thus, the forests of northern Indiana where the maple-beech type is the dominant forest type has greater risk to spread and introduction of this disease.

To date, the disease has not been detected in Indiana. The future for Indiana is to remain aware of the symptoms of this disease and monitor beech trees for its presence. Early detection will aid in slowing and preventing the loss of this species in the woods.

Declines – Aging Forest

The Ozark forests of Missouri and Arkansas have experienced a severe oak decline starting in 1999 through 2002. Oak decline continues to occur in this area because of increasing tree ages, high stand densities and site conditions (Lawrence et.al. 2002).

The insects involved in the oak decline are red oak borer, carpenterworm and two-lined chestnut borer. The diseases involved are Armillaria root rot and Hypoxylon canker. Other factors that contributed to the oak decline are tree age (older trees), high stand density, site conditions, severe drought, insect defoliation and frost, ice or wind (Lawrence et.al. 2002).

Observing the oak decline event in the Ozark provides awareness that the same event may occur in the oak-hickory forest type in Indiana.

One factor in oak decline in the Ozark forests is increasing tree age. For Indiana, Tormoehlen, Gallion and Schmidt report in the 1998 overview of Indiana Forests that the oldest trees are oaks and hickories. They also report that the Knobs survey unit (south central Indiana) tends to have older trees than other areas of the state. This is due to public land in this area, which they report to have older trees than private land. They also report state land has more old trees than any other land ownership (private and federal), but the age distribution on state land is evenly distributed (Tormoehlen et.al. 2000). Thus, there is concern that Indiana forests are moving to a status – old age – that is a contributing factor to a decline.

Another factor to indicate an oak decline event could be starting is average annual mortality amounts. Moser, et.al. report from the 2002 forest inventory data 'other red oak species' accounted for 18.5 percent of all hardwood mortality. They also report that 20.8 percent of the 'other red oak species' mortality occurred on public lands and that this was the highest percentage for all hardwoods (Moser et.al. 2004).

With this information from survey data, the 1999 drought, the looper defoliation in the Knobs survey unit from 2002 through 2004, the forests, especially forests on public land, in southern Indiana are at risk for an oak decline event and increased oak and other species mortality. It is recommended that state forests and the national forest examine forest inventory data to determine which stands have a high percentage of old age trees, high stand density, sites that are prone to drought stress, pockets of mortality and poor crown conditions. For the stands identified, management measures should be applied to reduce stand density, reduce over all stand age, salvage any mortality and improve tree crowns.

References:

Barry, P.J., Doggett, C., Anderson, R.L., and K.M. Swain. 1998. How to Evaluate and Manage Storm-Damaged Forest Areas. R8-MB63. USDA Forest Service, Southern Region, 11p.

Belanger, R.P. & B.F. Malac. 1980. Silviculture Can Reduce Losses from the Southern Pine Beetle. USDA Agriculture Handbook 576.

Bosworth, D. 2004. Four threats to the Nation's forests and grasslands. Speech, Idaho Environmental Forum, Boise, Idaho—January 16, 2004.

Bratkovich, S., Burban, L., Katovich, S., Locey, C., Pokorny, J., Wiest, R., 1994. Flooding and its effect on Trees. USDA, Forest Service, Northeastern Area State and Private Forestry; St. Paul, MN. 55 p.

Cannon, W. N, Jr. and D.P. Worley. 1976. Dutch elm disease control: performance and costs. Northeastern Forest Experiment Station, Upper Darby, PA. 7 p.

Cummings-Carlson, J. and A.J. Martin. 1994. Lake States Woodlands: Oak Wilt Management-what are the options? University of Wisconsin Extension Publication G3590. 6p.

Elliot, K.J., W.T. Swank, 1994. Impacts of drought on tree mortality and growth in a mixed hardwood forest. J Veg Sci 5:229-236.

Francl, L.J. 2001. The Disease Triangle: A plant pathological paradigm revisited. The Plant Health Instructor. DOI: 10.1094/PHI-T-2001-0517-01

Gottschalk, K.W. 1993. Silvicultural guidelines for forest stands threatened by the gypsy moth. USDA Forest Service General Technical Report NE_171. Radnor, PA,

Hicks Jr., R.R., K.S. Riddle & S.M. Brock. 1989. Direct control of insect defoliation in oak stands is economically feasible in preventing timber value loss. IN: Proceedings, 1989 Seventh Central Hardwood Forest Conference, 1989 March 5-8, Carbondale, IL, Gen Tech Rep NC-132. U.S. Department of Agriculture, Forest Service. 86-94 p.

Holmes, F.W. 1962. Recorded Dutch Elm Disease Distribution in North Amercian as of 1961. Plant Disease Reporter 46:10 715-718 p.

