The Effects to Southern Appalachian Assessment Forest Ecosystems from Native and Exotic Pests

Question 7:

How is the health of the forest ecosystem being affected by native and exotic pests?[1]

In answering this question, impacts of the most damaging diseases, insects, and exotic plants in the Southern Appalachian Assessment (SAA) forests were considered. For each disease or pest, the historical and current status of the forest health problem are presented with a discussion of the host type, vulnerability, biology, expected trends of infestation, mortality or damage potential, and possible ecological implications.

Declines are complex diseases initiated by adverse environmental factors that create biotic and abiotic stress and often culminate in lethal attacks by organisms that are otherwise not harmful. Thus, these diseases differ from those caused by single primary pathogens in that trees suffer from many abiotic and biotic stress factors. In the context of these diseases, predispositional stress refers to environmental pressure sufficient to trigger changes in the physiology, form, or structure of a tree. The stress factors can be abiotic (e.g., extremes of moisture or heat) or biotic (e.g., insect defoliation, infection by fungi, or combination of these). In the absence of such stresses, the organisms of secondary action, often ubiquitous in the ecosystem, occupy various niches ranging from saprophyte to weak pathogen. Without these organisms, trees would most likely recover when the stress abates.

In recent decades, decline diseases have killed or damaged millions of trees in the eastern United States. Because declines are frequently initiated by broad environmental changes, they may suddenly emerge over a wide area, and the types of sites where they develop may appear to be closely related. This assessment examines the impact of oak and red spruce declines on the regional forests.

Several forest tree diseases that are not defined as declines also occur in the Southern Appalachians. In some instances, these diseases have symptom complexes similar to those induced by air pollutants. Causal disease agents range from simple abiotic stress, such as prolonged drought or spring frost, to complexes of fungi, insects, and abiotic stresses. This assessment considers the impacts of dogwood anthracnose, beech bark disease, butternut canker, Dutch elm disease, and the chestnut blight.

Numerous insect species injure trees in the forests of the eastern United States. Insects attack all parts of trees, including foliage, shoots, cones, seeds, stems, and roots. Injury may be negligible, or it may be catastrophic. With the exception of this southern pine beetle, this assessment of forest insect concentrates on exotic species, including the European and Asiatic gypsy moth, hemlock woolly adelgid, balsam woolly adelgid, and the Asiatic oak weevil.

Tree Declines

Oak Decline

Oak decline is not new. Forest workers have reported occurrences since the mid-1800s (Beal 1926, Balch 1927) and in every decade since the 1950s (Millers and others 1990). In fact, oak decline may have become more common and severe since the 1950s due to the

1 The original assessment question included air pollution. The SAA Atmospheric Technical Report (1996b) includes a discussion of ozone predisposing action of an extreme drought early in that decade (Tainter and others 1990, Dwyer and others 1995). An apparent increase in incidence and severity in the early 1980s led to an intensification of survey and monitoring activities (Starkey and others 1989, Starkey and others 1992, Oak and others 1991) and, more recently, to development of risk rating systems for managers (Oak and Croll 1995, Oak and others, in press).

Forest Inventory and Analysis (FIA) surveys have determined that oak types mostly in upland oak and oak-pine stands cover 17.4 million acres in the Southern Appalachians. Oaks, therefore, are extremely important both economically and ecologically. Oak decline is a widely distributed disease that is changing forest composition and structure in this vast resource.

Oak decline is a disease complex involving environmental stress (often drought), root disease (e.g. Armillaria root disease), and insect pests of opportunity (e.g. 2-lined chestnut borer), and physiologically mature trees (Staley 1965, Wargo and others 1983, Wargo 1977). The diagnostic symptoms separating it from other diseases of oak are slow, progressive dieback of overstory trees from the top downward and from the outside inward. It results from disturbed carbohydrate physiology and water relations when mature trees become stressed and subject to root disease (Wargo and others 1983, Manion 1981, Hyink and Zedaker 1987). The introduction of the gypsy moth has exacerbated and accelerated oak decline because oaks are preferred hosts and spring defoliation contributes to the chain of events that increase susceptibility. Susceptible trees die within a few years after dieback exceeds one-third of the crown volume, but not all affected trees reach this point. Trees with lower levels of dieback often recover from visible crown symptoms (Oak, unpublished). Species in the red oak group are most susceptible (particularly black, *Quercus velutina,* and scarlet oaks, *Quercus coccinea).* Hickories are the only non-oak species commonly observed with symptoms in decline areas (Starkey and others 1989).

Like all native diseases and insects, oak decline is a completely natural ecosystem process that has always affected some component trees. The unprecedented amount of oak and changes in stand structure caused by past land use distinguishes the current decline situation from those that have occurred in the past. The decimation of the once-dominant American chestnut by the chestnut blight and land abuse early in the 20th century have resulted in forests with a higher percentage of oak now than at any time in the past.

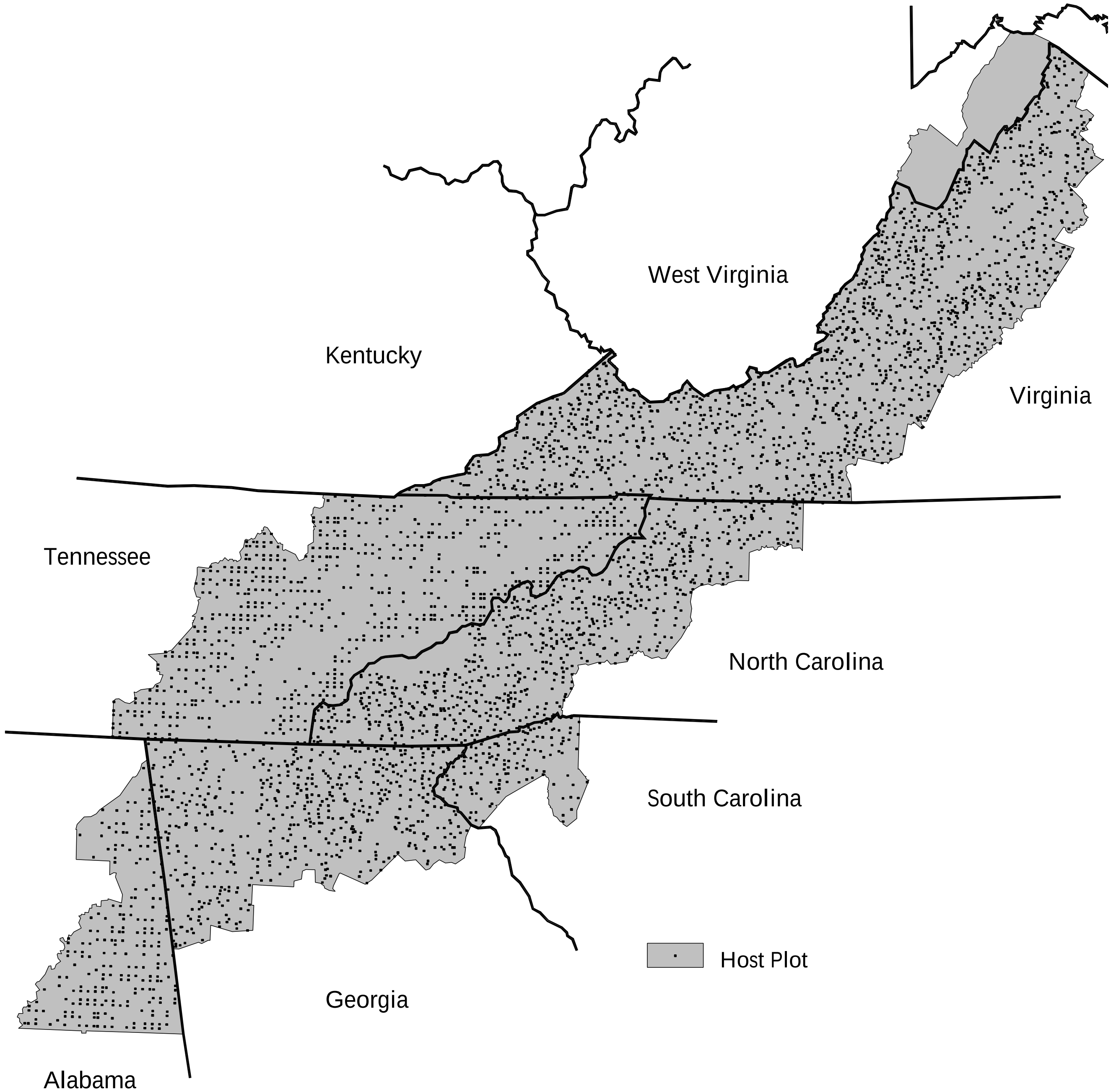
Methods developed by Starkey and others (1992) permit the classification of oak forests into several categories with respect to oak decline–host type, vulnerable host type, and affected. Stands in which oaks comprise a plurality of stems are considered to be in the host type (fig. 6.1). Fifty-four percent of the host type is considered vulnerable (fig. 6.2). Vulnerable stands are old enough to have attained pole or sawtimber size and have at least 30 sq. ft. of oak basal area per acre–sufficient for potentially serious resource impacts if oak decline develops.

About 1.7 million acres of vulnerable host type were in turn found to be affected by oak decline based on the detection of dieback symptoms in one or more dominant or codominant oaks (fig. 6.3). Thus, 8 percent of the vulnerable host type area and 10 percent of the host type are affected.

