United States
Department of
Agriculture

Forest Service

FS-919

March 2009

Major Forest Insect and Disease Conditions in the United States 2007

USDA

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Cover photo: *Island Lake in the Beartooth Mountains of Montana. Courtesy of Jeremy Marshall, Interior West Forest Inventory and Analysis crew leader, Bozeman, MT.*

Preface

This report represents the 57th annual report prepared by the Forest Service, U.S. Department of Agriculture of the insect and disease conditions of the Nation's forests. Insect and disease conditions of local importance are reported in regional and State reports.

This year's forest insect and disease conditions report has been redesigned to focus on the 20 major insects and diseases that annually cause defoliation and mortality in forests of the United States. We have provided more detail on these pests, including photographs, charts, tables, and maps. Detailed descriptions of other insects and diseases similar to that of previous years' reports can be found at the following Web site: http://www.fs.fed.us/foresthealth/management/index.shtml. As part of this change, we are developing a database and linking it to other data sets so that interested users will have access to more information and will able to do their own analysis, especially over time. One of the primary goals is to make the database useful and user friendly to those interested in this type of information. We would, therefore, appreciate any feedback you have regarding this database and related output reports.

The information in this report is provided by the Forest Health Protection Program of the Forest Service and its State partners. This program serves all Federal lands, including the National Forest System and the lands administered by the Department of Defense and the Department of the Interior. Service is also provided to tribal lands. The program provides assistance to private landowners through the State foresters and other State agencies. A key part of the program is detecting and reporting insect and disease epidemics. Detection surveys are conducted on a regular basis by State and Forest Service program specialists.

For additional information about conditions, contact the Forest Service office listed on the next page (see the map on page v for office coverage) or your State forester.

United States Department of Agriculture

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Forest Service Regions and Area

Copies of this report are available from:

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This report is also available on the Internet at http://www.fs.fed.us/foresthealth/current_conditions.shtml.

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Beech Bark Disease..........Manfred Mielke

Butternut Canker..........Manfred Mielke

Executive Summary/Introduction

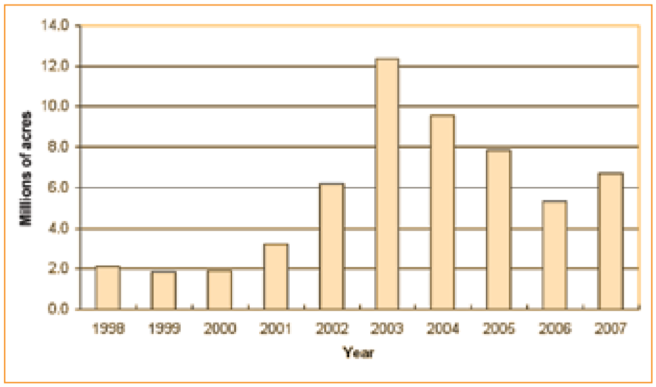
The forests and trees of the United States are an important natural resource that provide Americans with goods and services that help make the United States a strong country. The Nation's approximately 750 million acres classified as forest land are the source for much of the clean water we drink, the timber we use to build our houses and businesses, the outdoor recreation we are able to enjoy, terrestrial carbon sequestration, and even the forage for livestock, in addition to other benefits and services. To provide these goods and services, we need healthy forests, especially on a long-sustainable basis. One aspect of maintaining and even enhancing a healthy forest is to protect and restore forests from both native and nonnative insects and diseases, which can cause significant damage. Surveys describing the forest insect and disease conditions are an important tool to help prioritize actions by Federal agencies, States, and other stakeholders. As with most biological systems, the overall mortality caused by insects and diseases varies from year to year and pest to pest. The chart (fig. 1) illustrates how mortality has varied over the past 10 years.

Acres of Tree Mortality Caused by Insects and Diseases

In 2007, nearly 6.8 million acres of mortality caused by insects and disease were reported nationally, a 1.5-million-acre increase from 2006, when 5.3 million acres of mortality were reported. Nearly 61 percent of the mortality was caused by one pest, the mountain pine beetle, a native pest found in Western U.S. forests. Although only mortality is represented in the chart, defoliation has significant effects on our forests. The European gypsy moth caused more than 1.4 million acres of defoliation damage in 2007. A single infestation by gypsy moth larvae on a tree usually does not cause mortality, but, combined with continued attacks or severe weather factors, trees can succumb to this nonnative insect.

Every year, hundreds of native and nonnative insects and diseases damage our Nation's forests. The following pages describe 20 of the major insects and diseases that annually contribute to mortality and defoliation.

Figure 1.—*Surveyed acres of mortality from 1998 to 2007.*



Mountain Pine Beetle

Dendroctonus ponderosae Hopkins

Current Conditions

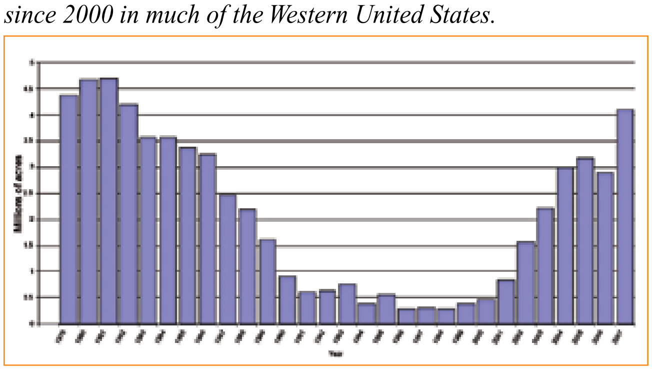
Renowned Forest Service mountain pine beetle researcher Gene Amman described the mountain pine beetle as the most important biotic agent of change in western pine forests. Since 2000, the mountain pine beetle has been on the rise again, changing pine forests on millions of acres across the Western United States from green to red to gray (fig. 1).

In 2007, aerial surveys detected about 4 million acres where mountain pine beetles were actively killing trees (fig. 2). Hundreds of thousands of acres were affected in Colorado, Wyoming, Utah, Idaho, Montana, Oregon, and Washington (fig. 3). The mountain pine beetle epidemic in the central Rocky Mountains is larger than any previously recorded in the area and is expanding rapidly. Notable outbreaks also exist in the Warner Mountains of California and the Black Hills of South Dakota.

Damage

The damage caused by this native pest is most widespread and dramatic in the aging lodgepole pine forests that dominate many of our scenic western park and resort destinations. Other western pines are also being killed in large numbers, including high-elevation whitebark pines in the northwest and northern Rockies, centuries-old limber and bristlecone pines in the central and northern Rockies, sugar pines and western white pines in the Northwest, and ponderosa pines throughout the West. Western pine mortality is especially common during multiyear droughts and mild winters.

Figure 1.—*Mountain pine beetle activity has risen dramatically since 2000 in much of the Western United States.*



Biology

Mountain pine beetles attack susceptible trees en masse by using chemical "messengers" (pheromones) to attract other mountain pine beetles. As trees become fully occupied, the beetles produce antiaggregation pheromones to repel incoming beetles. Larval feeding and microorganisms, including blue-stain fungi that are introduced by the mountain pine beetle, contribute to the trees' death. Dying trees change from green to red the year following infestation.

Figure 2.—*Counties where mountain pine beetle was reported in 2007.*

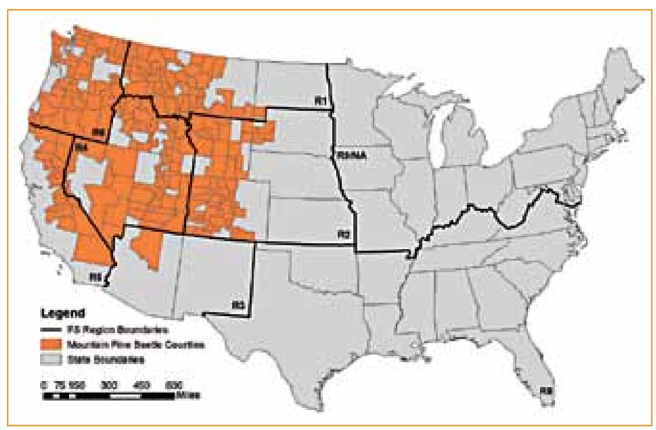
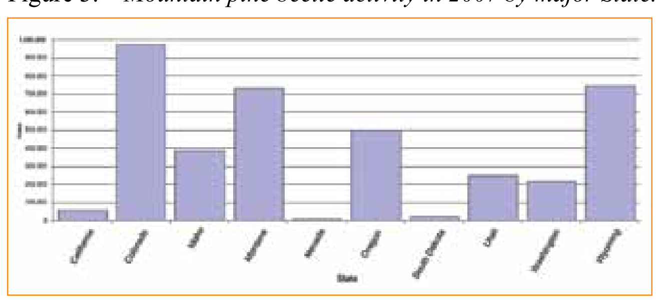


Figure 3.—*Mountain pine beetle activity in 2007 by major State.*



Historical Trends

The mountain pine beetle was first described in 1902 by pioneering forest entomologist A.D. Hopkins from specimens he collected from ponderosa pines in the Black Hills of South Dakota. Since that time, many notable mountain pine beetle outbreaks have occurred across the Western States and much has been learned about the insect's biology, its role in the ecosystem, and stand susceptibility (fig. 4). One of the largest and most-studied outbreaks occurred in Utah, western Wyoming, Idaho, and Montana in the late 1970s and early 1980s. Research has shown that lodgepole pine stands highly susceptible to mountain pine beetle infestation typically have the following characteristics: average diameter at breast height greater than 8 inches, average age greater than 80 years, and a suitable climate for beetle development. Close proximity to existing infestations can also put stands at risk. Later studies in ponderosa and lodgepole pine stands have shown that stand density contributes to stand susceptibility as well.

Figure 4.—*Mountain pine beetle in the inner bark. Beetles are about ¼ inch long. Photo by Kari Greer, 2008.*

Weather conditions can also influence the course of mountain pine beetle epidemics. Critically low temperatures for mountain pine beetle larvae vary at different months of the year. During the winter months of December, January, and February, larvae are extremely cold hardy, with many surviving at temperatures of -30 °F and below. Critical temperatures vary incrementally in the fall and spring months. An extreme cold period during the winter of 1984–85 is reported to have contributed to the collapse of a mountain pine beetle epidemic that began in 1980 in Grand County, CO.

Management and Treatment Actions

Where possible, prevention and suppression strategies are being used to mitigate the effects of the mountain pine beetle. Removing infested trees can reduce localized populations of beetles. Thinning pine stands is an effective treatment to reduce tree loss. In lodgepole pine forests that are not currently affected by beetles, creating age-class diversity by regenerating selected stands can reduce tree loss in future outbreaks.

High-value trees in campgrounds and landscapes can be protected during outbreaks by safely applying registered pesticides to the trunks of uninfested trees to prevent beetle attack. Experiments with verbenone, an antiaggregation pheromone that signals mountain pine beetles that a tree is already infested, has shown some success in protecting trees from mountain pine beetle attack. Continued work with mountain pine beetle pheromones—both attractant and antiaggregative ones—shows promise for the development of new forest management tools. In areas where the mountain pine beetle has killed mature forests (fig. 5), managing the regenerating forest for greater age-class, size, and species diversity will become the priority.

Outlook

Much of the lodgepole pine forest type in the West was regenerated following intensive harvest and fires in the 1800s and early 1900s. Forests now 100 to 150 years old provide ideal conditions for mountain pine beetle outbreaks to develop. Consecutive years of drought and warm temperatures that began in the late 1990s triggered numerous outbreaks throughout the West. Although moisture conditions have improved in many areas, forest conditions remain favorable for the beetles. At the same time, winter temperatures have remained relatively mild; these conditions are also favorable to outbreak development and expansion.

If observed trends continue, many mature lodgepole and ponderosa pine and associated five-needle pines in the central and northern Rocky Mountains will likely be infested. In many areas, only younger, more vigorously growing stands of mountain pine beetle hosts that regenerated in previously logged or burned-over areas are likely to remain green (fig. 6). In forests with reduced density or greater diversity of species and sizes of trees, the mountain pine beetle will have less of an effect.

Figure 5.—*Gray forests of lodgepole pines killed by mountain pine beetle in Colorado. Photo by Brian Howell.*

Figure 6.—*(left) Regenerated lodgepole pines growing in 1958 clearcuts on the Forest Service's Fraser Experimental Forest near Fraser, CO, demonstrate the mountain pine beetle's preference for older trees. (right) Unfortunately, beetle numbers are so great in the current outbreak that many younger trees are now being attacked. During mountain pine beetle epidemics, trees as small as 4 inches in diameter may be attacked.*

1958

2006

Gypsy Moth

Lymantria dispar (L.)

Current Conditions

The gypsy moth (Lepidoptera: Lymantriidae) is a major forest pest in North America. Native to most of temperate Europe and Asia, the insect was accidentally introduced into U.S. forests near Boston, MA, around 1868. About 10 years after this introduction, the first outbreaks occurred, and in 1890 the first large-scale Federal and State cooperative eradication program was initiated.

Since its accidental introduction near Boston, MA, the gypsy moth has become established in all or parts of 19 States and the District of Columbia (fig. 1). The gypsy moth entered another outbreak phase in 2005. Hot, dry weather occurred in the Mid-Atlantic region during the period when gypsy moth larvae were active, favoring the insect. The result was a rapid buildup of gypsy moth populations and widespread defoliation in 2006 and 2007, the likes of which had not been seen since the early 1990s. More than 1.3 million acres a year were defoliated in 2006 and 2007.

Damage

Gypsy moth populations are typically eruptive in North America. The insect is extremely polyphagous; it is known to feed on hundreds of different tree species in North America. When populations are low, nearly all feeding and defoliation occurs on favored hosts, such as oaks *(Quercus* spp.*)*. During population outbreaks, however, the insect feeds on more than 300 species of broad-leaved and coniferous trees and shrubs. Damage can be spectacular as well as extensive (fig. 2). Trees stripped of 50 percent or more of their leaves are likely to refoliate the same season, although new leaves are fewer and smaller than the original ones. This refoliation robs trees of vital starch reserves for future growth and health. A single year of defoliation rarely kills a healthy tree. Repeated defoliation in successive years, which is common during gypsy moth outbreaks, severely stresses trees and makes them susceptible to infestation by secondary organisms.

Several factors affect tree and stand mortality: severity, frequency, and distribution of defoliation; site and stand factors; environmental conditions; tree vigor; crown condition; and the presence and abundance of secondary organisms. Mortality can vary from stand to stand, even when stands have similar characteristics; mortality can reach 80 to 100 percent in some stands. Most mortality occurs during and after the initial outbreak, and severe mortality occurs along and behind an advancing outbreak front as the gypsy moth invades new areas. Defoliated trees already under stress from drought or other factors often succumb more quickly than healthier trees do.

Figure 1.—*As of 2007, gypsy moth quarantines were established in all or parts of 19 Eastern States and the District of Columbia.*

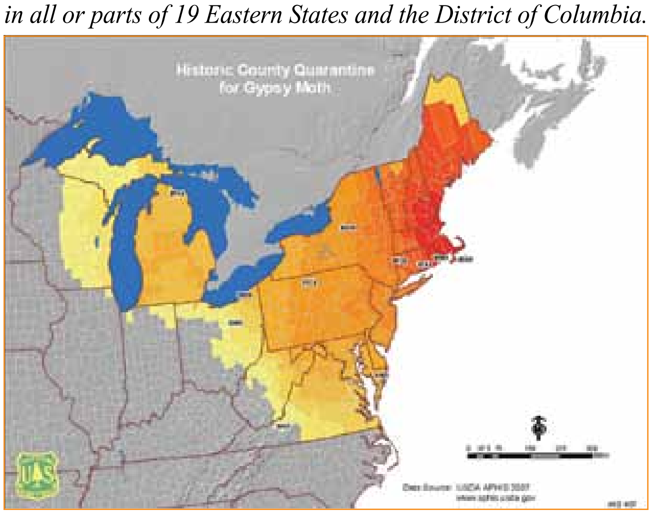
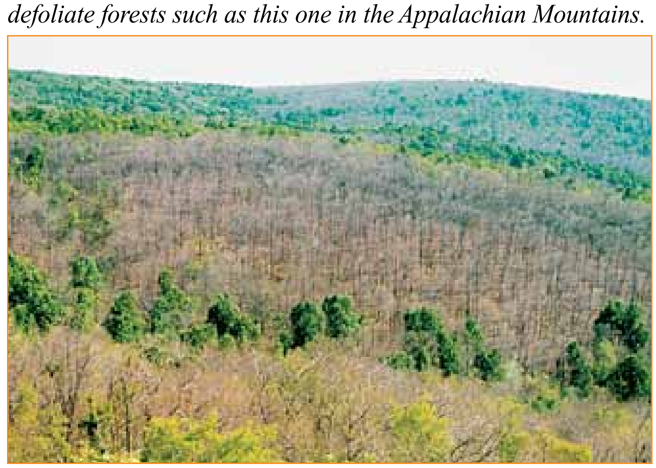


Figure 2.—*During outbreaks, gypsy moth larvae may completely defoliate forests such as this one in the Appalachian Mountains.*



Stands with basal areas of preferred species greater than 20 percent are particularly at risk. Gypsy moth hosts are located through most of the coterminous United States, but the highest concentrations of host trees are in the southern Appalachian Mountains, Ozark Mountains, and northern Lake States. Most (almost 70 percent) of the susceptible hardwood forests in the United States have not been infested by gypsy moth yet are still at risk (fig. 3).

Biology

The gypsy moth has a single generation per year and passes through four stages: egg, larva, pupa, and adult (moth stage). Only the larvae (caterpillars) damage trees and shrubs. Gypsy moths overwinter as eggs, which hatch in the spring just as the buds on most hardwood trees break. Newly hatched caterpillars begin feeding immediately, or disperse on silken threads that carry them on wind currents ("ballooning") to suitable hosts, usually a short distance away. Feeding continues through May and June, and the larvae progress through a series of molts as they grow. The stages between these molts are called instars. Male larvae normally go through five instars and female larvae go through six before entering the pupal stage. Older larvae exhibit the characteristic five pairs of raised blue spots and six pairs of raised brick-red spots along their backs (fig. 4).

When gypsy moth populations are sparse, the insect responds to light intensity by feeding at night and moving to sheltered places on the trees (e.g., bark flaps, crevices, undersides of branches) and ground (e.g., leaf litter, woody debris) during daylight. Most defoliation results from feeding by older caterpillars. When populations are dense, larvae feed day and night. Trees often appear as if they were stripped of their leaves overnight. Larvae commonly leave the trees and migrate in search of food and resting places, creating a significant nuisance around homes.

Mature larvae reach the pupal stage between mid-June and early July. In sparse populations, the insects seek out sheltered places to pupate. In high populations, the insects will pupate on any available substrate. The adult moths emerge about 10 to 14 days later.

The male gypsy moth emerges first and begins searching for females. When heavy, egg-laden females emerge, they emit a pheromone that attracts the males (fig. 5). The female moth does not fly. She lays her fertilized eggs in July and August close to the spot where she pupated (fig. 6), commonly on the tree trunk and branches but on just about any substrate when populations are high, including outdoor household articles and vehicles. Both the male and female adult gypsy moths then die.

Figure 3.—*Forest stands with 20-percent basal area or more of gypsy moth host trees are at the greatest risk of defoliation.*

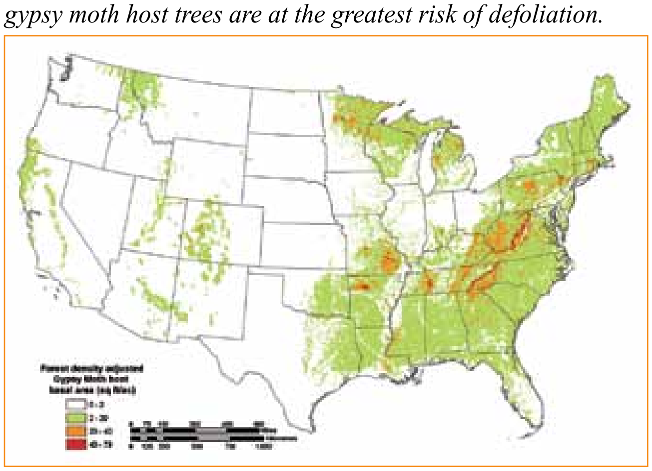


Figure 4.—*Older gypsy moth larvae exhibit a characteristic six pairs of raised red dots and five pairs of raised blue dots on their backs.*

Figure 5.—*Male moths emerge before the female moths and immediately begin flying in irregular patterns, zigzagging across the area until they catch the scent of the pheromone released by the females.*

Four to 6 weeks later, embryos develop into larvae. The larvae remain in the eggs during the winter. The eggs hatch the following spring.

Historical Trends

Between 1924 (when records were first kept) and 2007, the gypsy moth defoliated more than 89 million acres of hardwood forests in the Eastern United States. Many of these acres have experienced repeated defoliations over the years as the insect moved (and continues to move) through one outbreak episode after another. During the 1970s and 1980s, the insect entered a long-term period of sustained outbreak as it rapidly spread into the oak-rich forests of the Mid-Atlantic States. From 1971 to 1990, cumulative defoliation exceeded 56 million acres, representing nearly two-thirds of the total cumulative defoliation that has occurred since 1924. Half of that 56+ million acres was defoliated during just a 4-year period, from 1980 to 1983.

Figure 6.—*Female moths lay an egg mass on just about any surface and then cover the eggs with the buff-colored hairs from their abdomens. A very healthy egg mass may contain up to 1,000 individual eggs.*

In 1981, the gypsy moth defoliated a record 12.9 million acres across 12 Eastern States.

The gypsy moth remained active during the 1980s, leading to another outbreak phase between 1989 and 1993. During that period, more than 18 million acres were defoliated across 14 Eastern States and the District of Columbia.