Houston, D.R. & J.T. O'Brien. 1983. Beech Bark Disease. Forest Insect & Disease Leaflet No. 75. USDA Forest Service, Northeastern Forest Experiment Station, Hamden, Conn.

Karasevicz, D.M. & W. Merrill. 1989. Biodeterioration of Oaks Killed Following Defoliation by the Gypsy Moth. Southern Journal Applied Forestry, 13:3 139-145.

Lawrence, R., Moltzan, B. & K. Moser. 2002. Oak Decline and the Future of Missouri's Forests. Missouri Conservationist, 8 p.

Manion, P.D. 1981. Tree disease concepts. Prentice Hall, Inc. Englewood Cliffs, NJ. 399 p.

Marshall, P.T.& W.H. Hoffard, 1977. Biological Evaluation Following Two Years of Forest Tent Caterpillar Defoliation in South Central Indiana – 1976. USDA Forest Service, Northeastern Area, State & Private Forestry, Eval. Rpt D-8-77. 10 p.

Marshall, P.T. 1983. Forest Pest Informer 1983 Summary. Indiana Dept. Natural Resources, Div of Forestry. 21 p.

Marshall, P.T. 1984, Forest Pest Informer, 1984 Summary. Indiana Dept. Natural Resources, Div of Forestry. 18 p.

Marshall, P.T. 1990. Draft Report: Observations on ash decline/ash yellows over a 10 year period in Indiana. (Unpublished), 6 p.

Marshall, P.T. 1992, Forest Pest Informer, June/July 1992. Indiana Dept. Natural Resources, Div of Forestry. 8 p.

Marshall, P.T., 2005. Economic Analysis, Cooperative Gypsy Moth Project for Indiana, IN Decision Notice, Environmental Assessment, Biological Evaluation, Economic Analysis, Work & Safety Plan, Cooperative Gypsy Moth Project for Indiana 2005, 1 p.

McCullough, D.G., R.L. Heyd, & J.G. O'Brien. 2001. Biology and Management of Beech Bark Disease. Michigan State University. Extension Bulletin E-2746. 11p.

Moser, W. Keith; Brand, Gary J.; Marshall, Philip T.; Gallion, Joey. 2004. Indiana's forest resources in 2002. Resource Bull. NC-232. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 25 p.

Oak, S.W., J.R. Steinman, D.A. Starkey, & E.K. Yockey. 2004. Assessing oak decline incidence and distribution in the southern U.S. using forest inventory and analysis data. IN Spetich, Martin A., ed. 2004. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS-73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 311 p.

O'Brien, J.G.; Mielke, M.E.; Starkey, D.; Juzwik, J. 2000. How to Identify, Prevent, and Control Oak Wilt. NA-PR-03-00. USDA Forest Service, Northeastern Area State and Private Forestry.; St. Paul, MN. 12 p.

Orwig, D.A. & M.D. Abrams. 1997. Variation in radial growth responses to drought among species, site, and canopy strata. Trees 11:474-484.

Pokorny, J & W. Sinclair. 1994. How to Identify and Manage Ash Yellows in Forest Stands and Home Landscapes. USDA Forest Service, Northeastern Area State and Private Forestry, St. Paul, MN. 8 p.

Starkey, D.A., Oak, S.W., Ryan, G.W., Tainter, F.H., Redmond, C. & Brown, H.D. 1989. Evaluation of oak decline area in the south. USDA Forest Service, Forest Protection Report R8-PR 17

Schmidt, Thomas L.; Hansen, Mark H.; Solomakos, James A. 2000. Indiana's Forests in 1998. Resour. Bull. NC–196. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 139 p.

Schmidt, Thomas L.; Mielke, Manfred E.; Marshall, Philip T. 2002. **I**ndiana's forest resources in 2000. Resour. Bull. NC-206. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 25 p.

Sinclair, W.A., and H.M. Griffiths. 1994. Ash yellows and its relationship to dieback and decline of ash. Annu. Rev. Phytopathology 32:49-60.

Tormoehlen, B. J. Gallion, T.L. Schmidt. 2000. Forests of Indiana: A 1998 Overview. U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry, NA-TP-03-00. 17p.

Waltz, R. 2005. Final Accomplishment Report, USDA Cooperative Agreement (04-8218-04-31-CA), Indiana Emerald Ash Borer Eradication Project 2004/2005. 8p.

1999. Executive Order 13112. Invasive Species. Federal Register 64:25 – p. 6183-6186.

2004. Sudden Oak Death, Protecting America's Woodlands from *Phytophthora ramorum.* USDA Forest Service, FS-794. 12 p.

Website References:

Gypsy Moth Digest, Defoliation - http://na.fs.fed.us/wv/gmdigest/defoliation/index.html

Exotic Forest Pest Information System for North America - http://www.spfnic.fs.fed.us/exfor/

USDA Forest Service, Invasive Species Program - http://www.fs.fed.us/invasivespecies/