Occurrence of oak decline varies by ownership and state. Private owners control nearly 80 percent of the host type area but have the lowest oak decline incidence (18 percent of the host type). By contrast, national forests make up nearly 19 percent of the host type area, but the incidence of affected stands is 2 times greater than that for private owners (17 percent of host type) (fig. 6.4). The reason for the disparity in oak decline incidence is that national forests have a higher frequency of oak-dominated stands of advanced physiological age on sites with average to low site productivity (Oak and others 1991). Among states, North Carolina and Virginia have the highest decline incidences–17 and 14 percent of the vulnerable host type area, respectively.

Oak decline will continue to be a forest health issue in the SAA area, especially on national forests. About 19 percent of national forest land already has oak decline damage, and a nearly identical percentage has no damage but is vulnerable. Among national forests, the George Washington and Jefferson National Forests have the highest incidences (fig. 6.5).

Oaks will not be eliminated from decline-affected areas; their numbers and diversity are being reduced. Oak diversity is reduced because of the greater relative susceptibility of

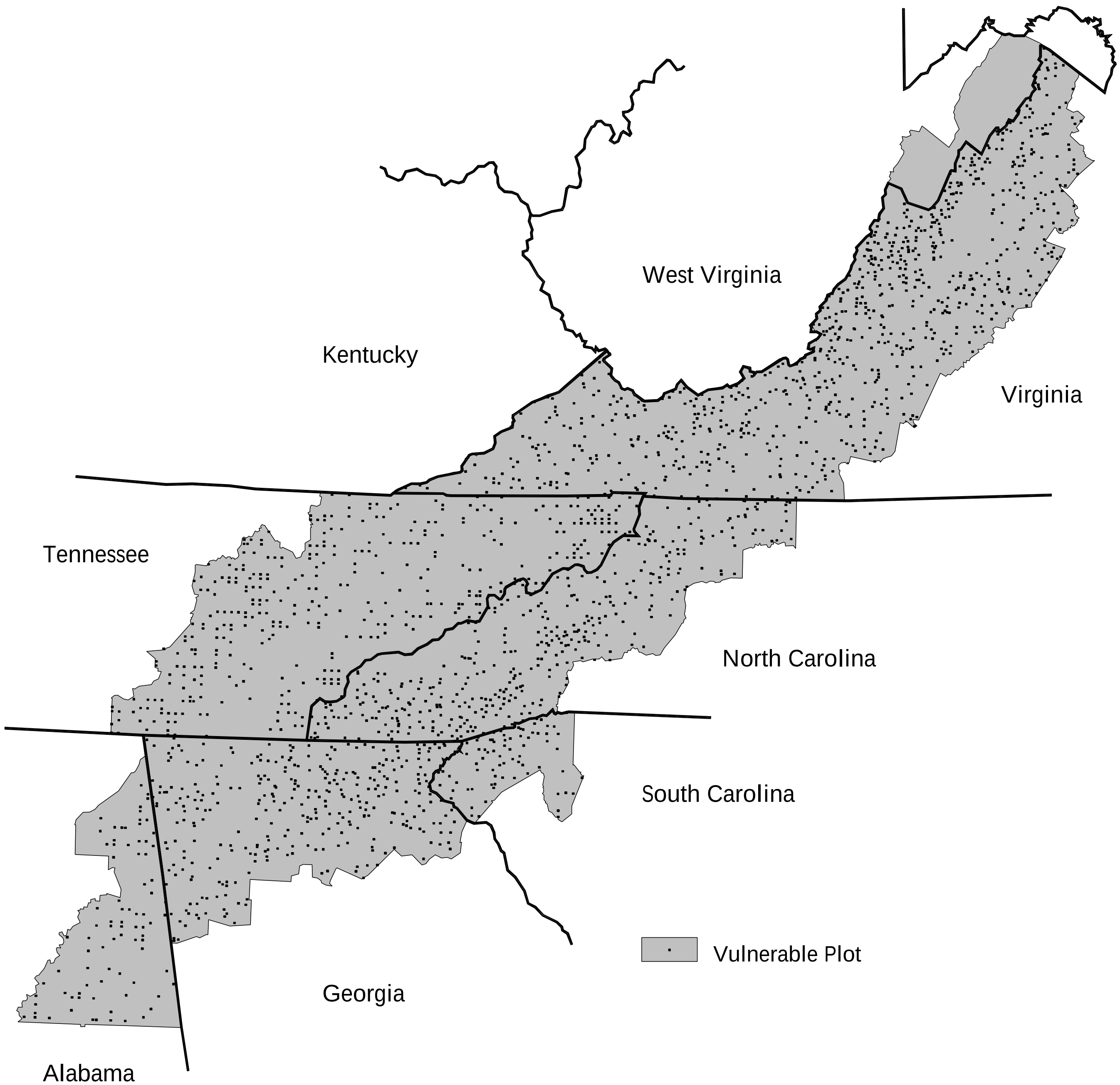


FH040

Figure 6.1 Stands classified as host type for oak decline if a plurality of stems are oak (Data source: FIA) in the SAA area.

species in the red oak group, and numbers are being reduced due to the replacement of dead and dying oaks by other species. Red maple *(Acer rubrum)*, blackgum *(Nyssa sylvatica)*, and other relatively shade-tolerant species are most commonly replacing dead and dying oaks

(Anderson and Cost, in press). This change has several effects on ecosystem structure and function. Structure becomes more complex as canopy density is reduced and the number of small openings increases. The quantity of dead standing trees and down woody debris



FH041

Figure 6.2 Oak decline vulnerable plots in the SAA area. Vulnerable plots are defined if pole or saw-timber size has at least 30 square feet of oak basal area per acre (Data source: FIA).

increases denning sites for some animals but perhaps more than can be effectively exploited. Overall susceptibility to decline and gypsy moth defoliation is reduced due to a smaller oak component. Hard mast production potential, already severely reduced from historic levels due to loss of the American chestnut to chestnut blight, is further reduced in quantity, quality, and diversity as the number of oak decreases and as species in the red oak group suffer greater impacts than those in the white oak group (Gysel 1957, Oak and others 1988).

FH042

Figure 6.3 Oak decline affected plots in the SAA area. Plots are affected when dieback symptoms are detected in one or more dominant or codominant oaks (Data source: FIA).

The areas of greatest impact will be immediately behind the advancing front of the gypsy moth. Repeated severe defoliation in spring by this insect increases susceptibility to decline (Wargo 1977). Heavy oak mortality has occurred over large areas. Major losses will probably be most common on national forests and in Virginia and North Carolina. Subsequent gypsy moth outbreaks and oak decline events will be less severe due to the reduction in abundance of preferred host species.

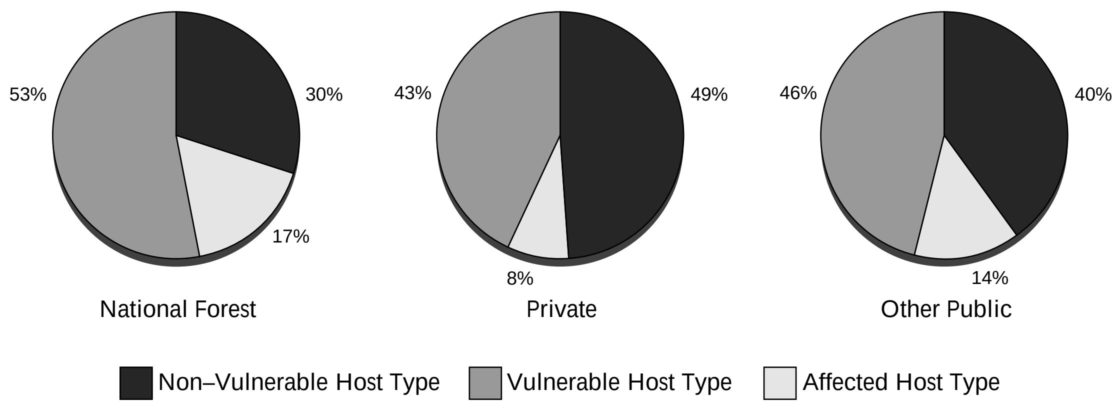


Figure 6.4 Proportion of host type that is non–vulnerable, vulnerable, and affected by oak decline for three ownership categories. (Source: FIA)