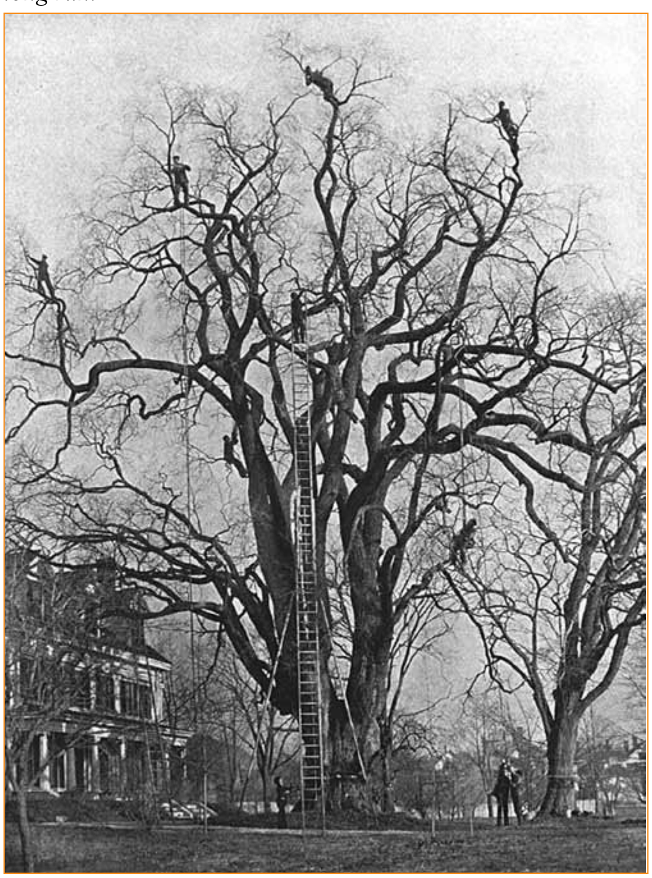
In 1989 a fungus, identified as *Entomophaga maimaiga (E. maimaiga)*, was discovered to be causing significant collapse of gypsy moth populations across a number of States. This "gypsy moth fungus" was known in Japan and had been released by scientists near Boston, MA, between 1910 and 1911. The fungus was never recovered again after those releases and thought to be a failure. How the fungus present today became established in the United States is uncertain. Two thoughts suggest that the fungus could have evolved from the 1910 fungus into a more virulent strain, or it may have been a recent accidental reintroduction of the fungus. In any case, by 1992 this fungus was recovered throughout much of the generally infested area in North America. Since then, the fungus has become the most visible natural gypsy moth control agent and has prevented periodic eruptions of gypsy moth infestation from becoming major sustained outbreaks.

Management and Treatment Actions

A variety of natural control agents are now known to help regulate gypsy moth populations. These agents include more than 20 insect parasitoids and predators that were introduced over the past 100 years from Asia and Europe. Small mammals (e.g., the white-footed mouse) are significant gypsy moth predators, especially at low population densities. To a lesser extent, some birds are also known to prey on gypsy moths. A nucleopolyhedrosis virus causes the collapse of outbreak populations and the entomopathogenic fungus, *E. maimaiga,* is now the major agent that keeps gypsy moth populations in check.

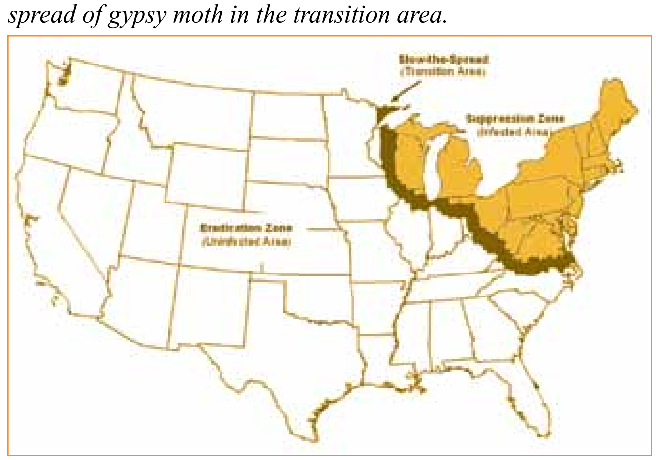
The early response to gypsy moth outbreaks consisted of collecting and destroying egg masses, larvae, and pupae; burning infested areas (fig. 7); and using insecticides (Paris green, lead arsenate). These efforts were labor intensive and costly and proved to be ineffective in containing and eradicating the insect. The last major attempt to contain the insect to the New England States, a barrier zone along the Hudson River in New York, was abandoned in 1939.

Figure 7.—*Hand scraping and destroying gypsy moth egg masses was a common control practice in the early years of gypsy moth control programs. The method was labor intensive, expensive, potentially dangerous, and not very effective in the long run.*



Today, the U.S. Department of Agriculture (USDA) National Gypsy Moth Management program consists of three strategies (fig. 8): (1) reducing damage to forests and trees caused by gypsy moth outbreaks in the generally infested area (suppression); (2) eliminating isolated spot infestations resulting from the artificial movement of gypsy moth into uninfested parts of the country (eradication); and (3) slowing the natural and short-range artificial spread along the leading edge of the generally infested area (slow the spread). The Forest Service and the USDA Animal and Plant Health Inspection Service (APHIS) share responsibilities for managing gypsy moth infestation and cooperate with State forestry and agriculture agencies to implement treatments. The currently approved treatments most often employed include the direct application of insecticides, including *Bacillus thuringiensis var. kurstaki (Btk);* diflubenzuron, an insect growth regulator; the gypsy moth virus product Gypchek; and the gypsy moth pheromone disparlure to disrupt adult moth mating. Other approved tactics include mass trapping and the sterile insect technique. Mass trapping is commonly used to help eradicate small spot infestations; the sterile insect technique has not been used operationally in many years.

Figure 8.—*The USDA National Gypsy Moth Management program consists of three strategies: suppression to reduce damage in the generally infested area, eradication to eliminate spot infestations in uninfested areas, and slowing the rate of spread of gypsy moth in the transition area.*



The approved insecticide treatments are very effective in protecting tree foliage and reducing gypsy moth populations in high-value areas. Since 1970, almost 14 million acres have been treated through Forest Service cooperative suppression projects with State and local agencies, Federal land managers, and tribal governments. Most of these treatments (covering nearly 11 million acres) took place during the major gypsy moth outbreaks of the 1980s and early 1990s. With the presence of hot, dry spring weather in the Mid-Atlantic States, gypsy moth populations started building again beginning in 2005. In 2007, approximately 192,000 acres were treated in Maryland, New Jersey, Ohio, Pennsylvania, Virginia, Wisconsin, and West Virginia to reduce damage to trees and forests.

Isolated gypsy moth spot infestations are often detected outside the generally infested area. These spots result from the artificial movement of gypsy moth life stages on commodities such as nursery stock, logs, and firewood, and personal items such as outdoor household articles and vehicles. The detection and elimination of these spot infestations is important in keeping these spots from growing and coalescing, and thereby creating new generally infested areas. Since 1967, gypsy moth populations have been eradicated in a total of more than 4.6 million acres in just about every State. In 2007 eradication treatments included 5,189 acres in Indiana, North Carolina, Ohio, Oregon, Washington, and Wisconsin.

In 2000, the Forest Service and APHIS operationally implemented the gypsy moth Slow the Spread strategy. The strategy was developed based on information learned in several previous landscape-level pilot projects that began in 1979. Slow the Spread involves the implementation of a regionwide strategy involving 11 States (Minnesota, Michigan, Wisconsin, Iowa, Illinois, Indiana, Ohio, West Virginia, Kentucky, Virginia, and North Carolina) to minimize the rate at which the gypsy moth spreads into uninfested areas. As a direct result of this program, gypsy moth spread has been dramatically reduced by more than 70 percent, from the historical level of 13 miles per year to 3 miles per year. Since its inception in 2000, the Slow the Spread strategy has prevented outbreaks that would have occurred on more than 75 million newly infested acres.

In 2007, more than 61,000 acres in the Slow the Spread project area were treated with insecticides and nearly 365,000 acres were treated with the mating disruption pheromone. Approximately 73,000 pheromone traps were deployed in the project area to monitor gypsy moth levels.

Outlook

The gypsy moth will continue to cause significant defoliation periodically and, in some situations, tree mortality. The moth will also continue to spread into uninfested areas of the country, but very effective and proven tools and tactics can be employed to eradicate isolated infestations, reduce damage to trees, minimize tree mortality, and slow the natural and short-range artificial spread of the insect. The gypsy moth fungus probably will continue to regulate gypsy moth populations and prevent prolonged major outbreaks.

Of greater concern is the introduction and possible establishment of the Asian gypsy moth in North America. Because the Asian gypsy moth mates freely with the European gypsy moth strain present in North America and female Asian gypsy moths are capable of flight, considerable concern exists that the Asian strain could very quickly spread throughout North America. The Forest Service, APHIS, and Canadian counterparts are allocating considerable resources to monitor Asian gypsy moth populations in Eastern Asia, including Russia, Japan, Korea, and China; track and inspect ships bound for North America from those high-risk ports; and aggressively eradicate Asian gypsy moth spot infestations when found.

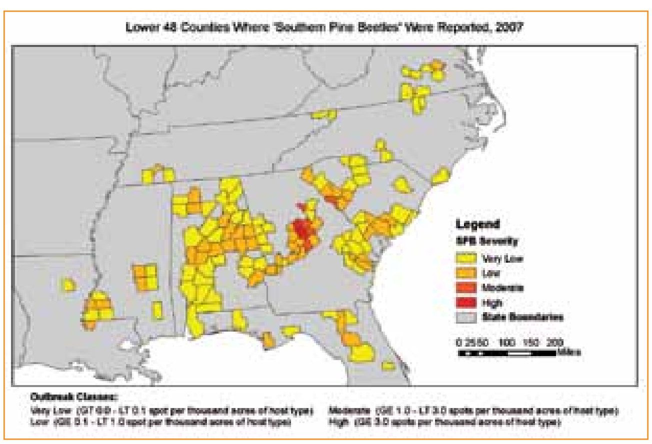
Southern Pine Beetle

Dendroctonus frontalis

Current Conditions

In 2007, southern pine beetle, *Dendroctonus frontalis,* infestations were reported in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia (fig. 1). A total of more than 10,000 acres were affected in these nine States (table 1). Most of the southern pine beetle activity (8,500 acres) occurred in the central piedmont region of Georgia, where southern pine beetle populations reached outbreak levels in Jasper, Jones, and Putnam Counties. The more than 2,000 infestation spots detected in these counties were primarily on the Oconee National Forest, the Piedmont Wildlife Refuge, the Hitchiti Experimental Forest, and surrounding areas. Clusters and foraging habitat of the red-cockaded woodpecker, a listed endangered species, were adversely affected. Hiking, hunting, and other recreational activities were restricted due to suppression activities and the hazard posed by dead and dying pines. The local standing timber inventory and timber markets also were affected.

Figure 1.—*Counties with southern pine beetle infestation in 2007.*



Biology

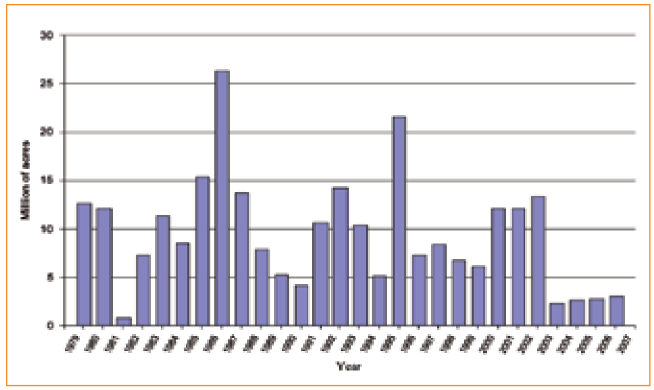
During outbreaks, the southern pine beetle attacks all pine species, and even marginal hosts, such as spruce and hemlock, may be killed. The southern pine beetle usually causes discrete infestations, often called spots. Females initiate attacks, and pheromones combined with host odors attract both genders. The mass attack allows the southern pine beetle to overcome tree defenses. The beetles tunnel beneath the bark, creating S-shaped egg galleries. Early larvae develop in the inner bark and then move into the outer bark to pupate. Both parent and brood adults emerge and can participate in additional attacks. After a tree has been fully colonized, the release of other pheromones shift attacks to adjacent pines if sufficient numbers of southern pine beetles are present. This attack process leads to the development of expanding infestations, which can become very large if not suppressed (fig. 2). Up to seven overlapping generations occur per year.

Table 1.—*Southern pine beetle activity by State.*

State	Acres Infested 2007	Number of Spots 2007
Alabama	405	765
Arkansas	0	0
Florida	182	43
Georgia	8,504	2,077
Kentucky	0	0
Louisiana	6	5
Mississippi	96	208
North Carolina	3	15
Oklahoma	0	0
South Carolina	157	734
Tennessee	5	39
Texas	0	0
Virginia	819	64
Total	10,177	3,950

Figure 2.—*Southern pine beetle mortality. Photo by Andrew J. Boone, South Carolina Forestry Commission, http://www.bugwood.org.*

Figure 3.—*Southern pine beetle outbreaks, 1979–2007.*



Note: The 2007 survey counted outbreak acres differently than in previous years. Previously, all acres in the county were counted if a single spot was positive for southern pine beetle. The 2007 survey reflects only the estimated actual affected areas by southern pine beetle.

Damage

The southern pine beetle is the most destructive insect pest of pines in the Southeastern United States, where its range stretches south from New Jersey to Florida and west to east Texas, generally coinciding with the range of loblolly pine. Disjunct southern pine beetle populations also occur in Arizona and New Mexico, where they are overshadowed by damage from other bark beetles. The southern pine beetle also occurs in Mexico and Central America. In the Southeastern United States, loblolly, shortleaf, pitch, pond, and Virginia pines are the favored hosts.

Historical Trends

One or more southern pine beetle infestations per 1,000 acres of susceptible host type is considered an outbreak. Historically, southern pine beetle populations have attained outbreak status every 8 to 12 years throughout most of the insect's range, with outbreaks lasting 2 to 3 years (fig. 3). From 1974 to 2004, an outbreak occurred annually in some region of the Southeastern United States. During the period, the average annual loss related to southern pine beetle infestation was $100 million, for a total loss from 1974 to 2004 of more than $3 billion. From 1998 to 2007, southern pine beetle infestations affected approximately 440,000 acres on Federal, State, and private forest lands. Most of the tree mortality occurred during an outbreak that lasted from 1998 to 2003 in Virginia, Kentucky, North Carolina, South Carolina, Tennessee, Georgia, and Florida.

Management and Treatment Actions

An effective southern pine beetle integrated management program consists of monitoring and prediction, detection, evaluation, suppression, and prevention. Funnel traps baited with the southern pine beetle aggregation pheromone frontalin and host volatiles are set out each spring during the primary dispersal period of southern pine beetle. The numbers of southern pine beetles and their predator, the clerid, or checkered beetle *(Thanasimus dubius)*, collected are used to predict current-year southern pine beetle population levels. Aerial detection surveys are used to locate specific southern pine beetle infestations. During outbreaks, biweekly detection flights may be needed from May through September. Suspect infestations are ground checked to determine the bark beetle species responsible, current level of spot expansion, and need for suppression. Prompt suppression is the key to reducing tree loss, and direct-control methods are efficacious. Suppression treatments include cut-and-remove, cut-and-leave, cut-and-hand-spray, and pile-and-burn. Cut-and-remove is the most effective treatment, with an efficacy rate of 97 percent or higher. If the cut-and-remove treatment cannot be used due to ground conditions, saturated timber markets, or other reasons, the cut-and-leave treatment is typically used. This treatment is effective when applied between May and October and is often used for small infestations with smaller diameter trees. The cut-and-hand-spray and pile-and-burn treatments are rarely applied. Inactive or small, slow-expanding spots may be monitored.

Prevention is the most effective method for managing southern pine beetle infestations, resulting in reduced effects after an outbreak occurs. Maintaining desired stand densities by thinning; planting site-appropriate species; removing lightning-struck, wounded, and other highly susceptible pines; and increasing tree vigor are the cornerstones of a southern pine beetle prevention program. The Southern Region's Southern Pine Beetle Prevention and Restoration Program promotes these strategies and assists landowners and forest managers with their implementation. Since the program's inception in 2003, more than 560,000 acres of the highest risk areas have been treated.

Outlook

Based on 2007 activity, southern pine beetle infestations are expected in Alabama, Georgia, Florida, Mississippi, South Carolina, and Virginia in 2008. Results from the annual southern pine beetle spring survey will help define the expected extent and level of southern pine beetle activity. A significant number of acres will be thinned as part of the Southern Pine Beetle Prevention and Restoration Program to help mitigate future losses from this insect.

Emerald Ash Borer

Agrilus planipennis Fairmaire

Current Conditions

The emerald ash borer was first reported in North America in the Detroit area and shortly thereafter in nearby Ontario, Canada, in 2002. This Asian native (fig. 1) kills ash trees and is thought to have entered the United States in the early 1990s, probably as a stowaway in solid-wood packing material. Since the initial reports, an extensive infestation has been found. The natural spread of the emerald ash borer is greatly supplemented by artificial or human-aided movement, such as on ash nursery stock, firewood, and logs. Isolated spots associated with artificial movement of the insect have been found in Illinois, Indiana, Maryland, Pennsylvania, Virginia, and West Virginia. By the end of 2007, Federal and State quarantines were established in all or parts of Illinois, Indiana, Maryland, Michigan, Ohio, Pennsylvania, and West Virginia (fig. 2).

The emerald ash borer is known to occur in China, Korea, Japan, Mongolia, and the Russian Far East (fig. 3). A Chinese report indicates high populations of the borer occur primarily in *Fraxinus chinensis* and *F. rhynchophylla* forests. Other reported hosts in Asia include *F. mandshurica* var. *japonica, Ulmus davidiana* var. *japonica, Juglans mandshurica* var. *sieboldiana,* and *Ptero.carya rhoifolia*. In North America, so far, the emerald ash borer has attacked only ash trees.

Figure 1.—*The emerald ash borer was largely unknown outside Asia until it was detected in the Detroit (MI) and Windsor (Ontario) metropolitan areas in 2002.*

Figure 2.—*By the end of 2007, the emerald ash borer had been detected in 132 counties across 7 States, including new isolated infestations in Pennsylvania and West Virginia.*

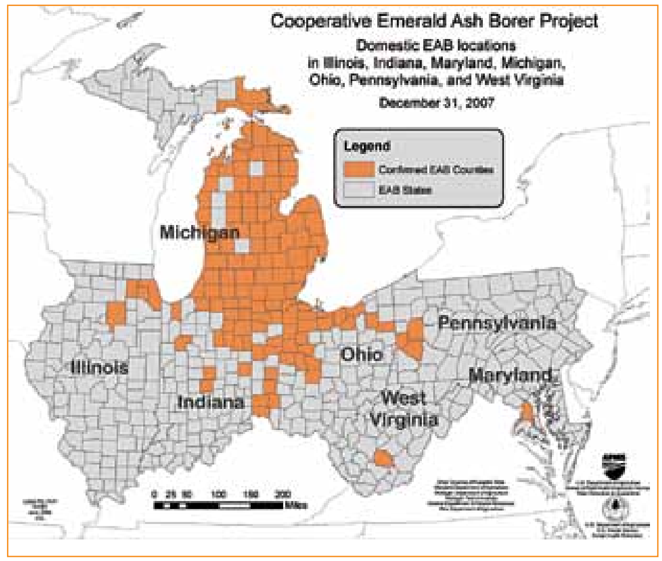
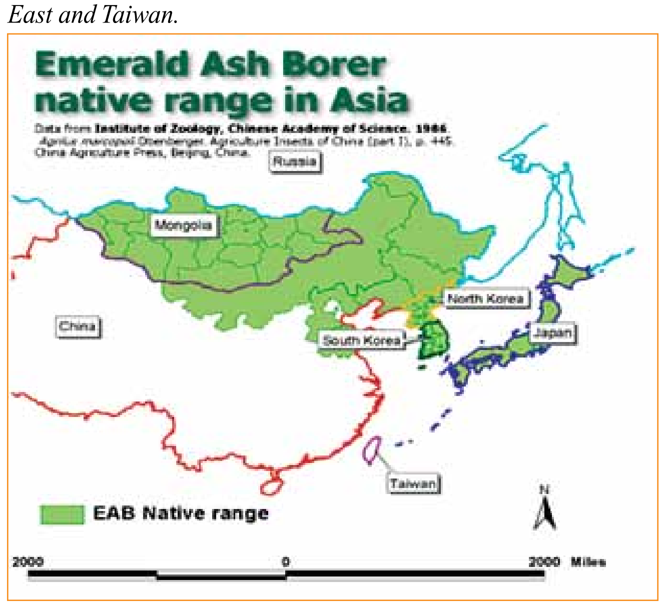


Figure 3.—*Early data originally placed the native distribution of emerald ash borer in parts of China, Korea, Mongolia, and Japan; however, it is known to occur also in the Russian Far East and Taiwan.*

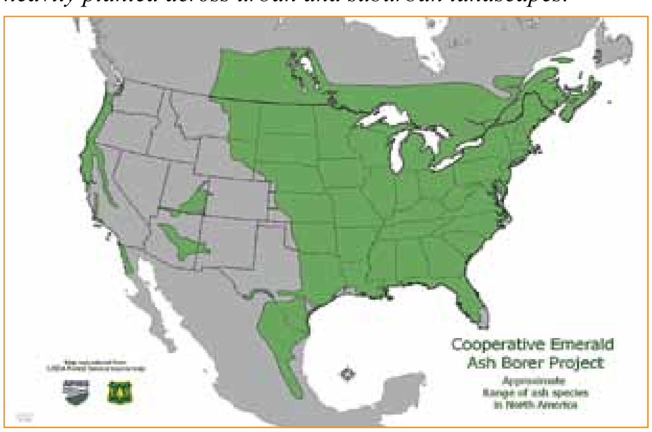


Damage

All 16 North American ash *(Fraxinus)* species appear to be suitable hosts for the emerald ash borer, although the insect does exhibit a preference for green ash *(F. pennsylvanica)*, followed by white ash *(F. americana)*, black ash *(F. nigra)*, and blue ash *(F. quadrangulata)*. Tree mortality is extensive in areas that have been infested for several years. Some experts have estimated the number of ash trees already killed at 20 million, but the actual number is probably much higher. The Emerald ash borer is a very efficient tree killer. In southeastern Michigan and northwestern Ohio, the mortality rates for ash trees are nearly 100 percent. This figure translates into millions of dead ash trees in the area. In 2004, the Forest Service estimated that the potential costs to communities and homeowners to remove and replace dead and dying ash trees could exceed $7 billion over the next 25 years.

Ash is common in forests throughout the Eastern United States and Canada and regularly occurs along riparian areas in the Western United States (fig. 4). In urban landscapes, ash is one of the most commonly planted trees along streets and parking lots, in yards and parks, and around commercial buildings. Typical symptoms of infested trees include a profusion of epicormic branching, crown decline and dieback, and, eventually, mortality (fig. 5). Heavily infested trees often exhibit woodpecker feeding damage and always exhibit the characteristic D-shaped exit holes (fig. 6) created by adult flat-headed woodborers as they emerge from infested trees.