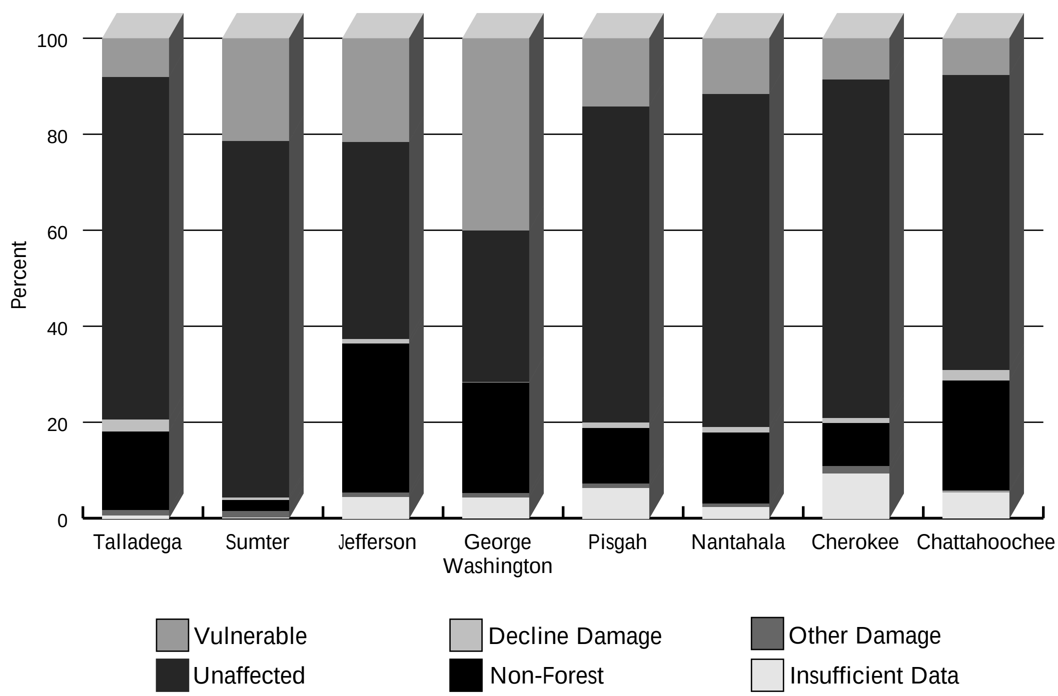


Figure 6.5 Proportion of area within each national forest classified according to oak decline risk. (Source: Continuous Inventory of Stand Conditions)

Management responses to oak decline range from doing nothing to altering forest composition and structure to maintain oak abundance and diversity through silviculture practices. The selection of an option depends on the relative importance placed on oaks in the landscape and the cost of treatment. One option is to maintain oak through timber harvesting or other disturbances (e.g. fire) that encourage oak reproduction. Portions of the landscape will always be vulnerable, but the present relatively uniform, vulnerable condition over large areas could be altered. In weighing the need for action, the value of oaks to wildlife should be added to their value as timber species.

Spruce Decline

Red spruce decline in the northeastern United States has been reported since the early 1980s (Peart and others 1992). Symptoms include high mortality rates, canopy crown deterioration, reduced growth rates, and shifts in forest tree species composition. Research results from the National Acid Precipitation

Assessment Program (NAPAP) suggest that atmospheric deposition may be implicated (NAPAP 1991). Exposure to ambient cloud water can reduce the cold tolerance of red spruce. Increases in winter damage to red spruce in the Northeast have contributed to crown damage and increased mortality in that region. This impact occurs infrequently in the Southern Appalachians, where temperatures seldom approach the cold tolerance limits for red spruce.

Evidence of red spruce decline and pollution involvement in the Southern Appalachians is less substantial. The red spruce-Fraser fir ecosystem occupies approximately 103 square miles in the Southern Appalachian Mountains of southwestern Virginia, eastern Tennessee, and western North Carolina. The trees are generally confined to mountain peaks above 5,000 feet elevation. NAPAP studies (NAPAP 1991) in the Southern Appalachians have documented extensive mortality of Fraser fir and decreases in crown vigor and annual growth in red spruce. Fraser fir (*Abies fraseri*) mortality, frequently pictured in popular publications, was the direct result of an insect, the balsam woolly adelgid.

Although it has been suggested that air pollution may have rendered fir more susceptible to the adelgid, supporting evidence is incomplete. In mixed stands with dying fir, spruce decline can be partially explained by increases in wind damage and soil temperatures (Nicholas and others 1992). Symptoms of decline in spruce-dominated stands, at high elevations with a high frequency of cloud interception, have led scientists to consider impacts of atmospheric deposition. Acid deposition components of sulfate, nitrate, and hydrogen ions at high elevations greatly exceed those at lower elevations. This is primarily due to the increased volume of precipitation and high ion concentrations in cloud water. Exposure to ambient cloud water with concentrated sulfate and nitrate anions (negatively charged ions) has been shown to accelerate foliar leaching of essential cations (positively charged ions). Field surveys and fertilization studies indicate that red spruce in the Southern Appalachians, are experiencing calcium and zinc deficiencies, while those in the Northeast are generally not (Eagar and Adams 1992).

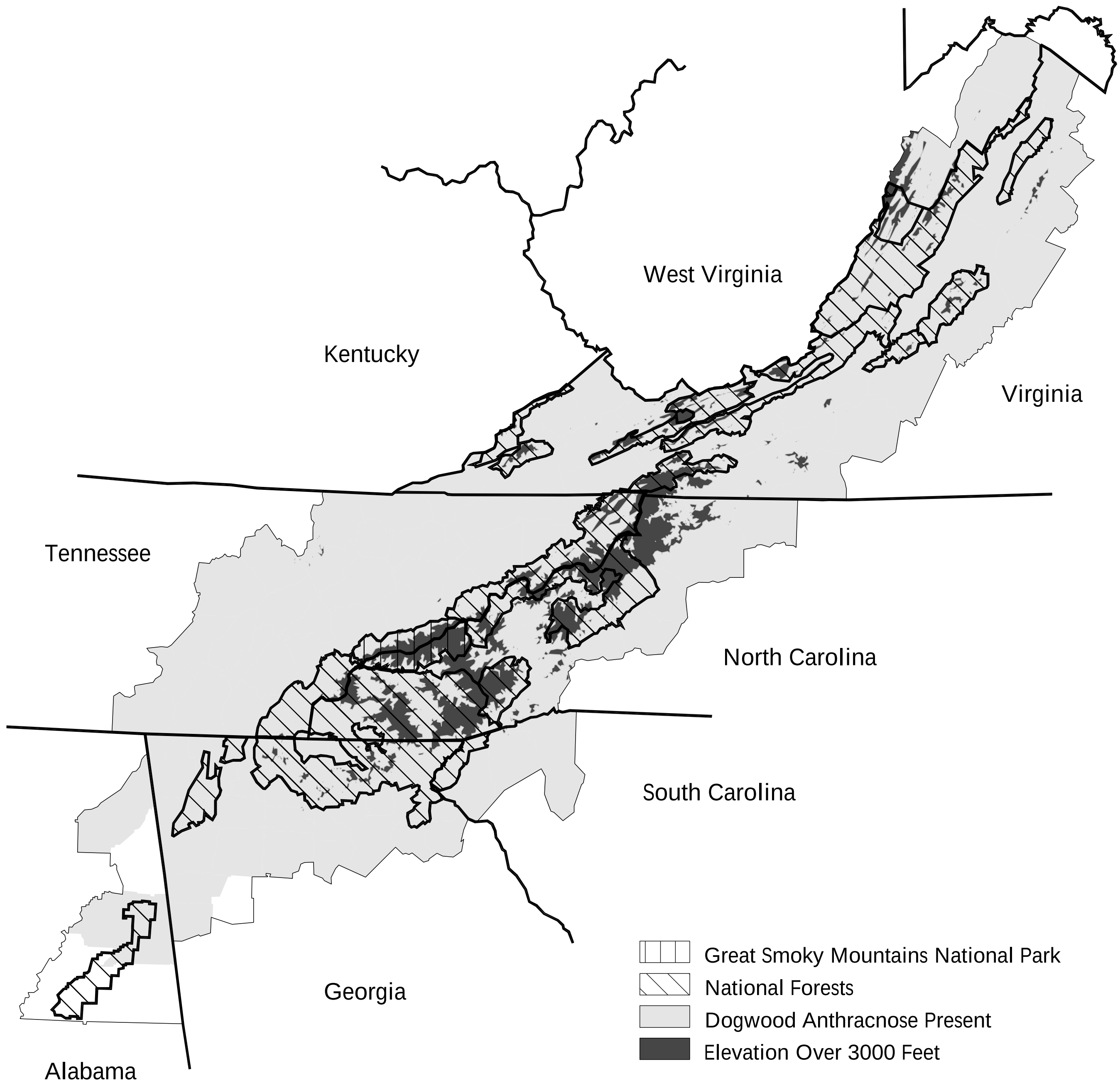
NAPAP research (Barnard and Lucier 1990, Shriner and others 1990), as well as ongoing studies (Nodvin and others 1995) have demonstrated that the high elevation forests appear to be nitrogen saturated. Nitrogen inputs from rain, snow, and cloud water combined with inputs from natural biological process exceed the capacity of soils and vegetation to immobilize nitrogen. The leaching of excess nitrogen depletes essential base cations from the soils and acidifies soil water. In addition, there is evidence that aluminum is being mobilized into soil water at levels that interfere with plant uptake of calcium, magnesium, and zinc. Soils in the Southern Appalachians generally have a large capacity to absorb sulfate, but current sulfate loading rates will likely exceed soil sulfate absorption capacity within a few decades (Johnson and Lindbert 1992).

Detection of a spruce decline in the Southern Appalachians is difficult since forest structure in most areas has deteriorated since the early 20th century due to logging and infestation of Fraser fir by balsam woolly adelgid. Species composition and site quality changes after logging have been documented and current work indicates the ongoing adelgid infestation is causing dramatic changes in forest structure and composition. Most information about southern spruce-fir forests is based on pre-adelgid old-growth stands, but future assessments must include the realities of disturbed, second-growth forests when determining if stand condition is normal or if other stressors are also present.

Exotic Diseases

Dogwood Anthracnose

Caused by *Discula destructiva,* Redlin, dogwood anthracnose was first observed in the United States in Washington state in 1976 and in New York 2 years later. The disease has spread rapidly down the Appalachians, primarily on *Cornus florida,* the eastern flowering dogwood. This species is the most common in the Eastern United States and is most affected by the disease, but other dogwood species are susceptible. By 1988, dogwood anthracnose had been reported in more than 60 counties in eight northeastern states, including West Virginia and Virginia. By 1995, the disease had been confirmed in northern Georgia (1987), western North Carolina (1988) and as far south as northern Alabama (fig. 6.6). This disease is now



FH031

Figure 6.6 The distribution of dogwood anthracnose in the SAA area.

found in over 12 million acres in 180 counties (Anderson and others 1994).

Infection begins as leaf spots that may enlarge to kill the entire leaf. The fungus also infects twigs and spreads to the main stem. Later, the main stem of the infected tree develops cankers and epicormic shoots along its entire length. The stem cankers are capable of killing dogwoods, however, larger dogwoods often die 2 to 3 years after the first symptoms are observed due to the stress of repeated defoliation.

Dogwood is an important understory and midstory species in many ecosystems throughout the southern United States and its loss from any of these systems would have significant ecological consequences.

It may be too soon for reliable projections about the future of flowering dogwood in the many forest types in which it grows throughout the SAA area. Rate and severity of infection vary with several factors. In the South, infection is most likely at high elevations and on moist to wet sites. Shade increases the risk of infection and mortality. Denser stands of dogwoods seem to have less severe infection however. Dogwood stands on a southern or western aspect also have less severe infection, possibly because these stands are drier and get more sunlight.

Research continues to find potentially resistant trees in woodlands where dogwood anthracnose has been present for more than a decade. Potentially resistant survivors have been identified from a population of flowering dogwoods devastated by anthracnose in the late 1970s in southeastern New York. *Cornus kousa* is a known host of *D. destructiva* but seldom shows the severe disease symptoms that *C. florida* develops. The first generation hybrids of *C. florida* x *C. kousa,* introduced as the Stellar series, possess increased genetic resistance to anthracnose.

High-value landscaping trees can generally be protected by mulching, pruning, watering during droughts, and application of a fungicide, but no practical controls are available for dogwoods in forest environments.

Beech Bark Disease

Beech bark disease (BBD) is a complex of two causal agents, the beech scale insect, *Cryptococcus fagisuga,* and a fungus, *Nectria coccinea faginata.* Beech scale insects are, and have long been, a common pest of beech and other trees throughout most of North America. The disease is easily identified by the white woolly material, secreted by the female, which can be seen on the trunks of infested beech. By itself, the scale insect does not fatally injure beech. However, when the insect joins forces with *Nectria,* the two of them together become a symbiotic and fatal combination (Houston 1975). Simply stated, the scale insect penetrates the bark, allowing the fungus to invade.

American beech *(Fagus grandifolia)* grows from Maine to Florida, west to Wisconsin and Texas, and in most counties in the Southern Appalachians. It is very shade tolerant and is often found growing in association with maples and birch (Houston and O'Brien 1983). In the Southern Appalachians, it is an important component of the cove hardwood forests as well as others. At high elevations it may form dense clonal stands known as beech gaps. Clonal refers to stands originating from sprouts of a single or small number of mother trees; hence has very low genetic diversity. Because of their lack of value to early loggers, many old beeches have survived and are frequently some of the oldest trees still existing in the SAA area. On the whole, American beech had no life-threatening diseases for many years. That began to change in 1890 with the arrival of beech bark disease to Nova Scotia.

Accounts from Europe indicate that the disease was killing European beech *(Fagus sylvatica)* before 1849, but it was not until 1914 that the disease complex was discovered and the *Nectria* fungus identified. By 1932, the scale-fungal complex had spread from Nova Scotia into the United States and had been identified in both Maine and Massachusetts (Houston 1975). By the 1980s, reports of the disease came from the Monongahela National Forest in West Virginia (Houston and O'Brien 1983) and, in 1993, it was found in the Great Smoky Mountains National Park in both North Carolina and Tennessee (Johnson 1995).

Declines in the beech scale population occasionally occur over large areas suggesting that environmental factors may affect the insect. More research is needed on biological control of BBD. The ladybird beetle, *Chilocorus stigma*, feeds on the scale; and a fungus, *Nematogonum ferrugineum (Gonatorrhodiella highlei),* has been reported to parasitize *Nectria* fungi. Scales on high-value ornamental trees can be controlled with insecticides. Some trees free of the disease have been found in affected areas, indicating some resistance to the scale insect. Breeding programs to increase resistance in the beech population and programs to discover the roles of biocontrol agents should be investigated (USDA FS 1993).

Butternut Canker

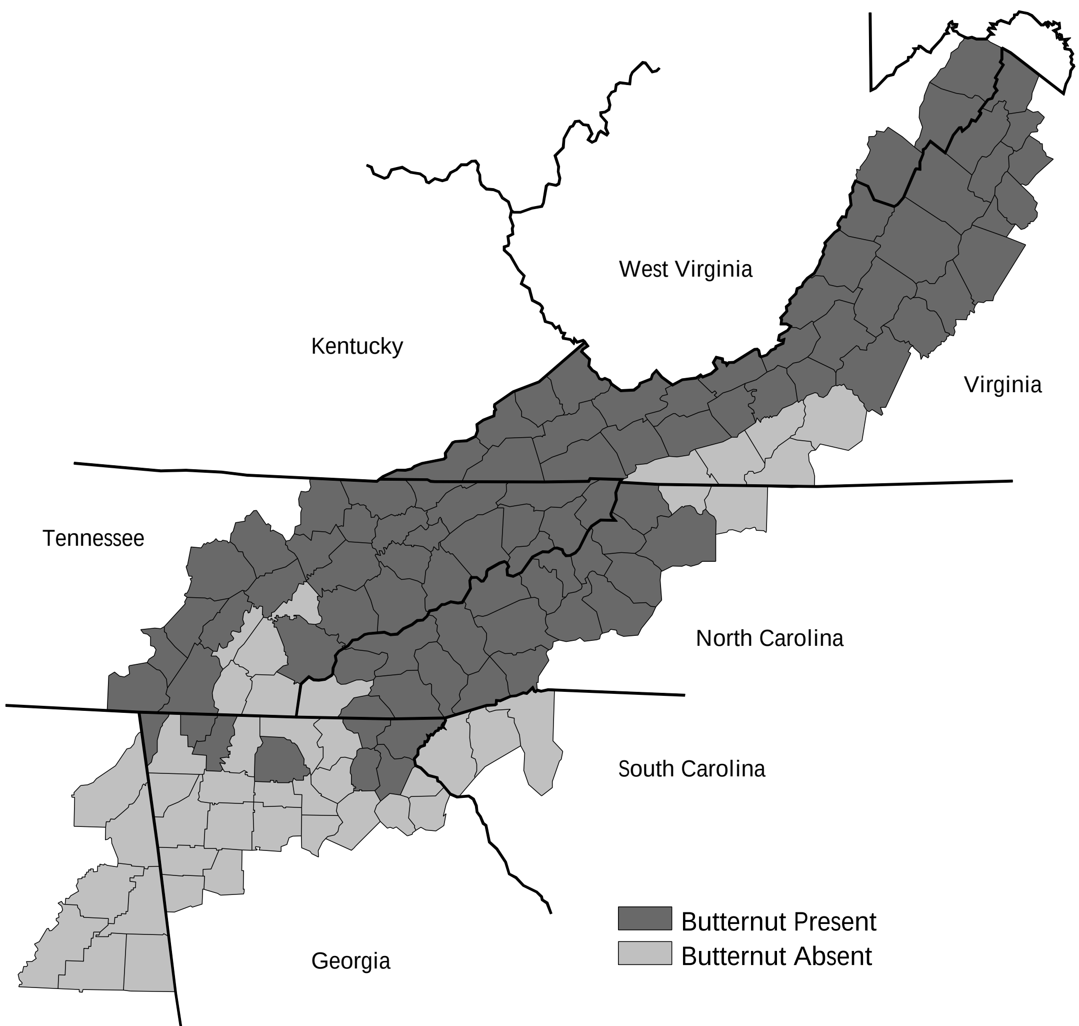
Butternut canker disease was first identified in 1967 (Anderson 1988). It is caused by the fungus, *Sirococcus clavigignenti-juglandacerum* (USDA FS 1994). During the past three decades the disease has killed nine-tenths of the butternut *(Juglans cinera)* trees in the Southern Appalachians. Unfortunately, the fungus went largely unnoticed because butternut trees are generally scattered and death from the disease is slow. Nuts from infected trees generally are not viable, therefore, declining trees do not reproduce.

Butternut normally does not occur in pure stands, but is scattered through cove and upland hardwood stands throughout its range (fig. 6.7). Its wood is highly valued and its nuts provide food for humans and wildlife.

Genetic resistance to the disease appears to exist–there are still scattered uninfected butternut trees throughout most of its range–but surviving trees are often being cut by landowners who fear that the disease will eventually infect and kill the trees, resulting in economic loss. This harvest of uninfected trees threatens to severely reduce the remaining genetic pool of resistant butternut. The identification and protection of surviving uninfected butternut trees on federal lands (Ostry and others 1994, USDA FS 1994) may be warranted. Private landowners should be informed of the genetic value of resistant or uninfected trees and encouraged to conserve such trees.