Figure 4.—*Ash occurs commonly in the hardwood forests, riparian areas, and shelterbelts of North America. It is favored by homeowners and communities and, consequently, has been heavily planted across urban and suburban landscapes.*



Biology

Adult beetles emerge from ash trees throughout the summer but are mostly present in June and July. Insect development and, therefore, adult emergence is temperature dependent. Adults are most active on warm, sunny days. Before mating, the newly emerged beetles commonly feed on the margin of ash leaves. Individual adults live for a few weeks, during which mated females locate ash trees and lay individual eggs in bark crevices on the trunk and branches. Eggs hatch 7 to 10 days later, and the tiny larvae chew through the bark into the cambium, where they feed for several weeks in the phloem and outer sapwood. The larvae create extensive S-shaped feeding galleries that wind back and forth, becoming progressively wider as the insects grow. Galleries are packed with fine, sawdust-like frass and often extend over an area that is 7.87 to 11.81 inches in length, although the length of the affected area can range from 3.94 to

Figure 5.—*Infested ash trees quickly succumb to the feeding by emerald ash borer larvae and often exhibit signs of decline and dieback, epicormic branching, and woodpecker damage.*

19.69 inches or longer (fig. 7). Feeding is completed in autumn and prepupal larvae overwinter in shallow chambers excavated in the outer sapwood or in the bark on thick-barked trees. Pupation begins in late April or May. Newly enclosed adults often remain in the pupal chamber for 1 to 2 weeks before emerging head first through a small, .12- to .16-inch D-shaped exit hole.

Damage by an individual larva is minimal, but, as a tree is repeatedly attacked, the population buildup of thousands of insects quickly overwhelms the ability of the tree to defend itself. Tree decline and death can be rapid. Adult emerald ash borers are good flyers and the insect is capable of spreading to adjacent areas. In most recently established sites with low densities of emerald ash borer, a 2-year life cycle appears more common than a 1-year life cycle. As densities build or as trees are stressed, most of the insects complete a 1-year life cycle. It often takes a few years for emerald ash borer populations to build and for tree symptoms to appear. These factors may help explain why new infestations are often not detected for several years.

Historical Trends

The emerald ash borer was largely unknown outside of Asia until it was detected and confirmed in 2002 in southeastern Michigan. Entomologists now believe the infestations in Michigan were most likely initiated 6 to 10 years before their discovery. As annual surveys were implemented, beginning in 2003, the insect was found in more counties in Michigan, in adjacent States, and in isolated spots far removed from the initial detections in Michigan.

In 2007, the emerald ash borer was found in an additional 24 counties, including new isolated infestations detected in Butler County, PA, and Fayette County, WV (fig. 2). The insect now infests major portions of the Lower Peninsula of Michigan and much of Ohio, northern Indiana, and northeastern Illinois outside Chicago. An eradication project in Prince Georges County, MD, was expanded slightly when several new infested trees were detected in 2007.

Management and Treatment Actions

Since the emerald ash borer was first detected in 2002, APHIS, the Forest Service, State foresters, and plant pest regulatory officials have implemented a strategy to minimize further spread of the insect. Tactics included aggressive surveys using girdled trap trees; felling and carefully peeling trees; conducting visual surveys; identifying and regulating pathways for artificial move-

Figure 6.—*Emerald ash borer adults leave a very distinctive "D-shaped" exit hole when they chew their way out of the tree. Only .12- to .16-inch in size, exit holes may be hard to see in lightly infested trees but are quite conspicuous in heavily attacked trees.*

Figure 7.—*In outbreak situations, emerald ash borer larvae excavate extensive serpentine galleries in the trunk of ash trees as they feed in the cambium layer. Trees are quickly girdled, disrupting the flow of nutrients, and die shortly thereafter.*

ment of the insect; developing compliance agreements with businesses to facilitate commerce; and eradicating infestations by felling and destroying infested and high-risk ash trees (fig. 8). Public communication and outreach are also integral parts of the early detection effort.

The Forest Service's role includes providing technical and science support to the emerald ash borer program, promoting early detection outside of the known infested areas, and helping communities and forest landowners deal with emerald ash borer infestations in affected areas. In 2007, the Forest Service supported work that focused on the following nine objectives: (1) integrated control and management of the emerald ash borer, including the development of options for managing isolated emerald ash borer spots; (2) insecticides for emerald ash borer control, including the development of preemergent trunk sprays and noninvasive trunk sprays and injectibles; (3) emerald ash borer biology, to better understand the extended larval development mechanisms and adult phenology; (4) population dynamics and rate of spread, including historical reconstruction of the emerald ash borer infestation in southeastern Michigan and evaluation of phloem reduction and emerald ash borer rate of spread models; (5) trap tree evaluations, including girdling techniques, timing, and sampling protocols; (6) trapping and attractants, including evaluations of host volatiles and attractants such as manuka oil and trap design and placement; (7) host preference and suitability, including evaluations of emerald ash borer feeding behavior, mating, oviposition behavior, larval density, and survival on different ash species; (8) evaluations of the ash seed bank in emerald ash borer-affected areas to determine the quantity and health of ash seed in the soil; and (9) biological control evaluations, including the discovery of a native parasitoid of buprestids found attacking the emerald ash borer and small field release of three natural enemies of the emerald ash borer from China. The Forest Service also implemented emerald ash borer trap tree surveys in 12 States.

Figure 8.—*The standard treatment for eradicating emerald ash borer infestations is to remove the infested trees and a buffer of high-risk ash trees and to destroy them by chipping or grinding and burning. This process is labor intensive and very expensive.*

In 2007, APHIS developed a new policy regarding eradication of isolated emerald ash borer spots, set in motion plans to begin using traps in place of trap trees, and implemented a national emerald ash borer survey. An ongoing eradication project in Maryland was the only federally funded eradication effort in 2007.

Outlook

The outlook for the ash resource in North America is problematic. The lack of host resistance observed in native ash to date suggests that the emerald ash borer could, over time, eliminate much of the existing ash resource across all landscapes. Street and landscape ash trees can be replaced with other tree species. It is not clear, however, what tree species will replace ash in hardwood forests and what changes that replacement will cause. Ash is often the predominant tree in riparian areas, shelterbelts, woodlots, rights-of-way, and places where vegetative disturbance has occurred naturally or by humans. Since 2002, however, we have learned much about emerald ash borer biology, population dynamics, dispersal, and host response. Advancements in survey and control technologies, including the development of biological control agents, continue and offer hope for detecting new isolated infestations early enough to apply appropriate tools to manage the insect and subsequent ash mortality.

Sudden Oak Death

Phytophthora ramorum

Current Conditions

Over the past decade, *Phytophthora ramorum (P. ramorum)*, the causal agent of sudden oak death, has killed millions of trees, including tanoak *(Lithocarpus densiflorus)*, California live oak *(Quercus agrifolia)*, Shreve Oak *(Quercus parvula)*, and California Black Oak *(Quercus kelloggii)* throughout 15 counties in the central and northern coastal areas of California and the extreme southwestern corner of Oregon (figs. 1 and 2). It has been estimated that this pathogen has caused mortality on more than three million tanoaks alone. The disease has also been found on nursery stock outside the infested areas of California and Oregon but has not established itself beyond nursery environs to date.

Damage

P. ramorum thrives in cool, wet climates, but significant infections can occur in environments with microclimates that favor disease. The organism is known to spread through wind-blown rain, waterways contaminated with irrigation water, and infected plants; it may also spread in ways not yet discovered. Movement of the pathogen in soil or potting soil is also possible. Depending on the plant species, *P. ramorum* infections may occur on the trunk, branches, and/or leaves. Infections that result in tissue death and callus response on the woody portions of a tree are referred to as cankers. In foliar and twig hosts, symptoms can range from leaf spots to twig dieback, but these hosts rarely die from the infection. Symptoms caused by *P. ramorum* are difficult to differentiate from those caused by other pathogens. For this reason, laboratory analysis is necessary to confirm the presence of *P. ramorum.*

Figure 1.—*Recently dead (brown) and 1-year-dead (gray) tanoak in California. Image from Web site of the California Oak Mortality Task Force, http://www.suddenoakdeath.org.*

Figure 2.—*Distribution of sudden oak death in California as of February 2008. Image courtesy of the Kelly Lab, University of California, Berkeley.*

Biology

P. ramorum is a water mold. Its spores can be spread in rainwater. It can grow on the leaves and twigs of more than 100 species. Most of these plant species do not die from this pathogen but can serve as sources of inoculum that can infect other plants. The most frequently killed species is tanoak, followed by California live oak. For the susceptible tree species, death takes place because germinating spores can penetrate the bark of the trees and cause cankers on the main bole. Recent studies indicate that xylem colonization of living tree hosts by canker-causing pathogens may be more widespread than recognized previously; thus, infected host species are killed by a significant reduction in water transport. Further studies need to be conducted to completely understand the mechanism of how *P. ramorum* kills host species. *P. ramorum* has also been known to show asymptomatic signs on some plant parts, making visual detection of the fungus difficult.

Historical Trends

Sudden oak death was first reported on the central California coast in the mid-1990s. The causal agent, *P. ramorum,* was later identified in 2001. By this time, the disease was already found in seven San Francisco Bay Area counties.

More than 1,667,000 dead trees were counted during aerial photo and sketchmapping exercises conducted annually between 2004 and 2007, suggesting that the number of dead trees has almost certainly surpassed 3 million. These dead trees are distributed over approximately 184,000 acres, including about 3 percent of the total population of tanoak and about 1 percent of the total population of California live oak.

One ongoing concern is that roughly 2 million acres of northern Pacific Coast forest have both a high population of susceptible species (tanoak or California live oak) and a moist climate conducive to the development of the disease. This pathogen has demonstrated a tremendous capacity to produce high spore loads and is capable of moving substantial distances via prevailing winds. New infections are favored during periods of long, warm, wet springs, as reported in 2006 and 2007.

Widespread mortality of oaks necessitates costly tree removal and directly contributes to higher fuel loading, increasing the risk of wildfires. Furthermore, animals that feed on acorns from these oaks will be negatively affected due to the loss of this food source. Indian tribes that use acorns for their cultural gatherings may also be adversely affected.

The continued mortality of tanoak and other susceptible oaks favors a species shift within stands, often toward higher proportions of Douglas-fir, bay laurel, and other species not killed by the pathogen. Although this species shift is ecologically important, other landscape-scale environmental problems, such as soil erosion, increased water turbidity, warming streamwater temperatures, and reduced carbon dioxide fixation, appear to be largely unaffected by the species shift.

Quarantines have been placed on the movement of proven and associated hosts, including nursery stock and other plant parts in counties in California and Oregon that are known to have *P. ramorum*. A strict monitoring and cleanup program has been established in the quarantined counties and areas where the pathogen has been detected to minimize further spread.

P. ramorum has yet to significantly affect forests outside the endemic areas in California and Oregon. Nevertheless, risk projections based on integrating host type, climate, and pathways of introduction show that eastern hardwood forests are at high risk, especially in the southern Appalachian Mountains, where oak and rhododendron densities are high and weather can be conducive to disease development. The large-scale nationwide movement of potentially infected nursery stock in 2004 only demonstrated the reality of disease risk. In response, continued national surveys are conducted annually to monitor nurseries and nearby forests to determine if the pathogen has become established. Except for two locations, survey results to date have been negative in forested areas. The two sites where *P. ramorum* was detected are currently undergoing followup sampling and verification.

Management and Treatment Actions

Many management activities are taking place that attempt to curtail the effect of this disease. They vary by region and the extent to which the disease might already be present in each region. These management activities include the following:

- An extensive detection survey that has encompassed as many as 39 States in the past, although the current effort is concentrated in 28 States with the highest likelihood of developing the disease.
- Close monitoring and careful management of nurseries in counties already known to be affected.
- Spraying as-yet-uninfected potential host trees with a chemical (Agrifos®) to induce resistance to *P. ramorum.*
- The removal of bay trees near vulnerable oak trees to lower the spore load.

Figure 3.—*Intensive management of infected areas in Oregon.*

- The development of host-free strips of forest land to prevent the movement of inoculum into areas that currently are not affected by the disease.
- The intensive eradication of infected and potentially infected trees in areas where the disease has just recently been identified (fig. 3).

Outlook

Conditions in some parts of coastal California and southwest Oregon have proven to be very conducive to the development of sudden oak death and *P. ramorum* has demonstrated that it can be a devastating pathogen. The disease will continue to kill many hundreds of thousands more tanoak and live oak in areas where it has already become established.

Nevertheless, there are some reasons for optimism. Cost-effective survey and diagnostic procedures are now in place for better detection of the disease so prompt action can be taken. Additionally, silvicultural treatments are being implemented that show promise in slowing the spread and reducing the negative effects of the pathogen. Finally, a good extension program is in place, especially in the most highly affected regions, that continues to increase awareness of this devastating pest.

Please visit http://www.suddenoakdeath.org (the California Oak Mortality Task Force Web site) and http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/index.shtml (the APHIS Web site) for additional information on this disease.

Spruce Beetle

Dendroctonus rufipennis Kirby

Current Conditions and Historical Trends

The spruce beetle (*Dendroctonus rufipennis* Kirby, Coleoptera: Curculionidae) is the most important biotic disturbance agent affecting postfire, spruce-fir forests in western North America (fig. 1). Populations of spruce beetles occur within the natural range of their principle host species, Engelmann spruce (*Picea engelmannii* Parry ex Engelm.).

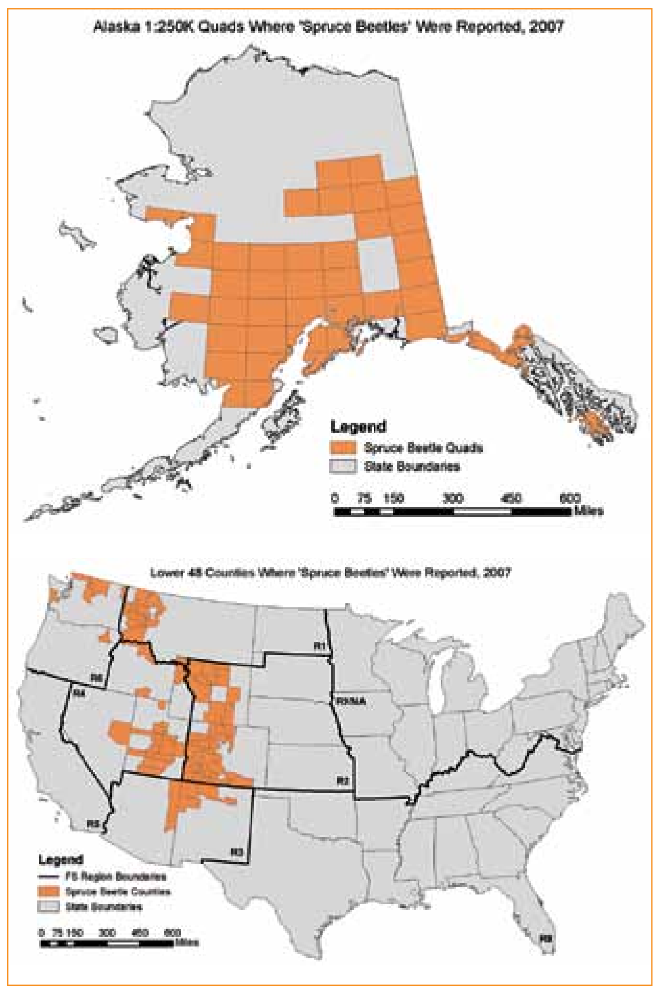
Spruce beetles typically infest newly fallen host material and overmature or weakened trees (fig. 2). Spruce beetle populations may reach epidemic levels following disturbances that produce large quantities of fresh host material and during periods of drought.

In 2007, spruce beetle epidemics affected approximately 360,000 acres of spruce-fir forest in the Western United States and Alaska (fig. 3). From 1997 through 2007, spruce beetles killed trees on a total of 3.8 million acres in these areas and caused the loss of more than 90 percent of the mature spruce component in many stands (fig. 4). Similar levels of mortality were reported for historic outbreaks on the White River Plateau, CO, during the 1940s and on the Aquarius Plateau, UT, from 1918 to 1930.

Figure 1.—*An adult spruce beetle and eggs. Photo by Edward H. Holsten, Forest Service, http://www.bugwood.org.*

Figure 2.—*Extensive blowdown in a spruce-fir forest on the Ashley National Forest in Utah.*

Figure 3.—*Maps of spruce beetle-caused tree mortality detected in 2007 by Forest Health Monitoring, aerial detection surveys.*



Biology

Depending on climate and elevation, spruce beetle flight begins in late spring (May through June). Pioneering females locate suitable host trees and bore into the inner bark to mate and lay eggs. After the eggs hatch, spruce beetle larvae feed in the phloem tissue of the host tree. Larval feeding results in tunnels that may effectively girdle the host tree, resulting in tree mortality (fig. 5).

The spruce beetle life cycle typically lasts 2 years, although warm seasonal temperatures may allow larvae to mature in 1 year. A high proportion of beetles mating in 1 year can greatly increase local populations, requiring more aggressive management strategies.

Implications of Spruce Beetle Mortality

As native insects, endemic populations of spruce beetles have an important role in removing overmature, diseased, and stressed trees from forest ecosystems. Birds, other wildlife, and insect predators consume spruce-beetles as food, and dead trees benefit snag-dependent wildlife species by providing nesting habitat. Over time, tree mortality produces coarse woody debris and initiates decomposition that contributes to nutrient cycling.

In turn, high levels of spruce-beetle-caused tree mortality can conflict with other important resource values. Stands composed of large, old Engelmann spruce provide a vegetative structure attractive to many users of popular campgrounds and trails. The loss of mature spruce in recreation settings reduces shade, screening, and aesthetics, thus compromising positive visitor experiences. Dead trees also pose potential hazards to public safety and require routine hazard tree inspections and maintenance.

Adverse effects on some wildlife species can include the loss of hiding and thermal cover and older tree habitat. Spruce beetle epidemics alter the structure and composition of subalpine forests by decreasing average spruce diameters, tree height, basal area, and age. Although some large-diameter spruce may escape infestation during epidemics, the number of these trees may not sufficiently satisfy management objectives that require the

Figure 4.—*Thousands of acres impacted by spruce beetle in the Western United States and Alaska from 1997 through 2007.*

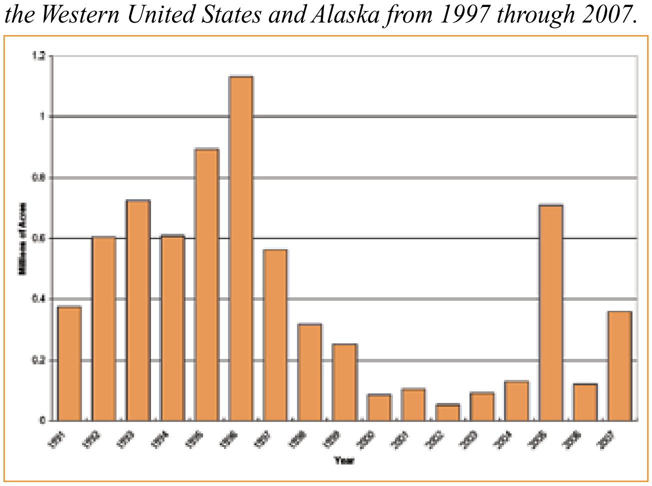


Figure 5.—*Spruce beetle galleries. Photo by Darren Blackford, Forest Service, http://www.bugwood.org.*

retention of larger, green trees for maintaining stand diversity and old growth. Another important consequence of potentially losing a large percentage of mature spruce is the elimination of seed sources that influence species availability and a reduction in genetic diversity. Spruce beetle epidemics also alter the amount, composition, and arrangement of living and dead biomass in various fuel complexes that affect fire behavior.

Management and Treatment Actions

Spruce beetle management strategies include prevention, suppression, and restoration activities. Prevention strategies often use silvicultural practices such as thinning to modify stand conditions favorable to insect and disease agents. To enhance treatment effectiveness, prevention treatments should occur before populations reach unmanageable levels. By increasing stand diversity and resiliency, prevention strategies may help prevent unacceptable losses of valuable spruce resources and maintain or enhance resource objectives.

Suppression strategies are usually implemented when spruce beetle populations increase. Silvicultural treatments include combinations of sanitation and salvage treatments to remove infested, dead, and susceptible host trees as well as directly affecting developing brood through peeling, burning, or bucking infected boles into short lengths. In recreational areas and other high-value sites, insecticide treatments can effectively protect susceptible trees from spruce beetle attack. Trap trees felled before the onset of spruce beetle flight can help capture dispersing adults and are often integrated with other treatments, such as sanitation and baited pheromone traps, to suppress local populations of the insect. An antiaggregation pheromone, 3-methylcyclohex-2-en-1-one, (MCH) has also been used to disrupt aggregation behavior in beetles in the Southwest.

When implemented during the initial stages of an outbreak, suppression activities can reduce population levels and the rate of insect spread. Treatment alternatives associated with suppression, however, are usually limited to smaller landscapes. Because treatments may not sufficiently modify stand conditions, suppression efforts are often short-term treatment strategies. Labor, material cost, mixed land ownerships, access restrictions (i.e., wilderness or roadless designations) and environmental considerations also constrain their use. Until spruce beetle outbreaks subside, the annual removal of infested trees and reapplication of insecticide for high-value sites will require a committed effort for a number of years.

Long-term thinning strategies in spruce are often designed to develop a mixed age-class of host trees by installing small, created openings (10 to 100 acres in size) within the spruce landscape. Although the overstory trees may be susceptible to spruce beetle mortality, the advance natural regeneration as a result of these treatments will ensure lower costs for restoring these sites and maintain spruce on the landscape. Whenever feasible, resource managers should try to encourage a species mix of nonsusceptible hosts to reduce spruce beetle effects. In landscapes where advance spruce regeneration has not occurred, restoration activities include planting trees to restore the spruce component on the affected landscape.

Outlook

Without the implementation of prevention strategies, subalpine forests will continue to experience high levels of spruce-beetle-caused tree mortality, especially under drought conditions. Effects from climate change could have a substantial effect on actual losses, by allowing larvae to mature in 1 year rather than 2, resulting in greater risk for outbreaks.

Long-term losses can be reduced by implementing forest management practices that address stocking conditions of spruce stands, resulting in increased stand diversity and resiliency. Suppression activities, although effective, are short term and can only be applied over small areas.