Dutch Elm Disease

Dutch elm disease, caused by the insect-carried fungus *Ceratocystis ulmi,* was introduced into the United States in 1930. It has been considered primarily an urban problem, as elms have been planted extensively as shade trees in cities and towns. This disease is spread



by two species of elm bark beetles and also by root grafts between trees in urban settings (Hanisch and others 1983).

American elm *(Ulmus americana)* is native to most of the United States, including the entire SAA region. It is most common on flats and bottomlands below 2,000 feet in elevation (Little 1971). American elm is a scattered component in mixed mesic hardwood stands throughout the SAA area, except at high elevations, but does not generally occur in pure stands. Dutch elm disease affects the species throughout its range. The disease also affects other elm species growing in the Southern Appalachians.

American elm is declining slowly in forest stands. Unlike urban elm populations, forest trees are relatively isolated from one another, and spread of the disease is slow and sporadic. Loss of American elm is of concern, but the disease is not an immediate threat to the species. Protection of individual elms in urban settings can be successful, but the cost is high. Treatment in forest settings is impractical. Additional research into both the ecological role of American elm and the health of wild American elms seems warranted.

Chestnut Blight

Chestnut blight (*Cryphonectria parasitica*) was first recorded in the United States in 1904 at the New York Zoological Park. The fungus probably arrived on nursery stock from Asia several years before. The disease spread rapidly because microscopic fungus spores can be transported by wind or on the feet of migrating birds and insects.

American chestnut had not co-evolved with the disease and had no resistance to it. Trees were quickly infected and began to die almost at once. Before the chestnut blight, American chestnut flourished on suitable sites between 1,200 feet and nearly 6,000 feet in elevation on southerly slopes and up to 4,800 feet on northerly ones. Preferring moist, but well-drained, upland soils derived from sandstone, shale, granite, or gneiss, American chestnut often made up 25 to 50 percent of hardwood stands. In many places, the proportion of chestnut in stands approached 100 percent. It did not grow well on limestone sites and was infrequent in valleys or other lowland sites with clay soils and poor internal drainage.

By 1929, nearly all counties in the SAA area were infested; and by about 1940, most of the standing chestnut trees were dead. Today, American chestnut persists throughout its former range as root sprouts growing in the understory, only occasionally attaining nutbearing age. Chestnut sprouts are numerous and will continue to survive as understory plants throughout the SAA area, though the number is probably decreasing. American chestnut is intolerant of shade and suitable disturbance is infrequent in most areas. A gradual loss of the genetic resources is expected over time without action. Sprouts generally live for 5 to 10 years before being top-killed by the blight, which girdles the stem. Often chestnuts reach heights of 25 feet or more, but they rarely flower and bear fruit before dieback.

If the species is to survive, areas with extensive chestnut root stocks should be identified and silvicultural practices should be employed in those areas to protect or enhance chestnut survival. Research should be continued into both genetic engineering for blight resistance and development of hypovirulence in the blight fungus. Planting of so-called “blight-free” chestnut has been widely publicized, but this practice is ineffective. Some seedlings advertised as “blight-free” are merely uninfected or, at best, less susceptible than chestnuts surviving in the woods as sprouts of the former population. This practice raises false hopes among the public and may discourage research funding. It should be publicly exposed.

Insect Pests

Southern Pine Beetle

Southern pine beetle (SPB) (*Dendroctonus frontalis*), infestations have occurred cyclically throughout recorded history in the South. An outbreak of SPB in a county is defined as a condition where one or more active SPB spots occur per 1,000 acres of susceptible host type. SPB outbreaks move from low levels of infestation to high levels over several years. The cycles may be localized or regional and depend upon weather and other stress factors as well as the interrelationship between the populations of SPB and its predators.

The SPB adult is 2 to 4 millimeters in length and brownish to black in color. The female SPB kills conifers by boring under the bark and destroying the cambium layer of the tree. They construct winding egg galleries while feeding and laying eggs. During outbreaks, trees are usually mass-attacked by thousands of beetles.

SPB outbreaks were reported in the late 1700s and early 1800s, but outbreaks were not systematically surveyed and recorded until the 1960s. The worst outbreak in the Southern Appalachians since the 1960s occurred between 1973 and 1976. Between 1960 and 1990, SPB outbreaks killed over $901 million worth of timber. Risk of attack by the southern pine beetle (SPB) is one factor in deciding whether to thin or regenerate southern yellow pine stands and mixed stands of yellow pine and hardwood.

The crowns of trees attacked by SPB during warm, dry weather may fade in color within 2 weeks. Dying trees are first light greenish-yellow, then yellow, and finally reddish-brown. Females often enter trees in bark crevices, and pitch flowing to the outside usually forms whitish pitch tubes. In conjunction with fading crowns and pitch tubes, reddish boring particles of chewed bark will accumulate in bark crevices.

SPB outbreaks in the SAA area are generally less dramatic than those on the Piedmont and Coastal Plain of the south because yellow pine forests types are less common in the Appalachian Mountains. SPB outbreaks have significant ecological implications, not only because of the loss of relatively scarce habitat, but because at least one yellow pine species, Table Mountain pine, cannot reproduce in the absence of fire. Table Mountain pine stands killed by SPB do not regenerate, and are permanently lost. To help land managers reduce stand susceptibility, hazard rating systems have been developed throughout the Southeastern United States. In the Southern Appalachians, the Mountain Risk System is recommended by most entomologists (Price 1994).

European Gypsy Moth

The European gypsy moth, *Lymantria dispar* (L.), is a major defoliator of hardwood trees in both forest and urban landscapes. It was introduced from Europe into Massachusetts sometime between 1867 and 1869, and because the favored host, oak, is widespread in the eastern deciduous forests, it thrived and continues to expand its range west and south each year. By the 1980s, gypsy moth was established throughout the Northeast. Today the quarantined area considered generally infested is in all or part of 16 states, including parts of West Virginia and Virginia which are in the SAA area.

The adult female gypsy moth cannot fly, so natural spread of this pest is limited to the distance that the young larvae can disperse on wind currents in a process known as ballooning. Occasionally, however, humans transport gypsy moth life stages over very long distances on vehicles, outdoor household articles, and nursery products.

The gypsy moth has a single generation per year. The egg masses, which contain from 75 to more than 1,000 eggs each, hatch in the spring at approximately the same time that budbreak occurs in the oaks. The young caterpillars climb upward, disperse via ballooning, then settle down to feed. Over the next six weeks, the caterpillars continue to feed and grow, going through six molts or growth stages, before pupating for two weeks, then emerging as adults. The adult stage is very short-lived (2 to 4 days) and does not feed at all. In fact, adult gypsy moths do not have the mouthparts necessary for feeding. The sole purpose of the adults is to locate a mate. The adult female gypsy moth cannot fly, but a chemical that she emits (pheromone) allows the males to locate her for mating. After mating, the eggs are laid in a single mass for overwintering (McManus and others 1992). Gypsy moth populations are subject to a number of natural controls that can limit their growth potential. Cool, wet weather during hatch can result in high levels of mortality in the young caterpillars. Epizootics of a naturally occurring virus and fungus can cause widespread collapses in gypsy moth populations. Despite these factors, gypsy moth populations periodically increase to outbreak levels and cause widespread defoliation (McManus and others 1992).

The gypsy moth has defoliated trees across nearly 72 million acres since 1924. About a half of that total, approximately 36 million acres, was defoliated between 1982 and 1992. This coincides with the advance of gypsy moths into the oak forest of Pennsylvania, Maryland, Virginia, and West Virginia. The gypsy moth arrived in the Southern Appalachians about 10 years ago. The first noticeable defoliation was reported in 1984. During the past 10 years, gypsy moths have defoliated more than 4 million acres in Virginia and more than 1 million acres in West Virginia (USDA FS 1994). Tree mortality after defoliation depends on the number of successive defoliations and the condition of the tree at the time of defoliation. The most severe losses occur in oak stands growing on poor sites in which trees have been under recent stress and are prone to oak decline.

Currently, only a portion of the SAA area is permanently infested by the gypsy moth. Isolated infestations have been detected and eradicated in the following counties in the SAA area: Clay, Buncombe, Ashe, Watauga, and Yancey counties in North Carolina; Giles, Floyd, and Carroll counties in Virginia; Rhea, Washington, Grainger, Johnson, Sequatchie, and Unicoi counties in Tennessee; and White and Fannin counties in Georgia. However, all of the area is at risk as the gypsy moth continues to spread. Oaks are a major component of the forests in the SAA area and a preferred food of gypsy moth larvae (Liebhold 1995).

Despite existing management strategies, losses are expected to continue as the moth migrates down the Appalachians. However, the rate at which spread occurs is affected by the strategies implemented.

Predictions based on the current rate of spread (fig. 6.8) are built on the assumption that eradication projects will continue to be implemented when isolated infestations are detected. Rates of spread would be expected to increase drastically if isolated infestations are not eradicated, with more than 90 percent of the SAA area becoming generally infested by the year 2010 (USDA FS & APHIS 1995, Liebhold and others 1995). Suppression programs do not have any effect on gypsy moth spread rates, but they may be used to mitigate losses in selected areas in the generally infested regions.

Although species vary in their ability to recover from gypsy moth defoliation, most will succumb after a few years of repeated attack. In some stands, trees die after several years of defoliation while in others one defoliation may kill trees depending on other site variables. Species composition and tree vigor are major factors in tree mortality caused by gypsy moth defoliation.

Vulnerability ratings of stands can be used to estimate the possible damage from gypsy moth attack. Vulnerability is defined as the probability of mortality that might result from defoliation.

Domestic quarantines are maintained to regulate the human-aided, long distance transport of gypsy moths from the infested to uninfested areas. Detection programs outside of the infested area pinpoint sites where gypsy moths have been introduced through inadvertent violations of the quarantine. When isolated reproducing populations are detected, eradication programs are implemented to eliminate them. Where gypsy moth is permanently established, suppression programs are carried out to reduce gypsy moth damages (USDA FS 1990).

In response to concerns that the U.S. Department of Agriculture (USDA) was not adequately addressing the apparent increase in spread rates over the past three decades (Liebhold and others 1992), the USDA Forest Service (FS) in cooperation with Animal and Plant Health Inspection Service (APHIS); the states of Michigan, West Virginia, Virginia, and North Carolina; and the National Park Service, has embarked on a pilot project called "Slow the Spread" (STS). The STS goal is to determine the feasibility of reducing the rate at which gypsy moth is currently spreading, by comprehensively implementing integrated pest management strategies over large geographic areas in the transition zone. The transition zone is located between the infested and uninfested areas. If the strategy proves successful, it could delay the impact and cost associated with gypsy moth outbreaks and suppression as gypsy moths spread through the SAA area. The STS project evaluation is expected to be complete by 1999.

The role of APHIS in STS is to administer the quarantine and conduct surveys to detect isolated infestations that are remote from the area that is generally infested. The role of the Forest Service is in gypsy moth survey and suppression in the generally infested area, either directly on federal lands or cooperatively with the states on nonfederal land. Both APHIS and the Forest Service assist states with projects to eradicate isolated infestations on nonfederal land, while the Forest Service alone is responsible for eradication on federal land (USDA FS 1990).

Specific management strategies for the gypsy moth are covered in detail in the Draft Environmental Impact Statement for Gypsy Moth Management in the United States, 1995 (DEIS). The preferred alternative includes USDA participation in suppression, eradication, and STS strategies. The DEIS is expected to be

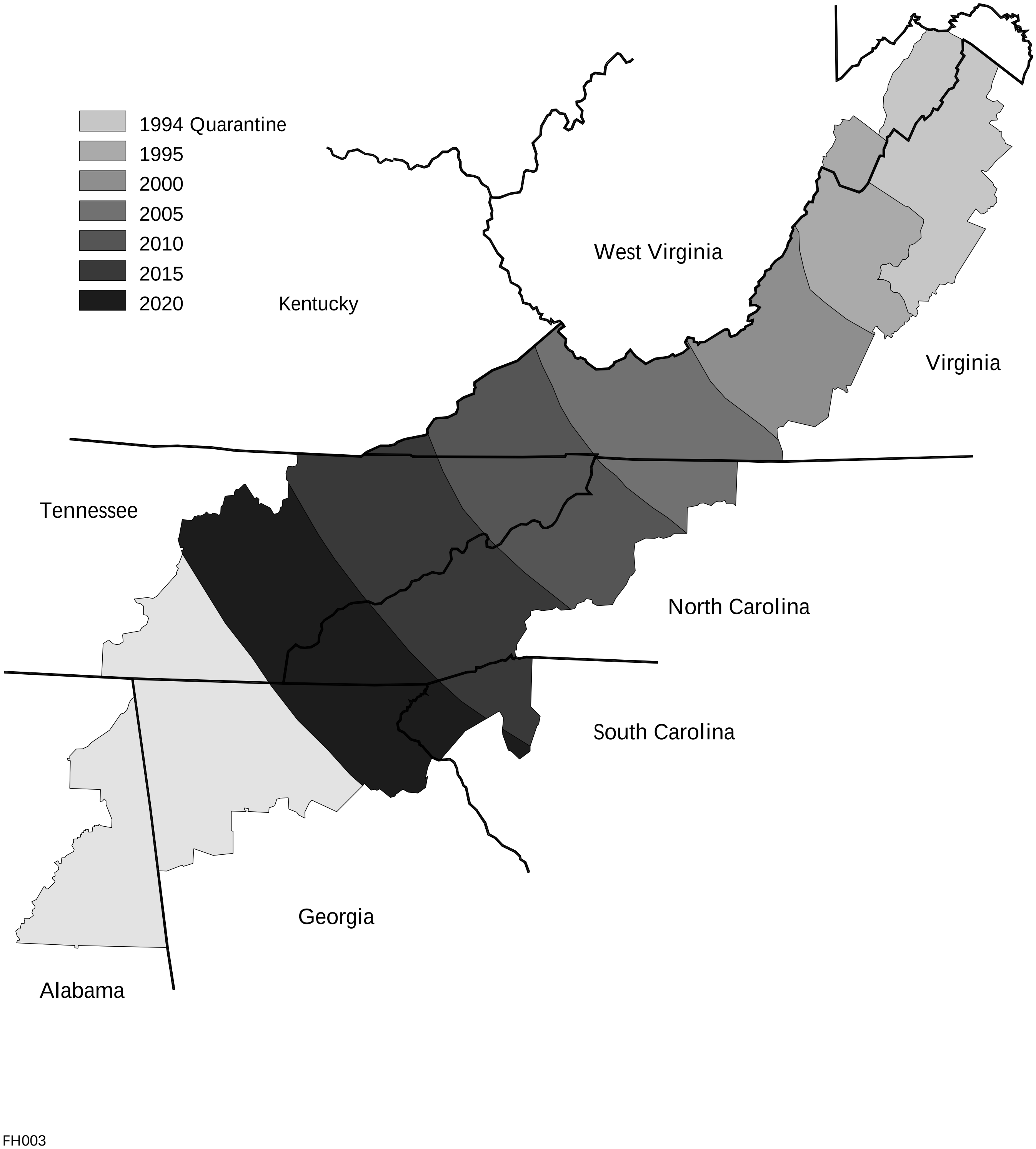


Figure 6.8 The current infestation and predicted spread of gypsy moth in the SAA area.

finalized by the end of 1996. The final document will supersede the existing 1985 FEIS and will provide the programmatic framework for gypsy moth control over the next 5 to 10 years.

Possible responses to gypsy moth range from doing nothing, to aggressively implementing one of the management strategies documented in the 1995 FEIS for Gypsy Moth Management in the United States. The selection of a management strategy appropriate to a specific area depends on the location of that area relative to the advancing front of gypsy moth populations. On sites where impacts from gypsy moth populations are expected to interfere with management objectives, such as recreation or timber, an array of control tactics is available to suppress or eradicate the infestation. Specific control tactics are discussed in detail in the 1995 FEIS and are briefly outlined in table 6.1.

Continued location, delineation, and elimination of isolated gypsy moth populations will be important to maintain gypsy moth spread at rates no faster than predicted. Further evaluation of the STS project is needed to determine if spread rates can be reduced from those predicted in Figure 6.8. If the STS strategy is demonstrated to be biologically sound and economically efficient, it may be integrated into the national strategy for management of the gypsy moth.

Silvicultural practices, in combination with programs such as STS, need to be implemented to control the damage from gypsy moth. Such practices can modify susceptibility and vulnerability of stands before the gypsy moth affects them.

It may be appropriate to develop plans to: (1) provide more information to the public about gypsy moth, (2) suggest control options, (3) develop and implement an integrated plan for altering the forest composition in high-risk areas on state and federal land, and (4) and assess high-risk areas on private land and assist landowners.

Hemlock Woolly Adelgid

Hemlock woolly adelgid, *Adelges tsugae,* an insect species native to Asia, was first identified in the eastern United States in 1924 in Richmond, VA, but it has recently expanded into the Southern Appalachians and threatens to spread throughout the ranges of eastern and Carolina hemlock. It is currently established along the mountainous regions around the Shenandoah Valley, and it is spreading southward along the Blue Ridge, and northward into New England. The adelgid may be spread by wind, birds, or mammals (McClure 1990). Long range movement of the adelgid by migrating songbirds in the spring could explain why northward spread has been faster than southward spread. All of the SAA area in Virginia, except for seven counties in the extreme western part of the commonwealth, are now infested.

There are two species of hemlock in the SAA area, eastern hemlock *(Tsuga canadensis)* and Carolina hemlock *(Tsuga caroliniana).* The former is an important component of riparian ecosystems, providing cooling shade for streams, contributing nutrients for streams through litterfall, and providing winter shelter for wildlife. It may also be important as a feeding and nesting niche for neotropical migrant birds (Rhea and Watson 1994). Carolina hemlock, on the other hand, is less understood ecologically. It generally occupies more xeric sites on ridges and rock outcrops, but it also probably provides cover and nesting sites for birds and small mammals. Both eastern hemlock and Carolina hemlock are threatened by the adelgid (figs. 6.9 and 6.10).