Western Bark Beetles

Numerous species

Current Conditions

Native bark beetles, no bigger than the head of a match or a grain of rice, are widely recognized as the most important tree mortality agents in western conifers. They can kill vast numbers of trees across landscapes when conditions are favorable. Bark-beetle-caused mortality is one of nature's ways of renewing a forest, but it can be costly from a human perspective. Consequences from bark beetle epidemics can include lost values from timber and property, hazardous dead trees, changes in aesthetics and wildlife habitat, and changes in forest fire behavior. Older, dense stands of trees and recent droughts, combined with warmer temperatures in some areas, have favored bark beetle population increases. Over the past several years, widespread outbreaks of native bark beetles have occurred across the Western United States, from the low-elevation pinyon woodlands of the Southwest to the high-elevation spruce-fir forests (fig. 1). Of particular note is the effect of the mountain pine beetle. In 2007, tree mortality caused by the mountain pine beetle was observed on approximately 4 million acres of the total 6.1 million acres affected by all bark beetle species combined. Table 1 shows the 2007 status of selected bark beetles that have caused significant tree mortality to their respective hosts in recent years.

Historical Trends

In 2007, spruce beetle populations increased again in Alaska. Through the 1990s, the largest spruce beetle epidemic ever recorded in North America affected more than 3.2 million acres in Alaska, including 1.4 million acres on the populated and extensively visited Kenai Peninsula. The spruce beetle has been active in other Western States as well. Strong winds that blew down high-elevation stands of Engelmann spruce created suitable host material that favored the buildup of spruce beetle populations. In the 1990s and 2000s, outbreaks were first noted throughout Utah and then in Colorado and Wyoming (fig. 2). Much of Utah's spruce forests have been killed, and areas of tree mortality continue to increase in Colorado and Wyoming.

During the late 1990s and early 2000s, the Southwest experienced extreme drought and warmer-than-average temperatures. Pinyon pines, although adapted to irregular moisture regimes and shallow soils, began to die in record numbers from pinyon ips and associated twig beetles (fig. 3). The effect was observed in six States, and more than 650,000 acres were affected. Improved moisture conditions by 2004 helped to end the pinyon ips epidemic.

During that same drought period in the Southwest, large areas of ponderosa pine forests in central Arizona were killed by the Arizona five-spined ips and associated bark beetles. Southern California's Angeles, San Bernardino, and Cleveland National Forests and adjacent land had extremely high levels of tree mortality due to a complex of native bark beetles, dense stand

Figure 1.—*Western bark beetle outbreaks, 1997–2007.*

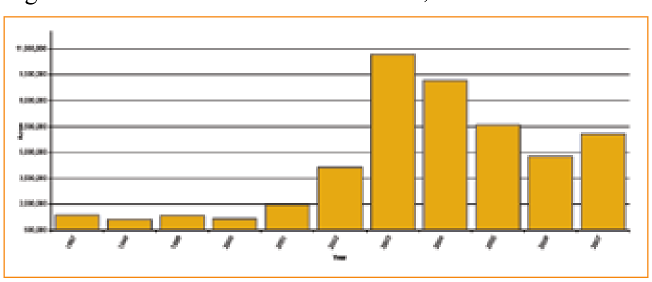


Figure 2.—*Spruce beetle activity on the Routt National Forest in northern Colorado, 2004. Photo by Andy Cadenhead.*

Table 1.—*Trends for selected western bark beetles and acres detected in aerial surveys during 2007.*

Bark beetle	Host	Acres detected with bark beetle activity in 2007*	Trend
Mountain pine beetle, *Dendroctonus ponderosae* Hopkins	Ponderosa pine (*Pinus ponderosa C.* Lawson), lodgepole pine (*P. contorta* Douglas ex Louden), white pines and others (*Pinus* spp.)	4,000,000 acres	Increasing across the West in lodgepole and five-needle pines and locally in ponderosa pine forests. Some areas are seeing host depletion.
Spruce beetle, *Dendroctonus rufipennis* Kirby	Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), white spruce (*P. glauca* [Moench] Voss), Sitka spruce (*P. sitchensis* [Bong.] Carr.)	359,000 acres (includes 150,000 acres in Alaska)	Alaska, Colorado, Utah, Washington, and Wyoming all report large, active spruce beetle outbreaks. Some areas are seeing host depletion.
Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins	Douglas-fir *(Pseudotsuga menziesii)*	287,324 acres	Trend varies regionally. Increasing in the Northwest, Intermountain West, central Rockies, and Southwest. Decreasing in the northern Rockies.
Jeffrey pine beetle, *Dendroctonus jeffreyi* Hopkins	Jeffrey pine *(Pinus jeffreyi* Balf.)	6,800 acres	Increasing on the east side of the Sierra Nevada from the Inyo National Forest north to the Lake Tahoe basin and up through the Modoc National Forest.
Western pine beetle, *Dendroctonus brevicomis* LeConte	Ponderosa pine, Coulter pine (*Pinus coulteri* D. Don)	30,000 acres	Decreased considerably throughout the West from 2006.
Western balsam bark beetle, *Dryocoetes confusus* Swaine	Subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.)	640,000 acres	Ongoing, particularly in the Rocky Mountains.
Fir engraver beetle, *Scolytus ventralis* LeConte	True firs (*Abies* spp.)	440,000 acres	Trend varies. Ongoing in the Southwest and some increase from 2006 in the Pacific Northwest and in northeastern California. Acres affected have declined where moisture conditions have improved.
Pine engraver, *Ips pini* (Say), Arizona five spined ips, *Ips lecontei* Swaine	Ponderosa pine	34,000 acres	Acres affected have declined dramatically since 2003 peak with improved moisture but are up slightly from 2006.
Pinyon ips, *Ips confusus* (LeConte)	Pinyon pine (*Pinus edulis* Engelm.), singleleaf pinyon (*Pinus monophylla* Torr. & Fen.)	20,000 acres	Acres affected have declined dramatically since 2003 peak with improved moisture but are up slightly from 2006.

** The number of dead trees per acre varies.*

conditions, and severe drought. From 2003 through 2004, western pine beetles, Jeffrey pine beetles, and mountain pine beetles all contributed to the dying trees that appeared on the landscape in and around resort communities like Arrowhead Lake (fig. 4). In 2003, massive wildfires driven by Santa Ana winds burned through chaparral, homes, and forested areas in which bark-beetle-killed trees were prevalent. Moisture conditions throughout the Southwestern United States have since improved in many areas and bark beetle activity has decreased.

The mountain pine beetle has been garnering the most media attention recently across the Intermountain West. Increasing levels of mortality have been observed in most western pine species; the most dramatic effect on the landscape is in lodgepole pine forests. Trees on millions of acres across the West have been killed by the mountain pine beetle in recent years. In the Rocky Mountains, the mountain pine beetle is killing lodgepole pine stands at the highest elevations of the cover type. In the northern Rocky Mountains and the Pacific Northwest, high-elevation whitebark pines stands are being killed on sites previously considered to be too cold for serious mountain pine beetle epidemics (fig. 5). In many cases, whitebark pine mortality is due to white pine blister rust predisposing the trees to bark beetle attack. Younger stands in old clearcuts and burns remain green, but some smaller trees are being attacked on the lower bole (fig. 6). Ponderosa pine in the Black Hills is also experiencing an intensifying mountain pine beetle outbreak.

Visitors to Yellowstone National Park will notice old Douglas-fir trees killed by Douglas-fir beetle along the road from Cody, WY, to the east entrance of the park. Douglas-fir beetle outbreaks followed forest fires and drought and peaked in 2005, when more than 670,000 acres were affected across the West (fig. 7). Acres of mortality have been declining, but in 2007,

Figure 3.—*Pinyon pine mortality in 2003 in the Four Corners area. Photo by Tom Eager.*

Figure 4.—*Bark-beetle-killed trees increase the concern in the wildland urban interface about fire danger and hazard trees. Photo by Laura Merrill.*

Figure 5.— *High-elevation whitebark pine killed in Idaho. Photo provided by Carl Jorgensen.*

Figure 6.—*Mature lodgepole pine killed by mountain pine beetles in north central Colorado, 2006. Trees only 5 inches in diameter are being killed by mountain pine beetles and twig beetles. Photo by Sheryl Costello.*

increases in Douglas-fir beetle activity were recorded in the central and southern Rockies, Intermountain West, and the Pacific Northwest. High winds that caused significant blowdown in some areas of northern and northwestern Washington have provided ideal habitat for Douglas-fir beetle populations to build up.

Many areas in the West have more than one bark beetle species active at the same time. On the Shoshone National Forest in northern Wyoming, uniquely pure forest stands of Rocky Mountain Douglas-fir are being killed by the Douglas-fir beetle adjacent to stands of Engelmann spruce being killed by the spruce beetle, and limber and lodgepole pine are being killed by the mountain pine beetle. This scenario has been repeated throughout the West in recent years, in different types of host stands and with different beetle species.

Other notable bark beetle infestations recorded in 2007 include 640,000 acres of western balsam bark beetle activity (430,000 acres in the central Rockies) and 440,000 acres of fir engraver beetle activity (300,000 acres in the Pacific Northwest).

Management and Treatment Actions

Forest management can be used to alter stand conditions to make them less favorable to western bark beetles. Prevention actions to reduce forest susceptibility include reducing stand density by thinning and managing for greater diversity of age-class, size, and species on the landscape. Methods for protecting high-value trees against bark beetle attacks include the application of registered insecticides and the use of attractants and or/and antiattractants (fig. 8). Other tools vary with the bark beetle species and may include sanitation cuts and the use of trap trees. Forest health protection professionals can assist forest land managers with evaluating appropriate management strategies.

Outlook

Vast acres across the western landscape have been and will continue to be affected by bark beetles. The current western bark beetle situation presents many opportunities to prioritize and implement proven forest management practices, evaluate new forest management tools, and study the implications of these large disturbance events. Many bark beetle outbreaks are influenced by weather trends and will abate when temperature and moisture conditions improve; however, stand susceptibility to bark beetles remains high until tree density is reduced. Bark beetle outbreaks triggered by drought or windthrow will continue to expand as long as stand conditions provide suitable host material. According to the National Insect and Disease Risk Map (http://www.fs.fed.us/foresthealth/technology/nidrm.shtml), approximately 22 million acres of western forests are at risk to bark beetle mortality.

Figure 7.—*Douglas-fir beetle-killed trees on the Bighorn National Forest in Wyoming. Photo by Kurt Allen.*

Figure 8.—*Successful use of antiaggregation pheromones to protect high-value campground trees in a Douglas-fir beetle outbreak on the Shoshone National Forest in Wyoming.*

Western Spruce Budworm

Choristoneura occidentalis

Current Conditions and Historical Trends

The western spruce budworm is one of the most economically important native defoliators of western coniferous forests and affects millions of acres during outbreaks (fig. 1). This native insect is found in the Pacific Northwest and in the Rocky Mountains from Canada to southern New Mexico. Although most outbreaks end after a few years, some have lasted for 20 years or longer.

The most recent budworm outbreak collapsed westwide in the early 1990s (fig. 2). Before this collapse, the northern Rocky Mountains had experienced an outbreak lasting more than 30 years. At least one or two outbreaks of shorter duration occurred in other regions.

Since the early 1990s, budworm-caused defoliation has generally remained at relatively low levels until recent years. Exceptions where budworm populations remained relatively high throughout most of the 1990s and early 2000s include the Mt. Adams area in south-central Washington and northern New Mexico. In recent years, defoliation has increased (fig. 3). In 2007, more than 2.2 million acres were defoliated by the western spruce budworm (table 1). Specific areas where defoliation increased in 2007 include central Oregon, north-central Washington, southwest Colorado, and New Mexico. Reported

Figure 1.—*Defoliation by western spruce budworm, Cedar Creek, Okanogan National Forest in Washington. Photo by David McComb, Forest Service, http://www.bugwood.org.*

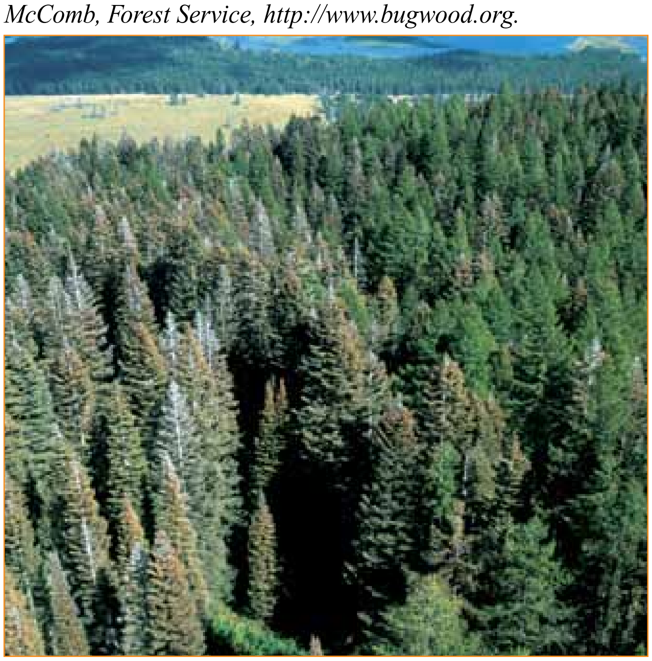
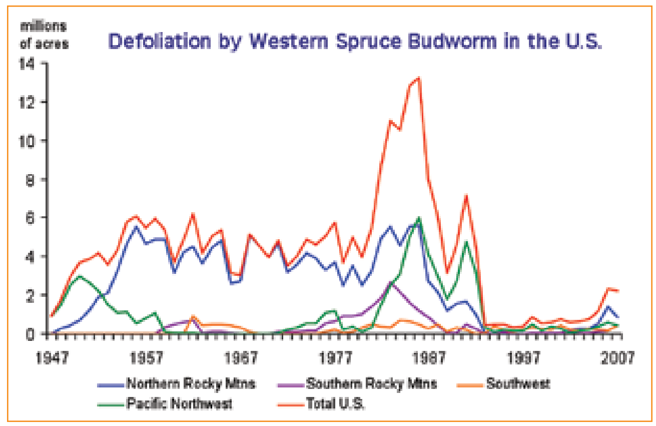
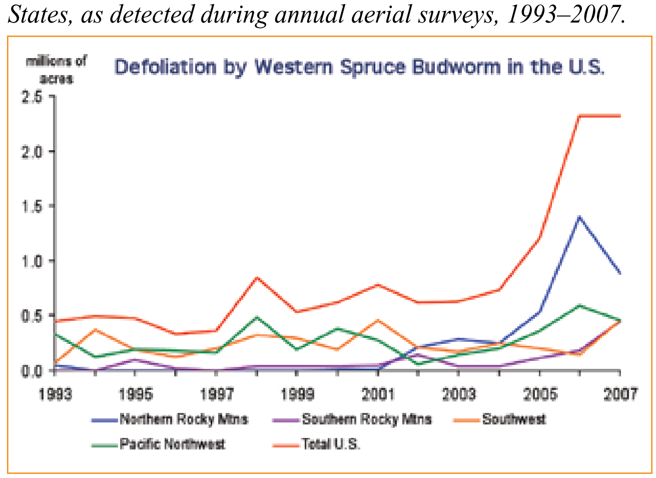


Figure 2.—*Defoliation by western spruce budworm in the United States, as detected during annual aerial surveys, 1947–2007.*



Northern Rocky Mtns = ID, MT, and WY. Pacific Northwest = OR and WA. Southern Rocky Mtns = CO, UT, and NV. Southwest = AZ and NM.
Sources: National Forest Insect and Disease Conditions Reports *and related reports (1947–2006), national FHP Insect and Disease Survey database (2007).*

Figure 3.—*Defoliation by western spruce budworm in the United States, as detected during annual aerial surveys, 1993–2007.*



Northern Rocky Mtns = ID, MT, and WY. Pacific Northwest = OR and WA. Southern Rocky Mtns = CO, UT, and NV. Southwest = AZ and NM.
Sources: National Forest Insect and Disease Conditions Reports *and related reports (1947–2006), national FHP Insect and Disease Survey database (2007).*

Table 1.—*Acres (in thousands) with western spruce budworm defoliation, 2002–07.*

State	2002	2003	2004	2005	2006	2007
Arizona	11.3	24.0	10.7	11.2	2.5	4.8
California	0.0	0.0	0.0	0.0	0.0	0.0
Colorado	131.1	20.0	20.0	71.4	93.7	390.2
Idaho	22.6	204.1	64.1	75.3	254.3	360.5
Montana	52.4	66.0	177.3	453.7	1,142.2	497.2
Nevada						0.7
New Mexico	198.8	143.2	238.2	183.8	142.5	452.2
Oregon	1.9	5.5	6.6	0.3	38.0	98.1
Utah	7.0	14.7	20.0	40.5	88.6	51.4
Washington	57.5	139.9	193.2	363.1	555.7	355.8
Wyoming	134.6	13.3	4.5	6.4	4.4	29.0
Total	**617.2**	**630.7**	**734.6**	**1,205.7**	**2,321.9**	**2,239.9**

defoliation decreased sharply in Montana and Idaho, but that reduction may reflect early aerial detection flights (before peak defoliation) and heavy smoke (obscuring defoliation and limiting detection flights) rather than actual decreases in defoliation.

Damage and Biology

Budworm larvae feed on developing buds and new foliage of Douglas-fir, white fir, grand fir, subalpine fir, Engelmann spruce, and western larch (fig. 4). Although light feeding generally does not cause noticeable effects on host trees, extensive defoliation over several years reduces both tree height growth and diameter growth. Feeding on pollen and seed cones during the early spring can greatly reduce seed production. Repeated defoliation at the tops of trees—where the new foliage favored by budworms is concentrated—can cause those tops to die and sometimes affect tree form and quality; consecutive years of heavy defoliation may also cause tree mortality. Many of the areas most affected by the western spruce budworm are former ponderosa pine and larch stands that are now dominated by host species with multiple canopy levels due to fire suppression and selective harvesting during the course of many decades.

Figure 4.—*Defoliation by western spruce budworm, 1978. Photo by Forest Service, Ogden Archive, http://www.bugwood.org.*

The western spruce budworm has a 1-year life cycle. Eggs are laid in the late summer and hatch after about 10 days. The young larvae spend the winter within silken webs in bark crevices and other protected locations and then emerge the following spring and search for food (fig. 5). When the timing of larval emergence and the growth of new foliage is well synchronized, larval survival is often high. Older larvae feed on new foliage—often spinning loose silken webs around the needles—and then pupate in midsummer. Adults emerge after about 10 days, and within a week or two the mated females lay the eggs of the next generation and then die (fig. 6). Budworm populations are affected by the amount, quality, and distribution of host foliage; weather; and natural enemies (birds, ants, and parasites).

Figure 5.—*Silken nests of western spruce budworm larvae made by webbing needles together. Photo by Kenneth E. Gibson, Forest Service, http://www.bugwood.org.*

Figure 6.—*Adult female with egg mass on needle. Photo by Ladd Livingston, Idaho Department of Lands, http://www.bugwood.org.*

Management and Treatment Actions

In recent years, land managers and the general public throughout the West have become increasingly concerned about defoliation caused by the western spruce budworm. When designing silvicultural prescriptions for susceptible stands, many land managers incorporate guidelines aimed at reducing budworm populations, such as favoring nonhost species and minimizing the number of canopy levels within a stand. Treatments that reduce stocking density or canopy levels may lessen the effects of both the western spruce budworm and the Douglas-fir beetle as well as reduce hazardous fuels.

Extensive direct suppression projects have been conducted on millions of acres in the past. Since 1985, suppression projects using mostly using *Bacillus thuringiensis var kurstaki (Btk)* were applied, but effects on subsequent defoliation were often limited due to problems with formulations, application timing relative to budworm development, inclement weather, or invasion from nearby untreated areas. Since the early 1990s, a few suppression projects have been conducted against the western spruce budworm, primarily in south-central Washington from 1999 to 2001 (about 109,000 acres) and in 2006 (about 5,000 acres); where *Btk* was applied to areas where budworm populations did not collapse in the 1990s. No suppression projects were conducted on State or Federal lands in 2007 and none are planned for 2008.

Outlook

In the absence of unfavorable weather, defoliation by the western spruce budworm is expected to increase during the next several years throughout the Western United States. In the long term, silvicultural treatments aimed at changing stand conditions that favor the insect will be needed to lessen the effect of budworm defoliation.

Hemlock Woolly Adelgid

Adelges tsugae

Current Conditions

The hemlock woolly adelgid, *Adelges tsugae*, is a serious nonnative pest of eastern *(Tsuga canadensis)* and Carolina hemlocks *(T. caroliniana)*. The insect is currently found in 17 Eastern States, from southern Maine to northeastern Georgia and west to eastern Kentucky and Tennessee (fig. 1). On average, hemlock woolly adelgid spreads about 7.77 miles per year. Hemlock woolly adelgid disperses naturally by wind, birds, and artificially on hemlock nursery stock. Infested nursery stock has resulted in isolated infestations in Michigan, Ohio, Vermont, New Hampshire, and Maine. Such isolated infestations are eradicated when detected.

Damage

Hemlock woolly adelgid feeds on stored nutrients in the ray parenchyma cells of the xylem by inserting its stylet bundle through the leaf cushion, where needles attach to the twig. Abundant adelgids soon deplete nutrients vital to shoot growth for the next growing season. Damage occurs over 4 to 10 years and includes stunted shoot growth or no growth at all, graying needles, branch dieback, and eventually tree mortality (fig. 2). Hemlocks of all ages are susceptible, from seedlings to mature trees. Hemlocks die faster in the South, partly due to the lack of sustained cold winter temperatures that periodically reduce hemlock woolly adelgid populations farther north. Other biotic and abiotic stress agents, such as the elongate hemlock scale *(Fiorinia externa)* and drought, hasten tree decline.

The hemlock decline and mortality that began to appear in the late 1980s in Connecticut, New Jersey, and Virginia are now widespread throughout the 17-State infested area. In some locations, adverse effects have been severe (fig. 3). For example, Shenandoah National Park in Virginia has lost more than 90 percent of the hemlocks in about 10 years. The closure of recreational areas such as Sparta Glen, NJ, and the Delaware Water Gap National Recreation Area in Pennsylvania commonly occurs so that dead hazard trees can be removed. Severe hemlock mortality continues to occur in the Great Smoky Mountain region of North Carolina and Tennessee.

The loss of eastern and Carolina hemlocks will have dramatic ecological effects in terrestrial and aquatic habitats, especially in headwater streams. Studies show that healthy hemlock forests moderate temperatures by several degrees in the summer and winter because of their dense canopy. Aquatic insects and fish dependent on cold water temperatures will likely be affected, particularly when they occur in marginally acceptable streams.