Once infested by the adelgid, hemlocks are weakened, gradually lose their foliage, and are unable to refoliate or produce cones. Mortality occurs after complete defoliation, generally within 5 years of initial infestation (McClure 1987). There is no known genetic resistance to adelgids in either of the native Appalachian hemlock species, but resistance is known to

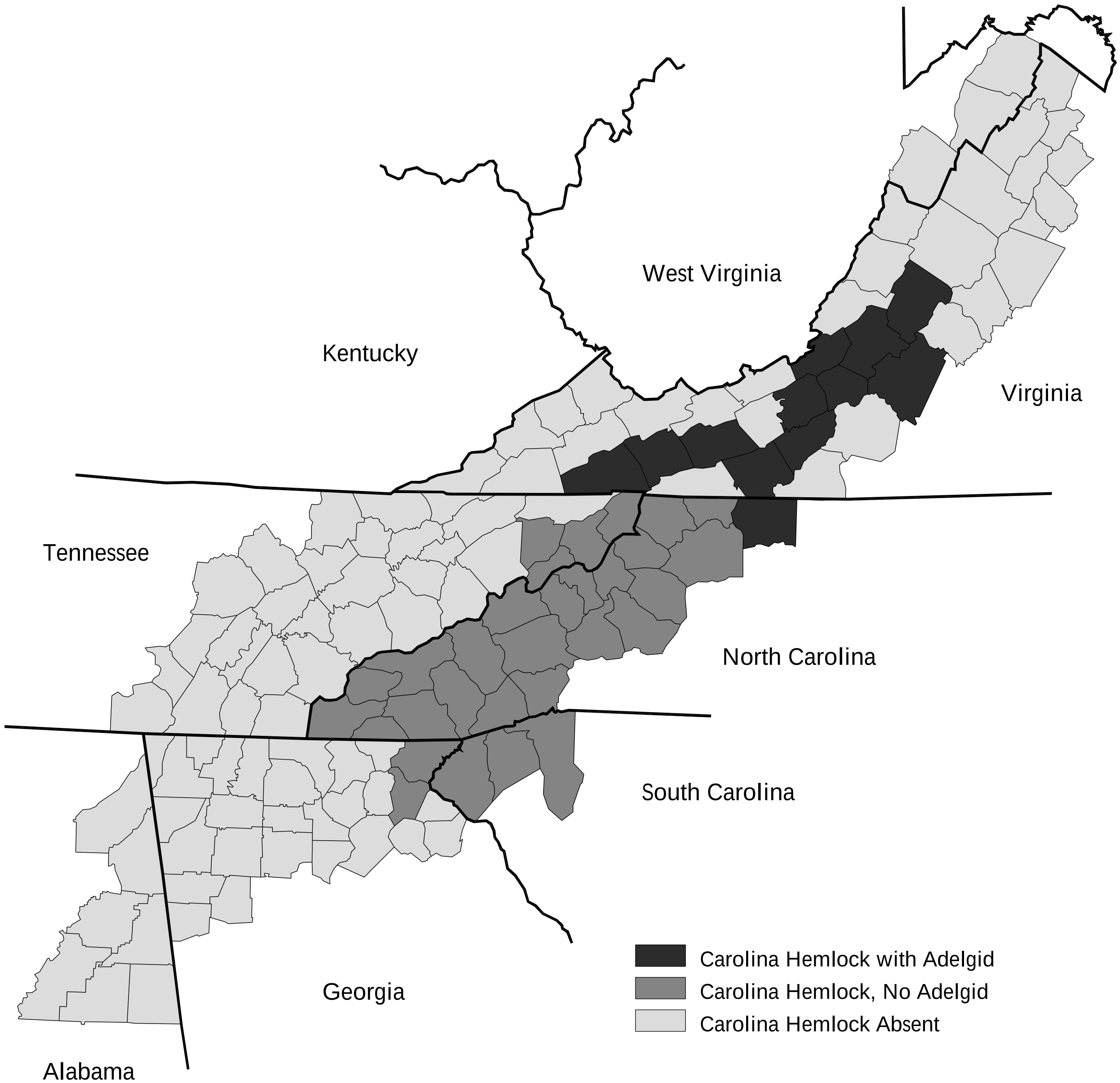
Table 6.1 Gypsy moth monitoring and treatment options available with suppression, eradication, and "slow the spread" strategies.

	Activity		
	Suppression	Eradication	Slow the Spread
	Monitoring Methods		
Treatment Options[1]	Defoliation survey	Pheromone traps	Pheromone traps
Bacillus thuringiensis	x	x	x
Diflubenzuron	x	x	x
Virus[2]	x	x	x
Mass Trapping[2]		x	x
Mating Disruption[2]		x	x
Sterile Insects[2]		x	x

[1]No treatment is an option in all strategies

occur in hemlocks native to Asia and in the two species native to the Western United States. Individual hemlock trees can be protected by spraying or soil treatments, but such treatment is impractical for forest trees (Rhea 1996). It appears that all untreated hemlocks, with the possible exception of small geographically-isolated populations, could eventually be killed by the adelgid. Loss of hemlock will negatively impact riparian ecosystems and may result in a substantial decline in habitat quality for birds and other wildlife (Rhea 1996).

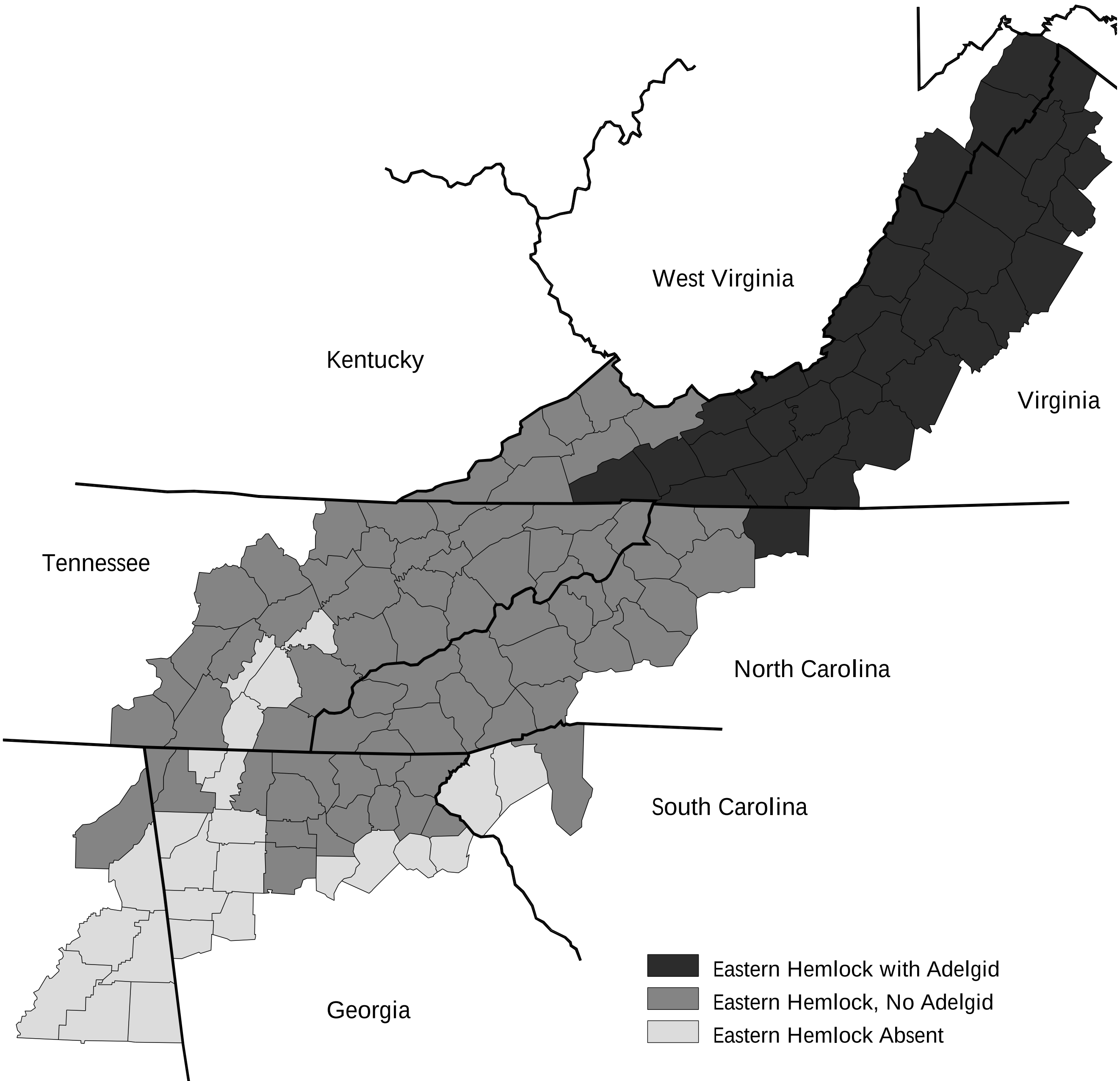
If the two species are to be preserved, efforts to treat and protect selected hemlocks in key areas should be continued and expanded. Research should be initiated into possible genetic engineering to transfer adelgid resistance from other hemlock species into eastern



and Carolina hemlocks. As soon as possible, a collection of seed and scion material should be made from throughout the ranges of both hemlock species in the Southern Appalachians. This material would then be used to establish a hemlock nursery in an area where it can readily be protected to preserve as much of the genetic bases of both species as possible.