Figure 1.—*Distribution of eastern hemlock and hemlock woolly adelgid in the Eastern States.*

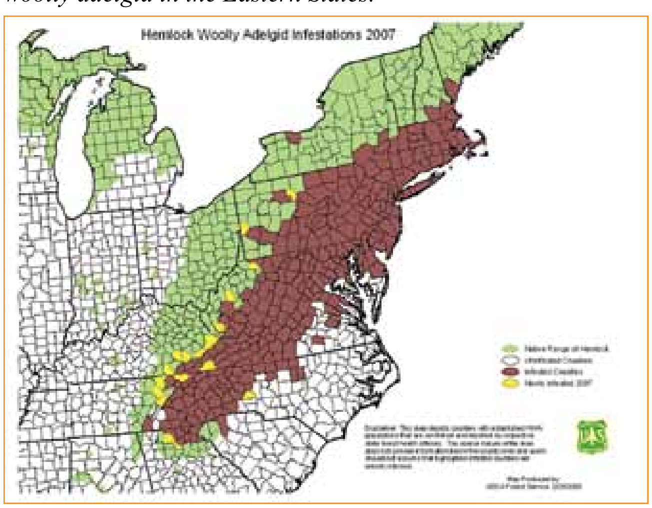


Figure 2.—*Hemlock mortality caused by hemlock woolly adelgid.*

For example, studies in northeastern Pennsylvania have shown that brook trout are three times more likely to occur and four times more abundant in streams draining hemlock forests compared with streams draining hardwood forests. Some birds are common in and apparently dependent on hemlock forests for breeding habitat. Common species in Pennsylvania hemlock forests include the blackburnian warbler, black-throated green warbler, and the blue-headed vireo.

The value of hemlock trees and forests to fish, wildlife, and the ecology of riparian areas likely exceeds the timber value of the wood alone (fig. 4). Hemlocks are highly valued in recreational areas and urban landscapes and are a favorite of homeowners. An assessment of property values in two northern New Jersey residential areas found that healthy hemlocks add to property values. The economic impact on property values attributed to the dead or dying hemlocks was estimated to be $1 million per community.

Biology

Hemlock woolly adelgid has a complex and unusual life cycle. It has two generations per year on hemlock; six life stages (eggs, four nymphal instars, and adults); is parthenogenic (all-female population that does not require sexual reproduction); and feeds primarily in the winter. The overwintering generation (sistens) occurs from July to March; the spring generation (progrediens) occurs from April to June. The generations often overlap for several weeks at the beginning and end of each generation. The first instar, or crawler, is the only mobile stage.

Crawlers typically move out to new feeding locations soon after hatching from eggs and are primarily dispersed by wind and birds. Once settled, the crawlers of the sistens generation enter a resting period (aestivation) during the warmer months from July through early October (fig. 5). Feeding and slow develop-

Figure 3.—*Eastern hemlock mortality in the New Jersey highlands.*

Figure 4.—*Eastern hemlock commonly grows in riparian areas.*

Figure 5.—*Hemlock woolly adelgid aestivating nymphs in July–October.*

ment occur during the winter. The progrediens crawlers quickly settle and begin feeding and developing during the cooler months in the spring (fig. 6).

The sistens generation often experiences significant mortality when winter temperatures are unusually low (sub-zero Fahrenheit) or when temperatures rapidly fluctuate. In New England, this mortality has ranged from 20 to 100 percent.

Figure 6.—*Hemlock woolly adelgid woolly ovisacs visible in October–June.*

Historical Trends

The hemlock woolly adelgid found in eastern North America is not native; recent molecular studies indicate it originated from southern Japan near Osaka. Genotypes of hemlock woolly adelgid found on other hemlock species are known to occur elsewhere in Asia and western North America. Hemlock woolly adelgid is not considered a pest in its native range, where natural enemies and host resistance regulate its densities.

Hemlock woolly adelgid was first reported in eastern North America near Richmond, VA, in the early 1950s and as far north as southeastern Pennsylvania in the 1960s. For more than 30 years, hemlock woolly adelgid was considered an ornamental pest in the urban landscape, one that was easily controlled with insecticides. In 1985, hemlock woolly adelgid was first reported as causing mortality in forest trees in Connecticut and northern New Jersey. With abundant host trees, hemlock woolly adelgid began to flourish and rapidly spread in the Appalachians.

Management and Treatment Actions

Hemlock woolly adelgid is easily controlled in urban areas on small trees or hedges with numerous insecticides, including horticultural oil and insecticidal soap. On large trees, where complete coverage with foliar sprays is impossible, insecticides can be injected into the stem or in the soil near the base of the tree using special equipment (fig. 7). In forests, treatment options are limited because of limited access and the costs of treating individual trees. No treatment is available for large landscapes.

In 2003, the Forest Service and States affected by the insect launched a hemlock woolly adelgid initiative to develop survey and control technology and implement hemlock woolly adelgid management strategies in forests. Establishing a complex of natural enemies may be the only realistic solution for regulating adelgid populations and protecting eastern hemlock forests (fig. 8). To date, the focus has been on predators (no parasites are known for this family of insects) that favor hemlock woolly adelgid and coevolved in Asia and the Pacific Northwest. Several hemlock woolly adelgid fungal pathogens are also being investigated for their potential in managing the insect. In addition to biological control, other research and technology development areas include hemlock woolly adelgid biology, insecticidal management, host resistance, silviculture, survey methods, impact assessments, hemlock woolly adelgid interactions with other hemlock pests, and information transfer.

Figure 7.—*Systemic insecticides can be injected into the soil near the base of trees to control hemlock woolly adelgid.*

Figure 8.—*Natural enemies of hemlock woolly adelgid currently being released for establishment and control of hemlock woolly adelgid. Left to right:* Sasajiscymnus tsugae *(Japan),* Scymnus sinuanodulus *(China), and* Laricobius nigrinus *(western North America).*

Management activities involving both chemical and biological control treatments within the generally infested area are focused primarily in recreational sites or other highly prized areas on public lands due to the large scale of the infested area and the cost of these treatments. Isolated infestations, such as those recently found in Michigan, New Hampshire, Vermont, and Maine, are also considered a priority in an effort to eradicate these populations and slow the spread of hemlock woolly adelgid to noninfested areas. In 2007, State and Federal land managers in 12 States treated more than 54,000 individual hemlock trees (approximately 500 acres in the Northeastern Area and 2,200 acres in the South). In 2007, hemlock woolly adelgid predators were released in 13 States and included approximately 556,000 *Sassajiscymnus tsugae* beetles (551,000 in the South and 5,000 in the Northeastern Area), 50,000 *Laricobius nigrinus* beetles (28,000 in the South and 22,000 in the Northeastern Area), and 7,700 *Scymnus sinuanodulus* beetles (2,500 in the South and 5,200 in the Northeastern Area).

Outlook

In the absence of effective management tools or natural enemies regulating hemlock woolly adelgid populations, the outlook for eastern and Carolina hemlock forests could be grim. Nearly half the eastern hemlock range and virtually all of the range of Carolina hemlock is already infested. The limited distribution of Carolina hemlock in the southern Appalachians offers little chance to escape hemlock woolly adelgid; hemlock could disappear from our forests if no resistance is found and trees are not protected. The future range of eastern hemlock could potentially shrink to only the coldest areas, where hemlock woolly adelgid has limited ability to survive. With the successful development of biological control agents, the rate of spread should be retarded. In the southern range, individual high-value trees and stands can be protected indefinitely by using insecticide treatments, so complete loss of the either hemlock species is unlikely. Ongoing gene conservation efforts also offer assurance that regional hemlock genotypes will be preserved for reestablishment purposes when an effective management solution is found for this pest.

Laurel Wilt Disease/Redbay Ambrosia Beetle

Raffaelea lauricols T.C. Harr., Fraedrich and Aghayeva • *Xyleborus glabratus* Eichhoff

Current Conditions and Historical Trends

In 2002, as part of the Forest Service Early Detection & Rapid Response Pilot Project, three specimens of *Xyleborus glabratus* Eichhoff (redbay ambrosia beetle) (fig. 1) were captured in traps near Port Wentworth, GA. This collection was the first record of this Asian species in North America. Additional traps were placed in the Port Wentworth area to delimit a possible establishment, but no additional catches of this beetle were made. Due to the small number of beetles collected and the location of the traps near warehouses, it was thought that the beetles had likely come directly from solid-wood packing materials and had not become established in native vegetation.

In 2003, however, significant redbay mortality on Hilton Head Island, SC, was reported to the South Carolina Forestry Commission (SCFC). Although drought and water-table fluctuations were initially suspected as the cause, SCFC staff and Forest Service Southern Research Station staff eventually found the redbay ambrosia beetle and an unknown wilt fungus in redbay trees on Hilton Head. The combination of these two species was heavily suspected to be the main cause of redbay death.

The insect that carries the laurel wilt fungus is a very small beetle named the redbay ambrosia beetle, or *Xyleborus glabratus*. This beetle is a member of a group of insects, known as ambrosia beetles, which carry fungi ("ambrosia") necessary for their young to develop.

As the redbay mortality problem spread into Georgia and Florida in 2004 and 2005, the beetle and associated fungus (identified as *Raffaelea lauricols [R. lauricols]* [fig. 2]) were confirmed as the cause. The natural rate of spread of the beetle is estimated at about 20 miles per year; however, greater spread

Figure 1.—*Redbay ambrosia beetle,* Xyleborus glabratus.

Figure 2.—*Discoloration caused by the laurel wilt fungus.*

via humans is a threat if the transport of firewood or infested plants is found to effectively transmit the insect and pathogen complex to new areas. As of 2007, nearly 40 counties in coastal Florida, Georgia, and South Carolina were infested (fig. 3).

Damage

Thus far, only trees and shrubs in the family Lauraceae (laurel family) are known to be affected by laurel wilt. Redbay *(Persea borbonia)* appears to be the most widely affected species (fig. 4). Other species that have developed the disease in the field include sassafras *(Sassafras albidum)*, pondberry *(Lindera melissifolia)*, pondspice *(Litsea aestivalis)*, and avocado *(Persea americana)*.

Trees diseased with laurel wilt initially exhibit drooping leaves with a reddish or purplish discoloration. On redbay, this discoloration may occur in a major portion of the crown at first, but gradually the entire crown wilts. The leaves eventually turn brown and may remain on the branches for up to a year or more. Removal of bark from wilted trees reveals a dark, blackish discoloration in the sapwood that can also be seen in stem cross-section.

Laurel wilt has been very damaging to populations of mature redbays. In forest stands where the disease has been established for several years, nearly all the mature redbays have been killed. Redbay seedling populations, however, appear to be much less affected by the disease, presumably because they are not as readily attacked by the redbay ambrosia beetle. The loss of redbay raises a number ecological concerns related to its use as a food source by a wide variety of birds, insects, and mammals.

Biology

Redbay ambrosia beetles bore into wood, usually recently dead trees, to create tunnels or galleries, where they lay their eggs. While boring into the wood, the beetles infect the tunnels with *Raffaelea lauricols* fungi, the pathogen that causes laurel wilt, which is carried in special pouches (mycangia) in their heads near the base of their mandibles. The larvae that hatch from the eggs live in the tunnels, where they feed on the fungi growing on the wood. We do not fully understand if the beetles attack preferentially at specific locations on trees. Field observations indicate that redbay ambrosia beetles can attack smaller branches in the upper crowns of trees, but we have also found isolated attacks by the beetles on the main stems of apparently healthy trees. Healthy trees are not attacked en masse by the redbay ambrosia beetle, and, often, trees in the initial stages of wilt have evidence of relatively few beetle attacks.

The yeast-like *R. lauricols* fungus is thought to ooze out of the mycangia and enter the water-conducting tissues (xylem) of redbay and other susceptible hosts as beetles bore into trees.

Figure 3.—*Laurel wilt fungus distribution map, as of March 2008.*

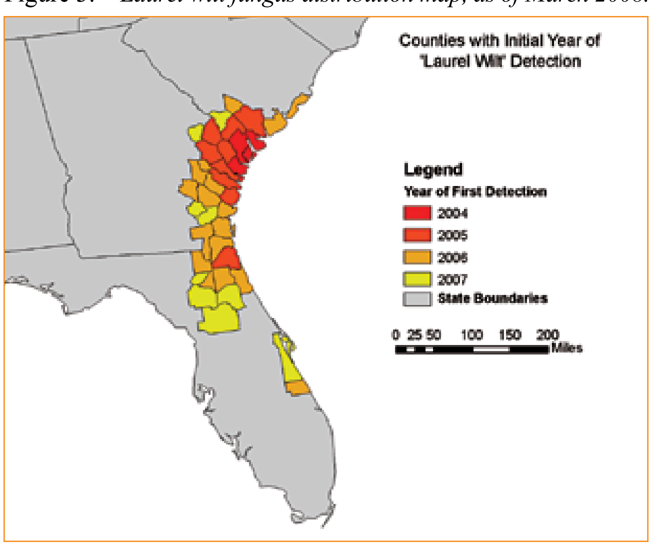


Figure 4.—*Redbay mortality caused by laurel wilt disease.*

Spores of the fungus germinate, and the fungus spreads within the xylem and plugs the tree's xylem, resulting in wilt and eventual mortality.

Management and Treatment Actions

Although effective strategies for managing this beetle and disease have yet to be developed, Forest Health Protection and its cooperators are actively pursuing several possible control options. Sanitation (cutting and destroying infested trees) might delay the spread of the disease in an area if it is pursued very early and diligently, with a focus on new infection centers (as opposed to areas where a large percentage of hosts have already served as brood material and from which ambrosia beetles have already dispersed). Initial sanitation projects have shown limited effectiveness thus far, but future sanitation work should prove more successful under the right circumstances. Systemic fungicides have been shown to effectively protect individual landscape trees; protocols are being developed to make this practice available as a management tool.

Redbay seed conservation efforts are under way through the Forest Service National Seed Laboratory to preserve seed sources for future use. In addition, studies on identifying and using genetically resistant trees have been initiated at the University of Florida.

After exhaustive field studies, an effective lure, Manuka oil, was finally found to be useful for trapping the redbay ambrosia beetle. Using this lure in funnel traps will allow for much quicker detection surveying and population monitoring.

Biological control and development of genetically resistant hosts are among the potential long-term management strategies that could eventually be developed to address laurel wilt.

Outlook

Stopping redbay ambrosia beetle infestation and laurel wilt will not be easy and may not be possible. Unlike many other insects that feed on trees and require hundreds or thousands of individuals to cause serious harm, only one redbay ambrosia beetle is necessary to inoculate and kill a tree. As a result traditional approaches to insect control, such as preventative insecticides, will only reduce the chances of a tree being infected. With large numbers of beetles and enough time, the chance that a beetle will find a place on the tree not covered by insecticide and successfully bore into the wood becomes increasingly likely. In addition, systematic fungicides require periodic reapplication to be affective.

Minimizing the potential of human-aided spread, developing possible biological control agents and genetically resistant hosts, and using systemic fungicides in landscape settings appear to be the most feasible options for controlling or limiting the effects of the redbay ambrosia beetle and laurel wilt disease. For all intents and purposes, however, the problem is likely to spread throughout the entire redbay range, killing most of these trees. Just how severe the effects on other hosts (sassafras, avocado, etc.) will be remains to be seen.

Spruce Budworm

Choristoneura fumiferana Clemens

Current Conditions

In 2007, spruce budworm populations remained low in Maine. The number of insects caught in pheromone traps increased on the northwestern border of the State, but increased monitoring yielded no larval activity or defoliation observed during field surveys. No significant defoliation was observed in New York, and pheromone trap counts were generally low to moderate. No damage was detected in Vermont. The most recent spruce budworm outbreak in the Lake States began in 2005, and the acreage affected has increased over the past 2 years. The outbreak is located largely in central St. Louis County, MN, the Upper Peninsula of Michigan, and northern Wisconsin. Balsam fir top kill and mortality are beginning to occur.

In Alaska, the current outbreak began in 2002 and peaked in 2004. This outbreak covered far less acreage than did the previous outbreak, which peaked in the mid-1990s. Defoliation of spruce continues to be heavily concentrated in the hills around Fairbanks, particularly along the Nenana Ridge. In 2007, the area of mapped spruce budworm defoliation and number of adult captures were down from levels recorded in 2006 and 2004 (figs. 1 through 3).

Figure 1.—*Alaska 1:250K quads where spruce budworm was reported, 2007.*

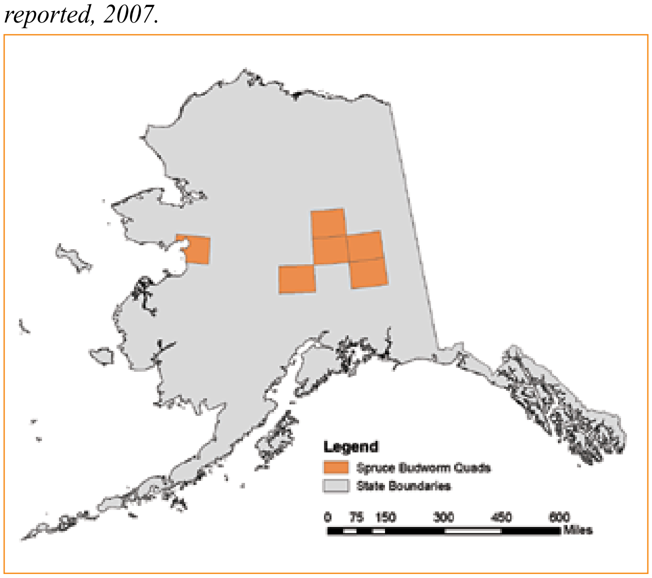
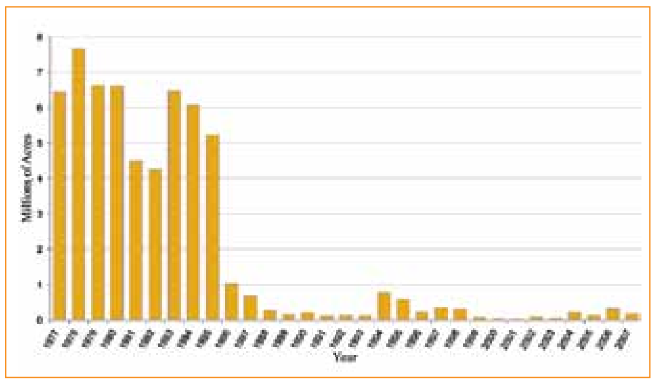


Figure 2.—*Lower 48 counties where spruce budworm was reported, 2007.*

Figure 3.—*Spruce budworm defoliation in the Eastern United States, 1977–2007.*



Biology

Balsam fir is the species most severely damaged by the native spruce budworm in the Eastern United States. White, red, and black spruce are also suitable host trees and some feeding may occur on tamarack, pine, and hemlock. Spruce mixed with balsam fir is more likely to suffer budworm damage than spruce in pure stands.

Early in an epidemic, defoliation is usually most noticeable in the top portion of the crown (fig. 4). After several years of heavy defoliation, the forest turns gray as dead tops become conspicuous. Depending on the general vigor of the host, individual trees may die after multiple years of heavy defoliation (fig. 5).

The spruce budworm has one generation per year. The female moth lays eggs (fig. 6) on the flat undersurface of balsam fir or spruce needles, generally within 3 inches of the buds or defoliated area. The spruce budworm overwinters as larvae, the damaging insect stage (fig. 7). In spring, the early emerging larvae feed on staminate flower buds and grow rapidly. The larvae migrate to the end of a twig and bore into needles or expanding vegetative buds. The new foliage is then eaten. When the larva is in the fifth instar, it begins tying the tips of twigs together with silk, forming a small nest where it will pupate.

The spruce budworm is a favored food of the Cape May Warbler, which is therefore closely associated with its host plant, black spruce. This bird, and the Tennessee and Bay-breasted Warblers, which also have a preference for the insect, lay more eggs and are more numerous in years of spruce budworm abundance.

Figure 4.—*Top defoliation by spruce budworm.*

Figure 5.—*Balsam fir killed by spruce budworm.*

Figure 6.—*Adult moth and egg masses of spruce budworm.*

Figure 7.—*Larva and pupa of spruce budworm.*

Historical Trends

The spruce budworm is one of the most destructive native insects in the northern spruce and fir forests of the Eastern United States and Canada. Periodic outbreaks of the spruce budworm are a part of the natural cycle of events associated with the maturing of balsam fir. Paleoecological studies suggest that spruce budworm outbreaks have occurred in eastern North America for thousands of years.

The first recorded spruce budworm outbreak in the United States occurred in Maine, circa 1807. Another outbreak followed in 1878. Since 1909, waves of budworm outbreaks have occurred throughout the Eastern United States and Canada. Spruce budworm defoliation has been recorded periodically by the Northern Area, St. Paul Field Office, aerial surveys since the mid-1950s. The last large-scale outbreak occurred from the mid-1980s to the early 1990s.

The spruce budworm can be found from Virginia to Newfoundland and west across Canada throughout the boreal forest region to Fairbanks, AK.

Management and Treatment Actions

Spruce budworm outbreaks develop and gain momentum in the Northeastern United States only when the forest has a large proportion of mature and overmature balsam fir. Management practices, including greater harvesting of balsam fir, regulating age-classes to prevent the occurrence of overmature balsam fir over large areas, and favoring or planting less-susceptible species such as spruce, make conditions generally unfavorable to the budworm and may materially reduce the risk of an outbreak. One way to prevent infestations in young trees growing under a mature balsam fir and white spruce overstory is to remove the overstory trees and replant the stand with nonsusceptible species such as white pine. Insecticides can be applied to adjoining mature stands to protect adjacent young stands.

Direct control by the application of chemical or biological insecticides is the most economical way to prevent widespread damage caused by heavy budworm populations. Aerial spraying of the bacterial pathogen *Bacillus thuringiensis (B.t.)* and registered insecticides satisfactorily controls larvae and, when applied against early instars, provides effective foliage protection. Among the registered insecticides are carbaryl, trichlorfon, acephate, Malathion, and fenitrothion. Several insecticides are registered for use under the supervision of licensed applicators. *B.t.* and fenitrothion are registered for use only in the Eastern United States. Over the past few years, spruce budworm population levels have been low and this treatment has not been used, except in isolated instances.

Both field tests of the pathogen and operational applications of *B.t.* effectively controlled moderate populations of less than 50 larvae per 18-inch branch. Despite the success of the pathogen in these instances, in extreme populations of more than 8,000 egg masses per 100 square feet of foliage, *B.t.* did not protect foliage or reduce the budworm population significantly.

In 1948, a polyhedral virus disease was reportedly found in budworm populations. At least four viruses are known to be endemic in North America (nucleopolyhedrosis, granulosis, cyloptasmic polyhedrosis, and entomopox). The current cost of applying a virus such as the nucleopolyhedrosis virus is about 30 times as expensive as applying chemical insecticides.

A microsporidian disease, *Perezia fumiferanae* Thomson, slows the rate of budworm development during the larval and pupal stages. The lifespan of infected adults is shortened. Females are affected more than males are. To date, neither viruses nor fungi have provided sufficient control in field trials.

Outlook

According to a common theory popularized in the 1970s, periodic outbreaks (40 to 60 years) of the spruce budworm are a part of the natural cycle of events associated with the maturing of balsam fir. Currently, the outbreak status is low and the last major outbreak occurred in the mid-1980s. Based on this theory and the current status, another major outbreak could occur in 20 to 40 years.

Sirex Woodwasp

Sirex noctilio F.

Current Conditions and Historical Trends

The sirex woodwasp (Hymenoptera: Siricidae) has been found in New York, Pennsylvania, Vermont, Michigan, and southern Ontario, Canada. The insect was first detected in Fulton, NY, in a trap deployed in 2004 to monitor for exotic bark beetles. Widespread delimitation efforts in 2005, 2006, and 2007 detected the sirex woodwasp further out from the initial detection point (fig. 1). The sirex woodwasp has been one of the most common species of exotic woodwasps associated with solid-wood packing materials intercepted in U.S. ports but had never been found outside the port environs until 2004.

Native to Europe, Asia, and North Africa, the insect has been accidentally introduced into a number of Southern Hemisphere countries, including New Zealand, Australia, Uruguay, Argentina, Brazil, Chile, and South Africa (fig. 2). Considered a secondary pest in its native range, it primarily attacks pines (e.g., Scots *[Pinus sylvestris]*, Austrian *[P. nigra]*, and maritime *[P. pinaster]*). The insect has become a serious pest in plantations of North American pine species grown in the Southern Hemisphere.

Trapping surveys in the summer and fall of 2005 yielded positive confirmation of the insect in five counties around Oswego, NY. During that same time period, the sirex woodwasp was also found along Lake Ontario and the St. Lawrence River in southern Ontario, Canada. Delimitation surveys were increased in 2006 to cover the area within a 150-mile radius of Oswego. This area included much of New York and parts of Pennsylvania and Vermont. Surveys were also conducted at a lesser intensity in other Eastern States and high-risk areas. In 2007, delimitation surveys continued; they included more areas of Pennsylvania and expanded to several Midwestern States and high-risk ports of entry. For the first time, trap trees were used in parts of the survey area as a new detection tool. By the end of the 2007 field season, the sirex woodwasp had been confirmed in 37 counties in 4 States (fig. 3).

Figure 1.—*Current distribution of* Sirex noctilio *in the United States.*

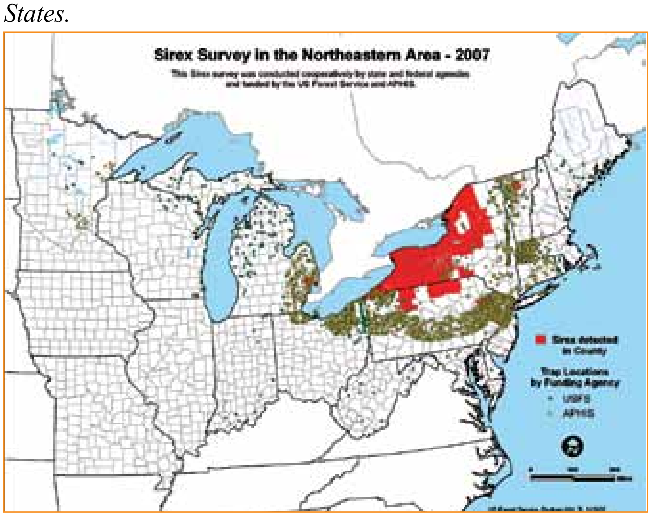
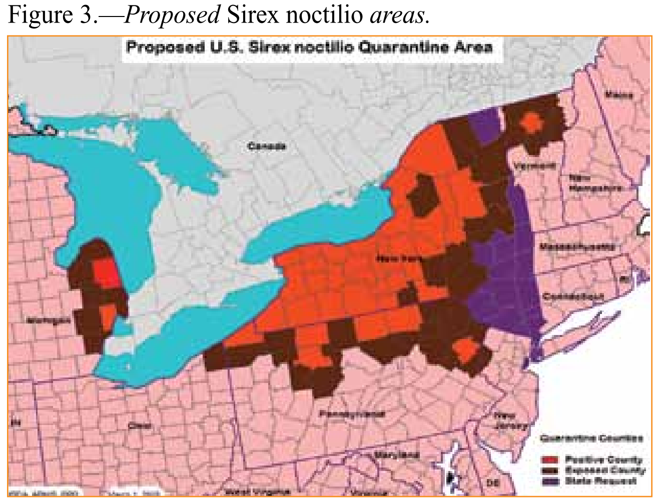


Figure 2.—*Global distribution of* Sirex noctilio.

Figure 3.—*Proposed* Sirex noctilio *areas.*

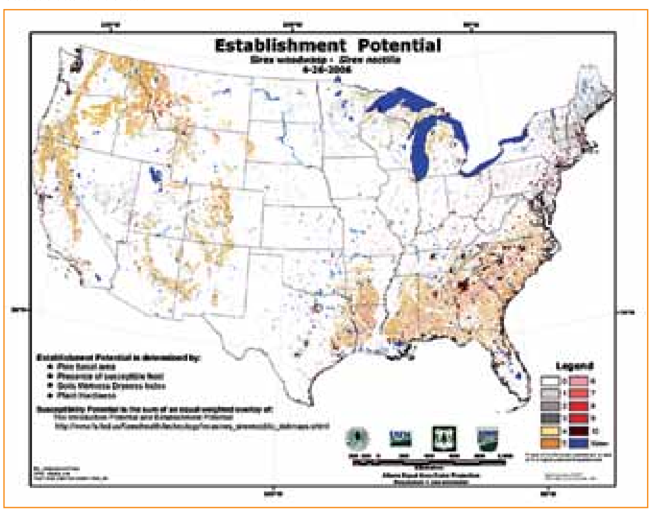


Damage

All North American commercial pine species are susceptible to the sirex woodwasp. The pine-growing areas of the Southeastern United States and western North America are at particular risk (fig. 4). Although little is known about sirex woodwasp colonization behavior in the insect's native Eurasian range, much work has been documented for Southern Hemisphere countries where the insect has been introduced into nonnative commercial pine plantations of North American species. In these stands, the sirex woodwasp is reported to focus initial attacks on suppressed or damaged trees in a stand. As the insect attacks suppressed trees and populations build, more vigorous trees are successfully colonized. Tree mortality up to 80 percent has been reported in some stands.

As of 2007, preliminary data suggest that, in North America, sirex woodwasp is colonizing smaller diameter, weakened trees in a stand. Some larger, apparently healthy trees are sometimes attacked as well, but much less frequently. So far, successful sirex woodwasp reproduction has been documented in red, white, jack, and Scots pine in North America.

Figure 4.—*Areas of high potential for* Sirex noctilio *establishment.*



Biology

Unlike native woodwasps, the sirex woodwasp can successfully colonize living trees. Females select a host tree, drill through the bark and phloem, and oviposit eggs directly into the sapwood. At the same time, a toxic mucus and symbiotic fungus *(Amylostereum areolatum)* are also deposited into trees. The toxic mucus helps compromise the tree's defenses, while the fungus becomes established and dries out the sapwood. This fungus serves as the sole source of larval nutrition. The number of larval instar varies from 6 to 12, and the larval stage generally lasts 10 to 11 months. Mature larvae pupate close to the bark surface, and adults emerge about 3 weeks later. Adult emergence occurs from July through September, with peak emergence during late July (figs. 5 and 6). In the areas of the United States and Canada where the sirex woodwasp had been detected, it produces a single generation per year.

Figure 5.—*Adult* Sirex noctilio.

Figure 6.—*Exit holes from* Sirex noctilio.

Management and Treatment Actions

In countries where the sirex woodwasp has been introduced, an integrated pest management approach has been employed consisting of silvicultural treatments to reduce the susceptibility of pine stands and the application of a nematode *(Beddingia siricidicola)* and parasites for biological control. Silvicultural treatments increase tree vigor and increase individual tree resistance to the insect. The application of biocontrol agents has helped keep sirex woodwasp populations below damaging levels.

Current emphasis in the United States and Canada is focusing on the following five objectives: (1) determining the extent of the sirex woodwasp distribution through extensive ground surveys; (2) developing biological control tools, including the nematode and native parasites; (3) refining traps and lures for surveying; (4) evaluating silvicultural treatments; and (5) developing regulatory and quarantine approaches. No treatments to contain or eradicate the sirex woodwasp are being contemplated at this time.

Outlook

The sirex woodwasp is a highly invasive species, and its introduction into North America and further spread could cause significant mortality to native and planted pines in some regions. The insect is a strong flier and can readily spread to uninfested areas.

In the Northeastern United States, landscape heterogeneity and tree species diversity is relatively high and could help minimize forest damage caused by sirex woodwasp. As this species spreads south and west, however, it will encounter more uniform landscapes with larger blocks of pure pine stands. Given these landscapes and forests, the sirex woodwasp may behave more as it does in the Southern Hemisphere and cause high tree mortality. Currently, the wasp is not causing extensive mortality in the United States.

In the meantime, the ongoing efforts to monitor the spread of the sirex woodwasp, evaluate and implement silvicultural treatments, and release biocontrol agents in newly infested areas will likely be the long-term actions needed to effectively manage this insect.

Dwarf Mistletoes

Arceuthobium spp.

Biology and Effects

Dwarf mistletoes are parasitic plants that grow on pines and other conifers, slowing and distorting growth and leading to early death. Infection by these plants is the most common and economically damaging forest disease in most of the Western States. Eighteen native species of dwarf mistletoe are found in the Western United States, each generally affecting one type of tree. Trees most affected include ponderosa pine, Douglas-fir, lodgepole pine, true fir, hemlock, and western larch. One species of dwarf mistletoe affects spruce in the Northeast and Lake States.

Depending on location, ground surveys have shown that about 15 percent to more than 50 percent of conifer stands throughout the West have some level of infestation (table 1). Dwarf mistletoe spreads by means of explosive seeds, which can fly up to about 40 ft (fig. 1). Spread occurs from tree to tree and within the crowns of previously infected trees. Because of its rather unusual means of spread, the distribution of dwarf mistletoe in a forest is usually quite patchy. Infected areas vary in size from a few trees to hundreds of acres. The spread of the disease is slow because it takes 6 to 10 years for new mistletoe

Figure 1.—*Parasitic mistletoe seeds.*

Table 1.—*Acres (in thousands) in the West Affected by Dwarf Mistletoes.*[a, b]

State (survey year)	National Forest System	Other Federal	State and private	Total
Alaska[c]				3,400.0
Arizona (85-89)	1,174.0	674.0	25.0	1,873.0
California (05)	2,536.4	76.7	2,123.1	4,736.2
Colorado (06)				815.9
Idaho - North (70-80)[d]	478.0	10.0	244.0	732.0
Idaho - South (94)[d]				2,600.0
Montana (70-80)	1,694.0	123.0	600.0	2,417.0
New Mexico (97)	1,144.0	348.0	581.0	2,073.0
Nevada (94)				49.0
Oregon (67)				3,940.0
Utah (94)				410.0
Washington (97)				5,678.3
Wyoming (06)				637.3
Total	**7,026.4**	**1,231.7**	**3,573.1**	**29,361.7**

[a] *Data last updated in 2006 for some States.*
[b] *For some States, only total affected acres is available.*
[c] *Commercial acreage only in Alaska.*
[d] *Idaho-North is in Region 1 and Idaho-South is in Region 4.*

plants to produce seed. On average, horizontal spread through a forest is only 1 to 2 feet per year; therefore, the overall incidence changes little from year to year. Because this disease tends to be long lived and persistent, it is best described as a chronic condition rather than an outbreak or epidemic.

All ages and sizes of trees can become infected. Generally, after a tree becomes infected, the disease slowly intensifies until the tree dies. Nevertheless, most infected trees can survive for several decades, with gradual decline in growth and vigor (fig. 2). Trees infected at a young age become stunted and deformed and rarely, if ever, become large trees. Losses in productivity from dwarf mistletoes have been estimated at more than 400 million cubic feet of wood annually. Although it is more difficult to quantify, infestation also tends to increase forest flammability. Over time, this disease can have a profound effect on forest structure and composition.

Because their effects are very gradual and less dramatic than those of many insects, dwarf mistletoes often are not managed intensively, if at all (fig. 3). Moreover, it turns out that these parasites—like most other native diseases and insects—have roles in the ecology of the forest and are beneficial to some wildlife.

Figure 2.—*Decline of host trees is gradual and may take decades before mortality occurs.*

Figure 3.—*Dwarf mistletoe in Douglas-fir. Often these trees are unmanaged, perpetuating the spread of this parasite.*

Historical Trends

It is generally agreed that a century or more of fire suppression and exclusion has resulted in increases in the abundance of dwarf mistletoe in many parts of the West. Fire has long been recognized as an important natural control of this disease. Following intense, stand-replacement fires, trees generally return to the burned areas well in advance of the mistletoe. The effects of low-intensity fire are more complex, but these often have a partial "sanitizing" effect within infested areas. In addition to these direct-controlling effects, frequent fire keeps forests more open and park-like. Fire exclusion has resulted in denser forests, with fewer openings to limit the spread of mistletoe. Poor logging practices in the past have also contributed to the mistletoe severity found on some sites today. Conversely, disease incidence *may* have been reduced in areas where clearcutting has been used extensively, particularly the lodgepole pine forests of the interior West.

Management and Outlook

Until late in the 20th century, management guidelines for dwarf mistletoes primarily addressed the sustained economic production of timber. In recent years, additional considerations have influenced management on public lands. Some previously recommended practices (even-aged forest management, clearcutting) have needed modification to accommodate a broader array of concerns and objectives. Today, management continues to focus on cultural methods, primarily the removal of infected trees, but with increasing interest in the use of fire. Opportunities for chemical, biological, and genetic control of dwarf mistletoe have been, and continue to be, investigated, but currently these options have limited practical use.

The management of dwarf mistletoe has always presented special challenges. On the one hand, the disease would seem relatively easy to control because it spreads slowly and dies when infected trees are cut. Not all infections are visible, however; moreover, following selective cutting and thinning, the remaining mistletoe tends to be stimulated by more open conditions. Without complete stand replacement, frequent treatments may be needed to keep the disease at non-damaging levels, at least in areas with extensive infection. Most lightly and moderately infested stands can be treated to satisfy a broad array of objectives by removing as much mistletoe as possible without sacrificing the best trees. Managing trees not susceptible to the type of mistletoe present can also be used to advantage on some sites.

A variety of cutting methods, in combination with the prudent use of fire, appears to be the best strategy for managing this disease at the landscape level. Some infested areas might best be deferred from mechanical treatment—not only because they are more difficult to manage than areas without the disease but also to maintain the unique wildlife habitat provided by infected trees and stands. In more actively managed areas, disease reduction can occur in conjunction with scheduled thinnings and fuels reduction treatments. The increased use of fire—both management-ignited prescribed burning and wildland fire use—would help to keep this damaging and persistent disease in check.

Asian Longhorned Beetle

Anoplophora glabripennis Motschulsky

Current Conditions

The Asian longhorned beetle *(Coleoptera: Cerambycidae)* was first reported to be infesting trees in North America in Brooklyn and Amityville, NY, in 1996. Subsequent infestations were detected in Chicago, IL, in 1998, in Jersey City, NJ, in 2002, in Toronto, Canada, in 2003, and in Carteret, NJ, in 2004. In 2007, the insect was detected in three trees on Staten Island, NY, and on Prall's Island, an uninhabited island located between Linden, NJ, and Staten Island. Prall's Island is about a half mile from the State-imposed quarantine area in New Jersey. This Asian native pest of hardwood trees is thought to have entered the United States in the 1980s, probably as a stowaway in solid-wood packing material. The natural spread of the Asian longhorned beetle is greatly supplemented by artificial or human-aided movement, such as through yard waste and on firewood and logs. The infestation in Amityville resulted from moving green waste from Brooklyn, NY. State and Federal quarantines have been implemented New York, Illinois, and New Jersey to prevent moving infested material.

Native to China and Korea, where the insect kills hardwood trees in roadside plantings, shelterbelts, and plantations, the Asian longhorned beetle has been accidentally introduced into other countries, including Germany, Austria, Italy, France, and Canada, presumably through infested solid-wood packing material. The beetle's extensive host range makes it a considerable threat when introduced (fig. 1).

Damage

In North America, suitable hosts of the Asian longhorned beetle include maples (*Acer* spp.), willow, horsechestnut, elm, birch, poplar, mimosa, hackberry, ash, London plane, and mountain ash. Asian longhorned beetle host trees occur commonly in urban landscapes along streets and parking lots, in yards and parks, and around commercial buildings. Maple is highly preferred by the Asian longhorned beetle and is a major component of northeastern hardwood forests. Typical symptoms of infested trees include oval oviposition sites, 3/8-inch exit holes, frass, oozing sap, midrib feeding on leaves, and, eventually, tree mortality (fig. 2). Heavily infested trees often exhibit woodpecker feeding damage and always exhibit the characteristic round exit holes created by adults as they emerge from infested trees.

Figure 1.—*Forests susceptible to Asian longhorned beetle occur largely in the northeastern and western parts of the United States; however, host trees have been extensively planted in communities and urban areas throughout the country.*

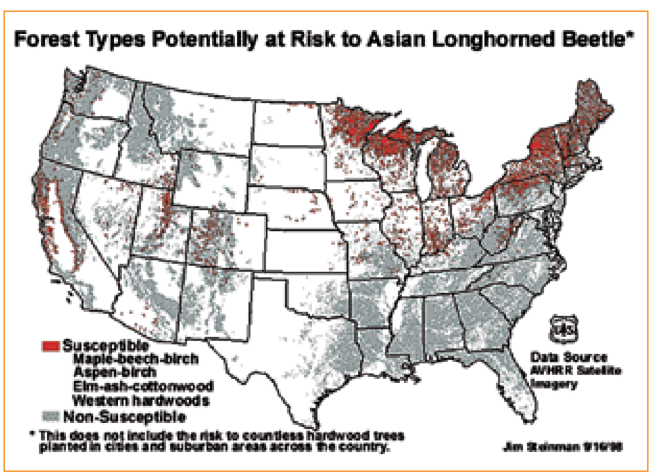


Figure 2.—*Oozing sap. In the summer, sap may flow from egg niches, especially on maple trees, as the Asian longhorned beetle larvae feed inside the tree.*

Tree decline and dieback in the crown occur over time as the insects bore through the sapwood and heartwood, disrupting water and nutrient transport (fig. 3). Tree mortality occurs after repeated infestation over several years. A 2001 Forest Service study estimated that potential national effects of the Asian longhorned beetle could be a loss of about 35 percent of the canopy cover, or 1.2 billion trees.

Biology

The Asian longhorned beetle has one generation per year. Adult beetles emerge from hardwood trees throughout the summer and early fall (fig. 4). Adults are most active on warm, sunny days. They usually stay on the trees from which they emerged, or they may disperse short distances to a new host tree to feed and reproduce. Each female is capable of laying up to 160 eggs. The eggs hatch in 10 to 15 days, and the larvae tunnel under the bark and into the wood, where they eventually pupate. The adults emerge from their pupation sites by boring a tunnel in the wood and creating the characteristic round exit hole in the tree (fig. 5).

Figure 3.—*Asian longhorned beetle larvae tunnel extensively through the heartwood of trees and disrupt the flow of water and nutrients in the process. Trees slowly decline and eventually die.*

Figure 4.—*Adult beetles ¾ to 1 ¼ inch long, with jet-black body and mottled white spots on the back. The long antennae are 1 ½ to 2 ½ times the body length with distinctive black and white bands on each segment. The feet have a bluish tinge. Female adults are larger than the males but have shorter antennae relative to their body length.*

Figure 5.—*Asian longhorned beetle adults chew a 3/8-inch-diameter round hole on trunks and branches as they emerge from trees.*

Damage by an individual larva is minimal, but, as a tree is repeatedly attacked, the population buildup quickly overwhelms the tree's ability to defend itself. Tree decline and death generally take multiple years and can occur by girdling or structural failure. Adult Asian longhorned beetles are poor flyers, so infestations tend to be localized unless artificially moved by humans. It often takes a few years for Asian longhorned beetle populations to increase and tree symptoms to become apparent. These trends may explain why new infestations are often not detected for several years.

Historical Trends

The Asian longhorned beetle is a serious pest in its native range in Asia, infesting many hardwood trees in China and Korea planted as wind breaks and street trees. Asian longhorned beetle-infested material is often used as cheap solid-wood packing material for exporting products worldwide. It is believed that the initial infestation of the Asian longhorned beetle in the United States in Brooklyn, NY, was related to importing plumbing supplies in the 1980s. Infestations in Illinois and New Jersey also have been linked to the solid-wood packing material pathway. The Asian longhorned beetle has been detected on solid-wood packing material in many different shipments in warehouses across the country. In 2005, three adult beetles were detected in the warehouse of a stone importer in Sacramento, CA, prompting massive survey and regulatory action.

In 2007, surveys found no new Asian longhorned beetle infestations in New Jersey or Illinois; however, a new, isolated infestation totaling 44 trees was detected on Prall's Island and neighboring Staten Island. The Forest Service provided certified chainsaw operators to the Asian longhorned beetle program to help cut down the infested and high-risk host trees on Prall's Island. An additional 55 infested trees were also detected in the core infestation in Brooklyn and Queens, NY. A survey around the Asian longhorned beetle warehouse detection in Sacramento found no additional presence of the insect in the area.

Management and Treatment Actions

Since 1996, the Animal and Plant Health Inspection Service (APHIS), Forest Service, and State plant pest regulatory officials have implemented a strategy to minimize the Asian longhorned beetle's spread and eradicate the insect. Tactics included aggressive surveying, quarantine, preventative chemical treatments, identifying and regulating pathways of artificial spread, developing compliance agreements with businesses to facilitate commerce, and eradicating infestations by felling and destroying infested and high-risk trees. A comprehensive public communication and outreach program to raise awareness about Asian longhorned beetle has also been an integral part of the early detection effort. In 2007, the Forest Service coordinated with the Asian longhorned beetle program on public outreach and communications strategies and provided funding to continue the operation of an Asian longhorned beetle hotline by Trees New York, a nongovernmental organization.

Early on in the Asian longhorned beetle program, it became apparent that "within-crown" surveys using tree climbers and personnel in bucket trucks were much more effective than ground surveys. Through an interagency agreement with APHIS, the Forest Service provided certified tree climbers (smokejumpers) to the Asian longhorned beetle program for survey duty in Illinois, New York, New Jersey, and California (fig. 6).