Balsam Woolly Adelgid

The balsam woolly adelgid is one of the most significant disturbance factors to high-elevation Southern Appalachian spruce-fir forests. The balsam woolly adelgid was first detected in the Southern Appalachians on Mount Mitchell in the Black Mountains of



FH026

North Carolina in 1957, but it is suspected to have arrived in the southern mountains in the 1930s via reforestation experiments. When mature, Fraser fir, a Southern Appalachian endemic, is highly susceptible to adelgid attack. Death occurs within 5 years after first attacks. Adelgid infestations spread throughout the Black Mountains within a few years after initial detection (Speers 1958). The insect then spread to the Fraser fir communities throughout the Southern Appalachians. Fraser fir is the only fir species found in the southeastern United States and only has natural populations in western North Carolina, eastern Tennessee, and southwestern Virginia. Since the detection of the insect in the Southern Appalachians, the insect spread to all natural fir populations by the early 1980s.

The balsam woolly adelgid is a small, wingless insect whose North American populations are entirely female and reproduce from unfertilized eggs. An adelgid may lay as many as 100 eggs. The balsam woolly adelgid produces at least two generations per year in North America, and may produce up to four generations in the South. The adelgid is primarily disseminated by wind, but also by gravity, humans, nursery stock, and animals.

During feeding, the adelgid injects salivary compounds into the Fraser fir bole, stimulating the cambium to produce abnormal xylem. The xylem forms wider-than-normal annual rings, called *rotholz,* that are a dark red in color. *Rotholz* causes an increasing and significant reduction in sapwood conductance; thus, the balsam woolly adelgid causes severe water stress in infested Fraser firs (Speers 1958).

While most fir species have a wound response to adelgid infestation, this mechanism seems to be incomplete in most Fraser fir. Other fir species, especially those that have co-evolved with the insect, respond vigorously to adelgid damage and often recover. In fact, even a few stands of Fraser fir seem to have some resistance. The infested Fraser fir on Mount Rogers, Virginia, for example, often produce more outer bark at a higher rate than infested fir in the rest of the Southern Appalachians. This response may explain what appears to be a limited resistance of the Mount Rogers populations.

Human control efforts to reduce the spread of the adelgid have failed. The first infested trees detected in the Great Smoky Mountains were cut to slow the spread of infestation. Preventative cuts were soon discontinued, however, when it was discovered that eggs and young adelgids are detached during felling, literally creating a cloud of infestation sources that can be carried a considerable distance by wind. Various insecticides have proven effective. Unfortunately, most are also highly toxic to other insects. In addition, since the adelgid is a stem-feeder, aerial application techniques do not work, and each infested bole must be sprayed by hand. A less toxic, but less effective, alternative (potassium oleate soap) is applied annually to stands around the parking lot and observation tower trail at Clingman's Dome, but even these stands are beginning to show significant impact from the adelgid (Eager 1984).

The balsam woolly adelgid is extremely resistant to climate-caused mortality. Native and introduced predators of the insect have had little effect. The result has been that the adelgid has dramatically changed the Southern Appalachian spruce-fir ecosystem (Nicholas and others 1992).

The biology of the balsam woolly adelgid has been studied for more than 30 years, but the probability of Fraser fir extinction has not yet been answered satisfactorily. This uncertainty is reflected by the U.S. Fish and Wildlife Service's 1993 review of Fraser fir for possible listing as a threatened or endangered species. Its listing was deemed "possibly appropriate." Some scientists predict that it will survive, based on observations of successful regeneration and cone-bearing trees. There may be a cycle of adelgid infestation followed by fir regeneration that survives to produce viable seeds before death.

Asiatic Gypsy Moth

In 1990, U.S. and Canadian regulatory officials documented the introduction of the Asiatic gypsy moth (AGM) into various ports in the Pacific Northwest. Ports in Washington, Oregon, and British Columbia first reported the AGM in 1991. Ships carrying egg masses from Russian ports most likely introduced the pest while visiting West Coast ports. The moths were reported to have entered North Carolina in July 1993, arriving on a munitions ship docked near Wilmington. North Carolina has since begun a $9.4 million project to eliminate AGM from the two counties apparently affected. Female Asiatic gypsy moths are capable of strong directed flight and have a host range broader than that of the European gypsy moth strain currently established in North America. Studies have demonstrated that the AGM feeds more voraciously than the European gypsy moth, and grows faster and larger, feeding on similar tree species. In the former Soviet Union, the AGM browses on an estimated 600 tree species.

The flying ability of the female AGM means that the species could spread at a rate of three times as fast as its European relative. It is virtually impossible to tell the difference between the two gypsy moth strains based on appearances. To identify the Asian strain, scientists must capture a female moth in flight or genetic analysis of mitochondrial DNA markers.

Asiatic Oak Weevil

The Asiatic oak weevil, *Cyrtepistomus castaneuous*, is an accidentally introduced pest that has spread throughout eastern North American forests. It feeds on many hardwood tree species in the eastern United States. The insect has one generation per year, and overwinters primarily as larvae in the soil. Adults are most commonly found from July to October (Campbell and Schlarbaum 1994).

The weevil has not yet been reported to be causing economic damage to timber. Probably the most critical damage is to the root systems in the dormant season through midsummer by the larvae. The insect usually does not cause enough visible damage to be noticed, but defoliation of seedlings, under controlled conditions can be severe (Schlarbaum and others 1993).

Future prognosis is uncertain. The Asiatic oak weevil may become a problem in seed orchards or in areas with high concentrations of oak (Triplehorn 1955). There have been few studies monitoring the populations or the damage to oak. If this pest is to be understood, it must be monitored for population increases and damage to forests. Recommendations for changes in management practices require sufficient data on susceptibility and vulnerability.

Exotic Plants

When exotic species are introduced into a favorable new environment without their normal complement of limiting factors such as pathogens, predators, and competition, they often expand aggressively. Introduced plants that can grow, reproduce, and spread rapidly tend to produce major disturbances in their new plant communities. The effects of exotic plants depend on the specific character of the plants themselves, and the intended use of the land they occupy.

Exotic plant species have been introduced into the Southern Appalachians since the beginning of European settlement of the region. Some plants were brought intentionally as agricultural crops and domestic plants. Others were introduced accidentally when seeds were carried into the region by wind, water, humans, or animals. Many of these introductions have posed no problems, remaining essentially within the boundaries of human cultivation. Some, however, have escaped and spread, displacing native vegetation, and causing ecological disturbance and, in some cases, economic loss or impaired land use.

Both privet (*Lingustrum* spp.) and Japanese honeysuckle *(Lonicera japonica)* are shade-tolerant and form a dense layer of low vegetation, sometimes altering forest regeneration patterns. Asiatic bittersweet *(Celatrus orbiculatis)* another pervasive shade-tolerant plant, is not known to hamper stand regeneration. Nepalgrass *(Microstegium vimineum)* carpets moist forest understories, changing the composition of the herbaceous layer.

Some introduced shade-tolerant species, such as autumn olive *(Elaeagnus umbellata),* multiflora rose *(Rosa multiflora),* and kudzu *(Pueraria lobata)* can cause local problems. Canada thistle *(Cirsium arvense),* is a large, fast growing, spiny plant that aggressively colonizes roadsides, fields, lawns, and other relatively open areas. It causes losses on cropland, obstructs rights-of-way, impairs use of residential and recreation areas, and displaces native flora on sites it colonizes.

Sometimes introduced plants produce positive effects. While Japanese honeysuckle *(Lonicera japonica)* can displace native vegetation, it produces valuable browse for deer, fruit for songbirds, and nesting and escape cover for a variety of birds and small mammals. It also bears masses of fragrant blossoms, which probably account for its original introduction. Honeysuckle, might be considered desirable in some residential areas, and in many forestry and wildlife management areas, but it is undesirable as a competitor with sensitive plants, or in areas such as national parks, where maintenance of native vegetation is a management objective.

National forests in the Southern Appalachians have generally not attempted to control exotic plants except for kudzu, which has serious localized impacts on forestry. Other exotics, such as introduced privet threaten to become problems in spots on national forests. Non-native plants such as crown vetch, lespedezas, white dutch clover, and tall fescue have commonly been planted for erosion control after timber harvests and road construction, or as food for wildlife.

National parks, however, generally have programs to control exotic plants. Parks in the SAA region list approximately 40 species varying by park requiring control. Other exotic plants currently in the U.S. have the potential to invade forests and parklands. Where national parks adjoin national forests and other federal and state ownerships, uncontrolled infestations of exotic plants often cross boundaries and create continuing management problems for the parks.

Four basic strategies are available for solving exotic plant problems: prevention, eradication, suppression, and biological control.

- Prevention is the identification and interdiction of exotic plants, plant parts, or plant propagules before they enter the United States.
- Eradication is the complete elimination of a population of an introduced exotic. It is effective against relatively small, localized infestations but requires intense effort and may be relatively expensive. Extensive use of herbicides is usually necessary, and some injury to desirable plants or the surrounding environment may be unavoidable. Eradication of large, well-established populations usually is not feasible.
- Suppression is the periodic control or elimination of a population of exotics within a generally infested area, such as the seasonal treatment of thistles within a campground. Suppression offers only a temporary solution to the exotic plant problem, and generally must be repeated at regular intervals. It generally becomes a permanent maintenance project unless biological control can be established.
- Biological control involves the identification and introduction of an exotic plant's natural control agents, usually insects or fungi, from its native environment. This is an expensive and time-consuming process because extensive research must be conducted to ensure that the proposed control agent will not cause further problems in its new environment. Biological control, if successful, brings the exotic plant species into balance with its environment so that it continues to be a component of the plant community but will not dominate it. However, biological control is not always possible or practical.