By the end of 2007, more than 42,000 infested and high-risk host trees had been removed and destroyed since the Asian longhorned beetle was detected in the various project areas. In 2007, more than 100,000 high-risk host trees were treated with insecticides in Illinois, New Jersey, and New York (fig. 7).

The Forest Service continued to facilitate replanting in the affected areas, and, by the end of 2007, more than 13,000 new trees had been replanted since the Asian longhorned beetle program began.

Figure 6.—A *Forest Service tree climber prepares to examine the crown of a host tree for signs of Asian longhorned beetle infestation.*

Figure 7.—*More than 100,000 trees were treated with insecticides in 2007, either through trunk injection (below) or soil injection methods to protect trees.*

Outlook

The outlook for Asian longhorned beetle eradication in North America is better than for most invasive species. Asian longhorned beetle infestations are slow to develop and spread. A recent Government Accountability Office report found that, compared with other major invasive forest pests, the Asian longhorned beetle will most likely be eradicated in the three States that have infestations. The signs of infestation are easily noticed, making the public a key player in the early detection of infestations. The eradication efforts in Illinois, Jersey City, NJ, and Islip, NY, have been successful to date. The timeline for eradication in New York City has been extended to 2020 based on the recent discovery of infested trees in 2007. An eradication declaration of the Asian longhorned beetle in the Chicago metropolitan area is likely in 2008.

White Pine Blister Rust

Cronartium ribicola

Adapted and excerpted from Samman, S.; Schwandt, J.; Wilson, J. 2003. Managing for healthy white pine ecosystems in the United States to reduce impacts of white pine blister rust. Forest Service Report R1-03-118. Missoula, MT: U.S. Department of Agriculture, Forest Service. 10 p. Goheen, E.; Goheen, D. 2007. After a century, white pine blister rust still a factor. Portland, OR: Society of American Foresters.

Current Conditions

Around the turn of the 20th century, white pine blister rust, a fungus native to Asia, was introduced to the eastern and western coasts of North America on infected white pine nursery stock from Europe. The pathogen has slowly spread to 38 States across the country, causing substantial damage and mortality to eight of the nine native white pine species. The eight species known to be infected by the fungus include eastern white pine, western white pine, sugar pine, whitebark pine, limber pine, southwestern white pine, Rocky Mountain bristlecone pine, and foxtail pine. Great Basin bristlecone pine is the only native white pine species not known to be infected by white pine blister rust. There is great ecological concern for the high-elevation whitebark pine and bristlecone pines as the disease begins to infect those species (fig. 1). These high-elevation species are found on harsh sites and any mortality caused by the rust will make restoration difficult.

Figure 1.—*High-elevation foxtail pine. Photo from Forest Service.*

Damage

White pine blister rust, *Cronartium ribicola (C. ribicola)*, causes the formation of resinous lesions, eventually girdling the host at the point of infection (fig. 2). This girdling results in branch and top mortality of larger trees and the death of smaller trees that suffer main stem infections. Large trees that are not killed immediately by the fungus itself may be predisposed to infestation by the mountain pine beetle as a result of the rust infection.

Figure 2.—*Resinous lesions on western white pine. Photo from Dorena Tree Improvement Center, Forest Service.*

The effects of blister rust go far beyond the loss of individual trees; a cascading effect on associated plant and animal communities occurs throughout the affected ecosystems. Seedlings and intermediate age-classes that have been rapidly killed by blister rust combined with a lack of regeneration opportunities threaten to eliminate the white pines as functioning components of forest ecosystems. This outcome has significant negative effects on watershed health and wildlife habitat and the ability of these ecosystems to respond to changes brought on by fire, insects, pathogens, and other agents of changes. For example, western white pine was once the dominant species on 5 million acres in the Inland Northwest. Today, less than 10 percent of that area has a significant western white pine component. Where western white pines have been killed by blister rust or removed to preempt blister rust losses, the forest becomes dominated primarily by Douglas-fir, grand-fir, western red cedar, and hemlock, species that are more susceptible to root diseases, bark beetles, windthrow, and drought. The increased mortality caused by these agents, along with changes in species and stand structures and subsequent fuel buildup, has led to a pattern of increased risk of catastrophic fire. The loss of white pine also means fewer old-growth trees and less large wood for fish, wildlife habitat, and nutrient cycling.

Biology

White pine blister rust has a complex life cycle involving five spore types and requiring both five-needle pines and *Ribes* hosts for its successful completion. Basidiospores of the rust infest pine hosts during the summer and fall. Infection takes place through needles of any age (fig. 3). The relatively delicate, short-lived basidiospores are wind dispersed, generally infecting hosts within 100 yards but capable of being moved longer distances in clouds and fog. Successful spore germination and infection of pine needles require 48 hours of 100-percent relative humidity with temperatures not exceeding 68 °F. Following germination and successful penetration, a sparse mycelium develops and grows from the needle into the bark of the stem. Twelve to eighteen months later, a slightly swollen, cankered area becomes visible. After 2 to 3 years, the rust goes through a sexual stage followed by a stage that requires the rust to infect an alternate host. The basidiospores produced on the alternate host then infect white pines, starting the cycle again. The entire life cycle requires 3 to 6 years for completion.

Figure 3.—*Needle infection from white pine blister rust. Photo from Dorena Tree Improvement Center, Forest Service.*

Historical Trends

Eastern and western white pines were the mainstays of the timber industry throughout their ranges. They were prized for their rapid growth and clear, straight-grained wood that commanded premium prices. The introduction of the fungus around the beginning of the 20th century quickly changed the prominence of white pine. In the West, the introduction of white pine blister rust resulted from one shipment of infected eastern white pine seedlings shipped to Vancouver, Canada, from France in 1910. The pathogen became established in the wild, but it was not until the 1920s before it was recognized; by then, it had spread throughout the western white pine region. The pathogen is now moving into higher elevations, affecting limber and bristlecone pines.

Management and Treatment Actions

Nature provides some natural controls for white pine blister rust. A native fungus, *Tuberculina maxima* can be found parasitizing blister rust-infected tissue and stopping or slowing canker growth. Even rodents do their share to control the disease, chewing on the sugar-laden infected tissue and girdling the cankers. Unfortunately, these controls will never be enough to truly slow down the pathogen. Heroic efforts aimed at eradicating the alternate host, *Ribes,* or killing the cankers on infected trees with chemicals have proven unsuccessful.

The most effective approach to control white pine blister rust involves planting pines with various levels of resistance to *C. ribicola*. Programs to identify and screen apparently resistant pines and to breed trees for increased resistance or tolerance show great promise, although the ability of the rust to mutate means that efforts to maintain as many kinds of resistance mechanisms as possible are necessary (fig. 4). Adding value to resistant rootstock by pruning young stands may be worthwhile to remove cankered branches before the fungus reaches the main stem and modify the microclimate in the lower crowns to discourage infection.

Figure 4.—*Testing white pine for resistance. Photo from Dorena Tree Improvement Center, Forest Service.*

Outlook

White pine blister rust is a pathogen that is well established, affecting nearly the entire range of native five-needle pines in the United States. The disease is moving to higher elevations, making management and control of this disease more difficult because of access and harsh environmental conditions. The migration of white pine blister rust to higher elevations is of special concern because bristlecone pines are thought to be the oldest living trees in existence. The goal is not to eradicate the blister rust but to promote the establishment and health of white pine trees and populations that will thrive while coexisting with the rust. Many efforts are in place to facilitate the survival of white pine species in the presence of the disease and minimize its ecological, economic, and aesthetic effects. These efforts are focused on restoring white pines where they have been lost, sustaining white pines in the presence of the disease, and planning mitigating actions when the rust spreads into new areas. Despite these efforts, land managers interested in managing white pines face many challenges. Some of these challenges include the loss of potentially resistant trees to bark beetles and fire, the lack of planting opportunities, the reluctance to plant white pines because of concerns about survival, the presence of the disease in land areas where traditional silvicultural approaches to management have been controversial, and the potential effects on a changing climate, particularly in high-elevation forests.

Oak Wilt

Ceratocystis fagacearum

Current Conditions

Oak wilt is a tree-killing, vascular wilt disease of oaks caused by the fungus *Ceratocystis fagacearum (C. fagacearum)* (fig. 1). It is widely present in the Eastern United States and its range extends southwest into central Texas (fig. 2). The disease is prevalent in rural and urban environments but has probably caused the greatest economic damage in urban areas, where oaks are valuable and favored shade trees. The origin of this fungus is unknown; it has been found only in the United States and has not been found in Canada or Mexico. The full extent of the disease in the United States is largely unknown. In many locations, oak decline has been mistaken for oak wilt, and vice versa.

Damage

The fungus most readily kills oaks in the red oak group; they are highly susceptible and usually die in a few weeks to a few months. Oaks in the white oak group are susceptible to infection, but they are infrequently killed and the fungus and damage are limited to one or several limbs within the tree crown, often allowing the trees to recover. Bur oak is somewhat intermediate in susceptibility and dies back over a period of years. Live oaks in Texas are also considered highly susceptible, partly because of their clonal, interconnected root systems. Live oaks often succumb to the disease (defoliate) within 1 to 6 months of initial infection and die within a year, although some individuals can survive in a severely damaged state for 1 year to several years.

Biology

An oak tree first becomes infected with oak wilt when a sap beetle (family *Nitidulideae*) visits a wound on a healthy tree to feed on the sap. These beetles are often contaminated with spores of *C. fagacearum,* which may be deposited on the exposed wound. From there, the fungus germinates, penetrates the vascular system, and begins to colonize the trunk and branches. Subsequently, the tree's reaction to infection, along with toxins produced by the pathogen, cause damage to the vascular tissues, resulting in a wilt that kills the tree (red oaks and live oaks) or branch (white oaks). Symptoms on red oaks include bronzed, water-soaked foliage, particularly around the margins and proceeding inward, that wilts, develops brown margins, and falls prematurely from the tree (fig. 3). On live oaks in Texas, yellowing, then browning of a zone along the veins is a unique and virtually diagnostic symptom (fig. 3). Less often, marginal browning occurs around the leaf edges—a much less diagnostic symptom. Sometimes both symptoms occur on a tree.

Figure 1.—*Aerial view of oak wilt infection center with dead and wilting trees. Photo by D.W. French, University of Minnesota, http://www.forestryimages.org.*

Figure 2.—*Distribution of oak wilt in the United States.*

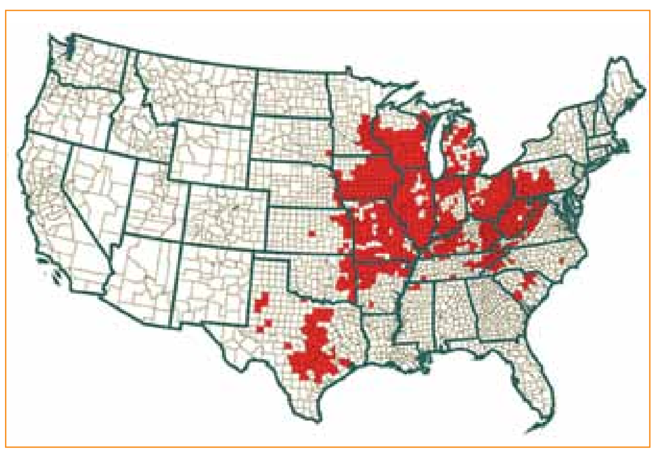


Figure 3.—*Common symptoms of oak wilt infection on red oak and live oak foliage. (left) Photo by D.W. French, University of Minnesota, http://www.bugwood.org. (right) Photo by R.F. Billings, Texas Forest Service, http://www.bugwood.org.*

The fungus most readily spreads to nearby trees through grafted or connected root systems. As nearby oaks are infected and killed, an "infection center" develops. In a forest of mixed oaks and other species, infection-center spread varies, resulting in small centers that often die out naturally. In Texas, where live oaks have common, clonal root systems, infection centers can become very large. Spore-producing fungal structures called "mats" or "pressure pads" (fig. 4) often develop under the bark of dead red oaks, pushing up the bark and creating fissures that allow insects to reach the mats. The fruity smell of the mats attracts sap beetles, which come to feed on the fungus. Here, they become contaminated with spores, which they carry to healthy (but usually wounded) trees in the area, initiating new disease centers. Fungal mats are not known to form on Texas live oaks.

Figure 4.—*Fissures in bark and underlying fungal mat on an infected red oak. (left) Photo by Forest Service. (right) Photo by T.W. Bretz, University of Missouri, http://www.forestryimages.org.*

Historical Trends

Oak wilt has been known since the 1940s and was initially thought to be a serious threat to oaks in the Eastern United States. Although the disease seemed to spread and was detected in more areas, the devastating epidemic that was feared never developed. In the 1980s, however, the disease was confirmed to be the cause of widespread and long-present mortality in live oaks in the central Texas area and was considered to be epidemic there. Also, in several areas in the upper Midwest (notably Michigan, Minnesota, and Wisconsin), the disease became extremely troublesome, particularly in areas of urban expansion and sandy soils with an abundance of highly susceptible red oak hosts such as northern pin oak. The increase in oak wilt in these areas is often directly related to human activity, which causes wounds on trees or reduces tree diversity by favoring oaks. Some expansion of the range in Texas is also occurring; in 2007, the disease was recorded in two new counties—McCulloch and San Saba.

Management and Treatment Actions

Oak wilt control in the 1950s to 1970s concentrated on preventing fungal mat formation by girdling infected trees. The most active programs were in Pennsylvania and West Virginia. This work was later perceived as expensive and ineffective in reducing the number of oak wilt centers and was abandoned. In the 1980s, however, disrupting grafted or common root systems with vibratory plows, trenchers, or other equipment provided some success in stopping the spread of individual infection centers (fig. 5), particularly in the central Texas area and in the Lake States, where homogeneous host forest types facilitated the development of rather large infection centers. Active suppression programs are operating in Texas, Michigan, Minnesota, and other States. Fungicide injections in individual, high-value trees, although expensive, have been successful in preventing mortality if applied before infection but must be reapplied every 2 years to be remain effective.

Outlook

Oak wilt will continue to cause problems in the Lake States and in central Texas for many years to come. The disease is widespread and can only be managed with concerted efforts. Programs combining prevention, detection, trenching, and red oak removals have experienced some success in slowing tree mortality. Because only wounded trees constitute the loci for new infection centers, educational efforts aimed at landowners and managers can have a significant effect on protecting trees from wounding and initial infection.

Figure 5.—*Trenching to sever connected or grafted roots and stop infection center expansion. Photo by Joe O'Brien, Forest Service, http://www.bugwood.org.*

Fusiform Rust

Cronartium quercuum f. sp. *fusiforme*

Current Conditions

Fusiform rust, caused by the fungus *Cronartium quercuum* f. sp. *fusiforme (C. quercuum* f. sp. *fusiforme)* on slash and loblolly pines, is native to the Southern United States. Since the 1930s, fusiform rust has developed into the most destructive forest tree disease of southern pines (figs. 1 and 2). Widespread planting of slash and loblolly pines, coupled with forest fire control programs, has resulted in increasing acreages of susceptible pines and increasing populations of the fungus' alternate host—oaks—which are necessary for the fungus to complete its life cycle and cause infections of pines.

Estimates of the incidence of fusiform rust in the South can be made from data collected by the Forest Inventory and Analysis (FIA) unit of the Forest Service's Southern Research Station. Until about 1998, FIA data were collected periodically from sample plots in each Southern State on a 6- to 10-year remeasurement cycle. Fusiform rust infection has been recorded since 1973 in most Southern States (fig. 3).

State-level estimates of the number of planted and natural slash and loblolly pine acres with greater than 10 percent rust incidence were made using data from the most recent periodic survey in each State in the South (i.e., before 1998) (table 1). Almost 14 million acres of slash and loblolly pine forest type have greater than 10-percent infection, representing 29 percent

Figure 1.—*Severe damage from fusiform rust. Photo by Paul A. Mistretta, Forest Service, http://www.bugwood.org.*

Figure 2.—*Sporulating fusiform rust galls on young pine. Photo by Robert L. Anderson, Forest Service, http://www.bugwood.org.*

Figure 3.—*Counties in Southern States, where more than 10-percent rust infection was recorded.*

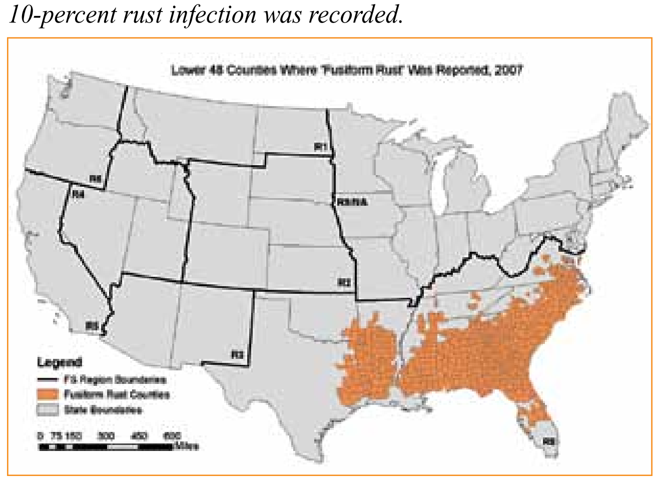


Table 1.—*Acres of loblolly and slash pine with more than 10-percent rust infection.*

State	Survey year	Host acres	Acres with >10% infection	Percent of host acres with >10% infection
		(thousands of acres)		
Alabama	1990	5,941	1,711	29
Arkansas	1995	3,444*	286*	8
Florida	1995	5,297	1,468	28
Georgia	1989	9,411	4,594	49
Louisiana	1991	4,574	1,658	36
Mississippi	1994	5,082	1,200	24
North Carolina	1990	3,872	969	25
Oklahoma	1993	465*	34*	7
South Carolina	1993	4,563	1,437	31
Texas	1992	3,690	419	11
Virginia	1992	1,996*	59*	3
Total		**48,335**	**13,835**	**29**

** Loblolly pine only.*

of the host acres (table 1). The highest percentage of affected host acreage was in Georgia, at 49 percent, and the lowest percentage was in Virginia, at 3 percent (loblolly pine only).

Damage

The fungus infects pines in the first few years after planting and results in the formation of swollen galls on pine stems and branches (figs. 1 and 2). Main stem infections in pines less than 5 years old are likely to kill the tree or result in disfigurement, rendering the tree to a bush-like form. Although stem and branch infections occurring on trees older than 5 years old normally do not kill the trees, they often result in cankers where breakage occurs during storms or that result in merchantable volume loss at harvest. Slash pine is generally more susceptible and more damaged by rust than loblolly pine is. Rust incidence varies greatly from year to year and across sites due to varying weather patterns and local conditions.

The actual effect of rust on forest stands is extremely difficult to assess. Rust may kill young trees, reducing stocking and sometimes necessitating stand liquidation and replanting. If sufficient numbers of healthy trees remain, however, no reduction in yield at harvest may occur. Volume loss can also accrue from trees that are deformed or cankered by infection but that will survive until harvest. Unfortunately, there is no direct way of assessing these losses from FIA data.

Rust infection is also a serious problem and a limiting factor in seedling production in bareroot southern pine nurseries. Without highly effective control measures, healthy southern pine seedling crops could not be produced. Fungicidal sprays must be used on a regular schedule to prevent infection.

The alternate oak host sustains only foliar infection and is virtually unharmed.

Biology

C. f. sp. *fusiforme* has a complicated life cycle requiring two hosts—pines and oaks—and multiple spore stages to annually produce the disease in pines. The fungus has no capability to live and survive outside infections of the host trees. The fungus' life cycle begins in early spring, when aeciospores are produced on the exterior of cankered pine tissues. These spores disseminate by wind to the emerging leaves of nearby alternate oak hosts. A repeating spore stage on oak leaves builds up inoculum of the fungus and a second spore stage is produced, which spreads to and infects the emerging shoots of pine hosts, ultimately causing galls and cankering. Galls and cankers can persist for many years as long as the host tree survives.

Historical Trends

Fusiform rust incidence from three periodic survey cycles is available for several Southern States (Arkansas, Florida, Mississippi, North Carolina, South Carolina, and Virginia), allowing analysis of the change in incidence over time (approximately the 20 years from 1975 to 1995). In most States, the percentage of acreage with rust infection has generally trended downward in the most recent survey (figs. 4 and 5), after some increases in the 1980s. Reductions in the incidence of rust over time may be the result of widespread application of management activities, particularly the planting of rust-resistant sources or genotypes in high-risk areas.

Management and Treatment Actions

Landowners concerned with fusiform rust have a number of management options they can implement, including the use of resistant planting stock, reduction of local oak populations, planting at higher densities, and species/site matching. Also, managers may apply thinning strategies during midrotation to reduce the effects of rust and to capture volume that would otherwise be lost. Nursery managers routinely use systemic fungicide treatment to protect seedlings; without it, they could not produce a disease-free crop. Genetic resistance provides the long-term management solution, and routine testing of improved loblolly and slash pine seed sources continues to aid in the development of greater resistance to the fungus.

Outlook

Optimistically, the incidence and effect of fusiform rust will continue to diminish over time with the deployment of resistant genotypes and the application of sound management practices. Although this result will be difficult to document precisely, continuing inventories should enable the tracking of fusiform rust incidence over time for many years to come.

Figure 4.—*Percentage of planted and natural slash pine acres with more than 10-percent rust infection for four States with three surveys.*

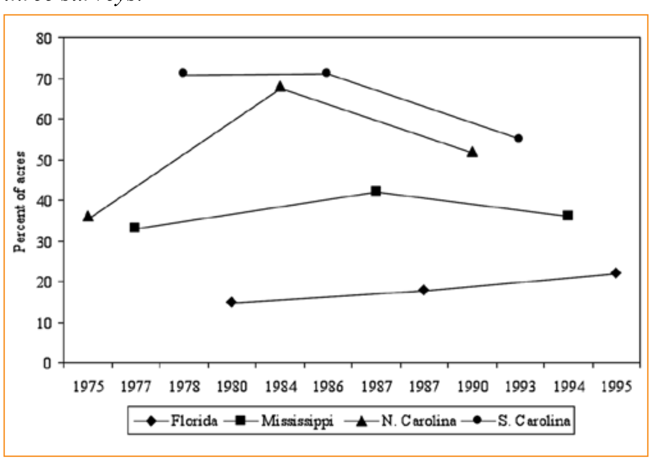
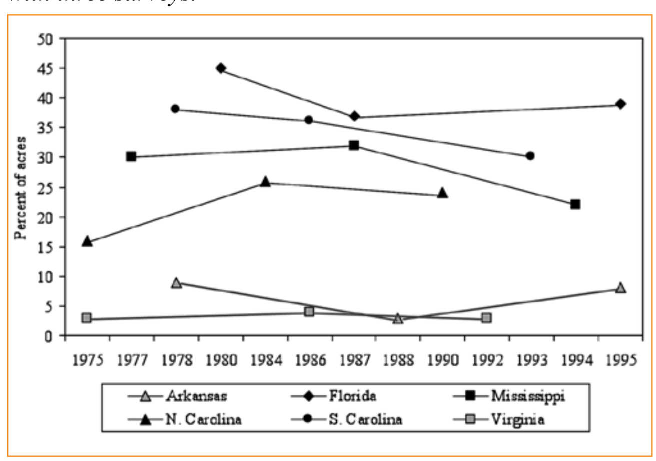


Figure 5.—*Percentage of planted and natural loblolly pine acres with more than 10-percent rust infection for six States with three surveys.*



Dogwood Anthracnose

Discula destructiva

Current Conditions

Dogwood anthracnose is caused by the fungus *Discula destructiva,* a fungus of unknown origin that became noticeably important during the 1970s and spread rapidly from the 1970s to the 1990s. This disease affects flowering dogwood *(Cornus florida)* throughout its range. Pacific dogwood *(C. nuttallii)* is also being affected by a distinct population of the fungus in the Western United States. In the East, mortality has been the most severe in cool, mountainous environments and in the Northeast and less severe in coastal or southern areas. Many areas in the South, including Virginia, North Carolina, and Tennessee, still have locations where dogwood anthracnose has not been documented.

Damage

Dogwood anthracnose is widely distributed throughout the range of dogwood and likely greatly exceeds the known, published distribution for the disease in the United States. Damage due to the disease is distinct from that of the many other fungi and insects that also attack dogwood. Signs and symptoms of anthracnose include tan leaf spots with purplish margins, wilted leaves still attached to twigs, stem cankers, epicormic branching, and lower limb mortality (fig. 1). The presence of all of these signs and symptoms eliminates any of the other pests and may be useful for disease identification in lieu of proper fungal identification. Dogwood anthracnose damage coincides with many natural agents but is likely the critical factor for the mortality of pole-sized stems (2 to 6 inches in diameter) if cankers are evident.

Biology

Dogwood anthracnose is capable of attacking all aboveground portions of the trees. Infections require about 48 hours of continuously wet conditions and fresh plant growth; therefore, infections during the spring or early summer may be quite common. Typically, small branches may be attacked first, with infections progressing down the twigs to the stems. Stem lesions, which may develop into cankers, are the lethal agents because after a branch or stem is girdled by the fungus, it may die or be attacked by other pests, such as the dogwood borer, decay organisms, drought, or other agents affecting dogwood.

Historical Trends

Before the disease was discovered, dogwood was a very important midstory tree, useful for its showy bracts (the white-colored

Figure 1.—*Symptoms of dogwood anthracnose. (left and center) Photos by R.L. Anderson, Forest Service, http://www.bugwood.org. (right) Photo by Joe O'Brien, Forest Service, http://www.bugwood.org.*

flowers), highly nutritious red seed, and locally cycling calcium back to the environment. From 1984 through 2004, dogwoods on forested FIA plots declined by 63.7 percent. Dogwood mortality varies by the major ecoregion and elevation. In coastal plains and piedmont areas, dogwood is reducing by approximately 3 percent per year; in mountainous and more northerly regions, dogwood is reducing by approximately 6 percent per year.

Management and Treatment Actions

The "Ten Essential Steps To Maintaining Healthy Dogwood" remain useful tactics to manage high-value shade trees and can be found in the Forest Service publication R8-FR-14, "Growing and Maintaining Healthy Dogwoods." On sites highly exposed to air movement or sunlight, expect dogwood to persist for many years with proper maintenance. In these settings, proper pruning, mulching, and irrigation during drought conditions are probably the most useful tactics for tree maintenance. In forested, shady, cool, or very moist environments, the disease can be expected to reduce the survivability or life of susceptible dogwood. In these settings, the creation of canopy openings, especially on eastern sides of dogwood, may prove beneficial.

Outlook

Flowering dogwood will remain suitable as an ornamental and shade tree. Due to the effects of the disease, many dogwoods have been entirely eliminated from forested conditions and can only persist in relatively exposed or open-grown conditions. Expect further reductions in dogwood as stands mature and canopy cover increases, especially during extended cool, moist conditions, which greatly favor the fungus. The planting of resistant growing stock is an available treatment strategy for growers interested in the appearance and utility of dogwood.

Beech Bark Disease

Cryptococcus fagisuga • Neonectria ditissima • Neonectria faginata

Current Conditions and Historical Trends

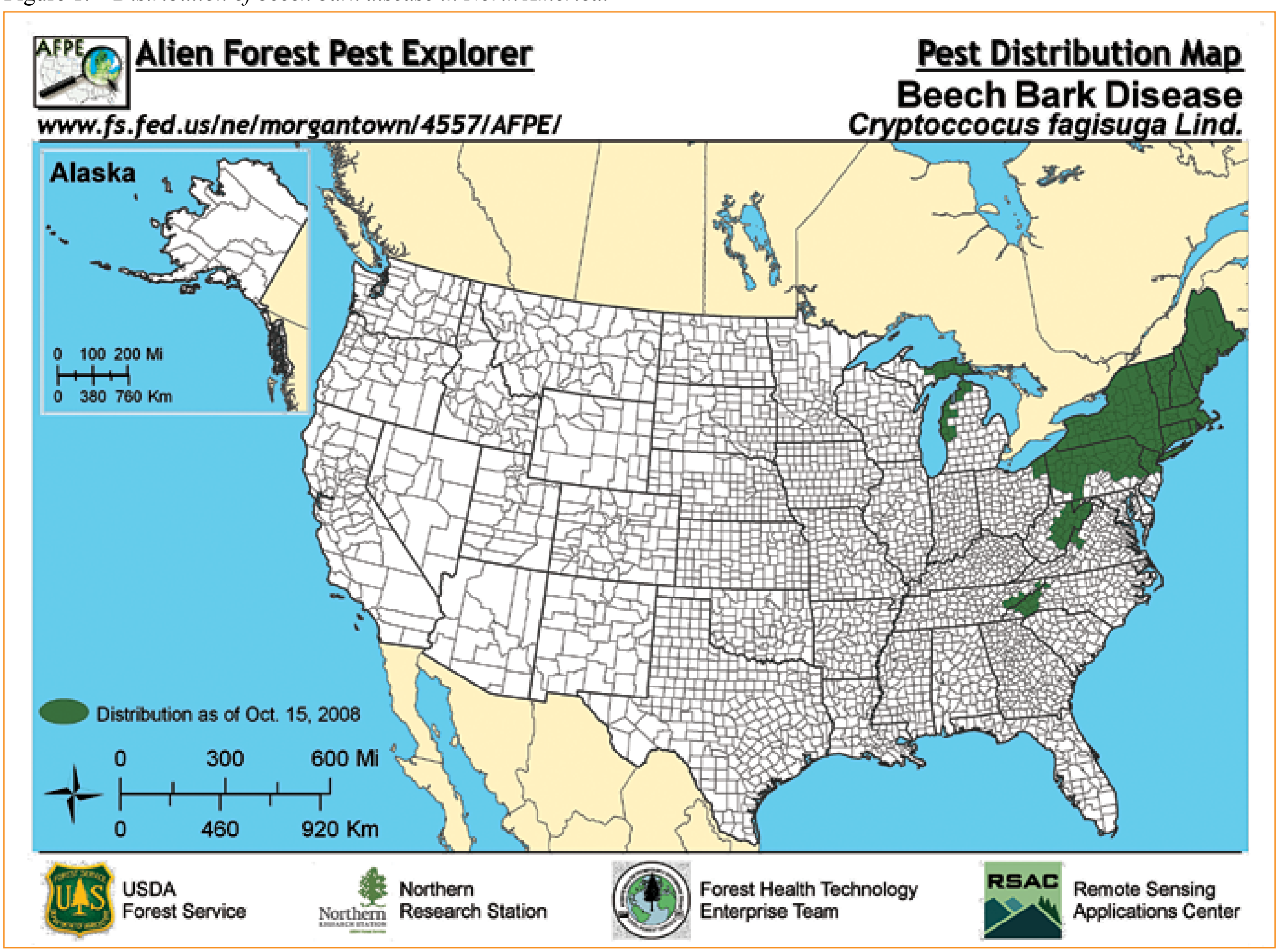
Beech bark disease has three general, temporal disease phases: the initial scale front phase, the second killing front phase, and the final aftermath forest phase. All three phases (and presently healthy, unaffected stands of beech) are found throughout the range of the disease, which extends from Maine to West Virginia with discrete outlier areas in Michigan, Tennessee, and North Carolina. Previous outliers in Ohio and West Virginia are now being considered part of the advancing scale front (fig. 1).

The beech scale and the exotic *Neonectria (N.)* fungus were introduced into North America through Nova Scotia, Canada, sometime in the late 1800s. By the 1920s, large numbers of native beech were being killed by the disease.

Damage

The killing front phase begins 1 to 19 years after the arrival of the scale. Throughout this phase, the scale-modified bark is killed and colonized by a species of *N.* spp., rendering the dead tissues vulnerable to additional decay fungi. The killing front phase results in the breaking of tree tops and eventually causes mortality. In some situations, the disease can kill up to 98 percent of overstory beech. The final aftermath forest phase

Figure 1.—*Distribution of beech bark disease in North America.*



results in either a change in species composition or the death or disfigurement of reemergent beech.

Between 1 and 10 percent of trees are potentially resistant to beech bark disease. Advance regeneration is attacked but responds to increased light by outgrowing the individual canker infections; however, the resulting maturing trees become defective and slow growing. After the killing front phases occurs, decades can pass before trees produce beech nuts again. Beech bark disease is the most significant mortality agent of American beech.

Beech is the only large-mast (nut) producer in most of the forest types in which it is a major representative. Black bear, marten, deer, and certain birds depend on the high-quality mast for reproductive success. Without it, their reproduction rate is much lower. In the past 5 years, more than 3 million living trees have been estimated to be infected with the disease. The resulting hazard trees pose a big challenge to recreation managers. An estimated 95 million dead standing beech are greater than 5 inches in diameter at breast height (d.b.h.); most have been killed by beech bark disease (fig. 2).

Biology

The exotic scale, *Cryptococcus fagisuga* (fig. 3), provides infection points for the *N.* fungi. This is the scale front*.* The old feeding wounds of dead scales become the infection sites for the ubiquitous native Northern Hemisphere fungus. The Northern Hemisphere fungus *N. ditissima* kills the outer layers of beech bark. As the killing front intensifies, the exotic fungus

Figure 2.—*Severe damage from beech bark disease. Photo by Mike Ostry, Forest Service, http://www.bugwood.org.*

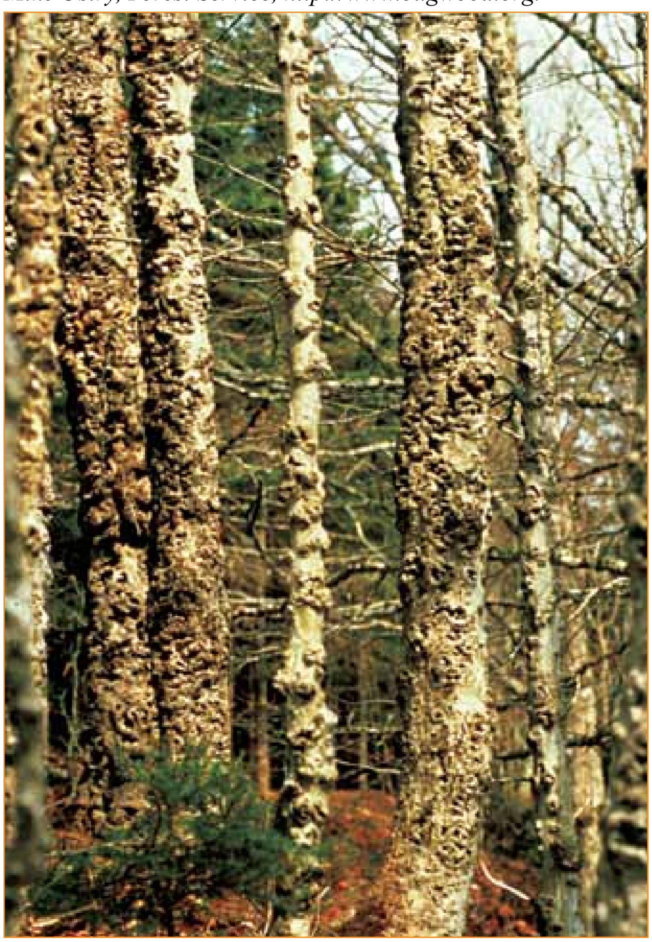


Figure 3.—*Beech scale. Photo by Steven Katovich, Forest Service, http://www.bugwood.org.*

N. faginata replaces the native fungus and eventually becomes the predominant fungus. Bark killed by the *N.* fungi provide the entry point for the decay fungi that lead to the "beech snap" or top-breaking phenomenon. Aftermath forests develop when there is an ecological accommodation of the now endemic disease complex. In forest types with low biodiversity and a high beech basal area, thickets of defective beech result. In other forest types where there is a high biodiversity, beech is simply replaced by species not affected by the disease.

Management and Treatment Actions

Currently, little is done to actively manage beech bark disease except limited salvage logging. The primary reasons are scarce resources and the fact that disease usually will not eliminate beech from a stand.

Although beech bark disease will not eliminate beech, it will cause a shift to more resistant genotypes in the gene pool as the disease selects against the more susceptible genotypes. Long-term observations have revealed clusters of apparently resistant trees. These clonal clusters must be reserved and managed. By thinning around the clone and applying herbicide to the stumps of cankered beech, additional growing space can be made available for the trees that will become the nucleus of the future beech resource.

Other treatments include preemptively salvaging beech in areas where the effect of the killing front will be difficult to manage and salvaging dead and dying trees in recreational areas and other sites where hazard trees may threaten people and property.

Outlook

The scale and all phases of the disease will continue to spread throughout the range of American beech. There is a need for more reliable ways to identify beech bark disease-resistant beech before the arrival of the killing front and to manage existing forests to increase their numbers. Managers should begin to gather either grafting material and/or seed from superior clones of beech for resistance evaluation and gene preservation.

Butternut Canker

Sirococcus clavigignenti-juglandacearum

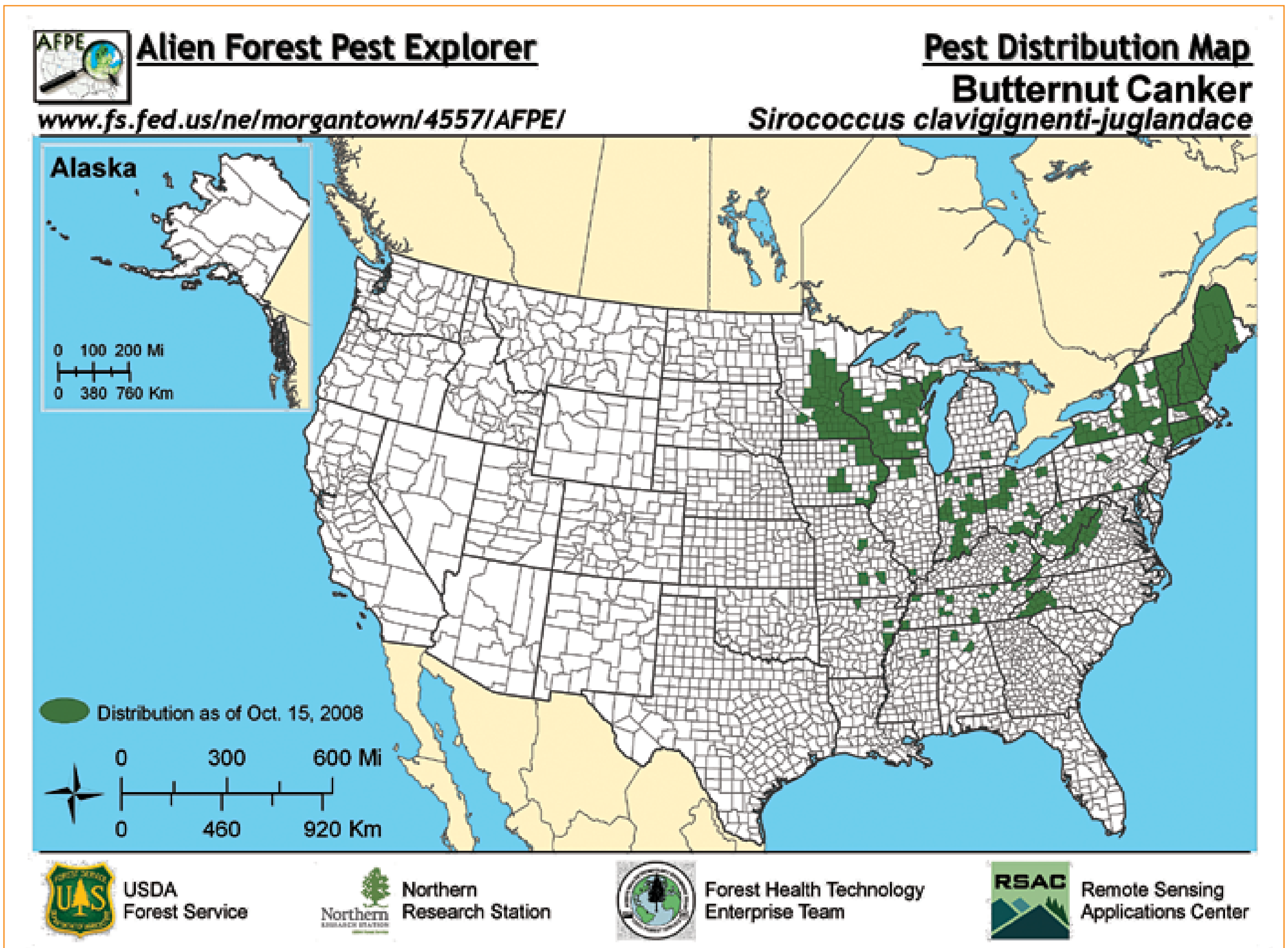
Current Conditions

Butternut canker is present throughout the range of butternut in North America. In 1967, the disease was first reported in southwestern Wisconsin. In 1978, a survey for butternut canker in the Eastern United States showed that the disease was present in at least 14 of the 16 States surveyed (fig. 1). In Canada, butternut canker was first detected and confirmed in Ontario and Quebec in 1991 and in New Brunswick in 1997, where it was thought to have been present for at least 7 years.

Damage

Butternut *(Juglans cinerea)* is being killed throughout its range by a canker caused by the fungus *Sirococcus clavigignenti-juglandacearum (S. clavigignenti-juglandacearum).* The wood is used in furniture, paneling, and small craft work. Its use has been limited primarily by its lack of availability. Rarely is butternut wood found in anything but a fine wood dealer's showroom. The nuts are prized but difficult to collect because of competition from wildlife. Butternut is one of the major large-mast producers for wildlife in the northern parts of its range. Nut and bark extracts are currently being investigated

Figure 1.—*Distribution of butternut canker in North America.*



by the pharmaceutical industry for their antibiotic properties, and butternuts are high in "heart-healthy" Omega-3 fatty acids. Historical uses of butternut, in addition to edible nuts and a source for syrup, include wood used by the Vikings, toxins used by Native Americans to kill fish, and dye for uniforms worn by the "Butternuts" (Confederates). Butternut is rare in the forest but often occurs in large numbers in localized areas, adding to overall forest diversity.

Biology

Spores of the fungus develop under infected bark in sticky masses and are dispersed by rain splash and wind during the growing season. Butternut and eastern black walnut *(J. nigra)* seed are known to harbor *S. clavigignenti-juglandacearum* (fig. 2). Although the fungus does infect black walnut and other walnut species, it has not been observed to kill them. There is no evidence that it can be spread on Japanese walnut *(J. ailanthifolia)* seed or seedlings, but this walnut species has been widely planted throughout the Eastern United States. Although there are no reports of this fungus outside North America, it is thought to be an exotic pathogen. The fungus could have been inadvertently introduced into the United States from Asia on seed. There also is evidence that several insect species are closely associated with healthy and diseased butternut and may act as vectors of the pathogen. Birds also may come into contact with the sticky spores and spread them from diseased to healthy trees within and between forest stands.

Figure 2.—*Butternut canker.*

Historical Trends

Precise species distribution and infection data are difficult to obtain because butternut trees tend to be scattered over a wide area. Most experts believe that the disease has essentially eliminated many populations of butternut in North Carolina and South Carolina. A 2003 study compared the two most recent FIA survey data sets in the seven Midwestern States, where the largest populations of butternut are located. The study found that, overall, the number of butternut trees in all size classes decreased by 23 percent between the two surveys. Another study in Wisconsin found 92 percent of the live butternut trees diseased with the canker and an additional 27 percent of the butternut trees dead. Most of the infected trees will eventually succumb to the disease.

Management and Treatment Actions

Butternut is a relatively short-lived tree and stress from old age and competition often leads to root diseases, decay, infection by other fungi, and invasion by wood-boring insects, resulting in tree death unrelated to butternut canker. If butternut canker is responsible for the loss of crown volume, there is almost always evidence of a stem canker. Currently, few management options are available to effectively control this disease.

If management objectives include conserving potentially resistant trees, the following guidelines will be helpful in retaining trees for seed and nut production and in selecting trees for breeding:

1. Retain trees with more than 70 percent live crown and with less than 20 percent of the combined circumference of the stem and root flares affected by cankers.
2. Harvest dead or declining trees to salvage the quality and value of the wood, or maintain the trees in the forest for their wildlife value.
3. Retain trees free of cankers with at least 50 percent live crown and growing among diseased trees. These trees may be resistant and have value for propagation by grafting or for future breeding.

Outlook

In many areas throughout its range, healthy butternuts have been found growing adjacent to trees infected and killed by butternut canker. Some of the trees have remained healthy for more than 12 years despite severe disease on neighboring trees, minimizing the likelihood that disease escape is responsible for trees being symptom free. Although these relatively rare trees may be disease resistant, there is no proof yet to demonstrate the existence of effective tolerance or resistance. Current evidence of resistance mechanisms is circumstantial, based on examining butternut over the years in search of trees that may have disease resistance. A study is currently underway to further test for butternut canker resistance in replicated plantings in Minnesota, Wisconsin, Iowa, Illinois, New York, and Vermont. These trees will be screened for their level of disease resistance, and genetic typing will be used to examine genetic variation among the trees and eventually the patterns of inheritance of disease resistance.