How have biological agents including insects and disease-causing organisms influenced the overall health of the South's forests and how will they likely affect it in the future?

Chapter 17: Impact of Pests on Forest Health

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Key Findings

■ Insects and diseases have had considerable impact on southern forests during the past century, and serious damage from native pests and nonnative invasive pests is expected to continue.

■ Generally, the more diverse and vigorous a stand, the less likely it is to suffer significant insect or disease damage. As diversity decreases or vigor declines susceptibility to catastrophic pest damage increases.

■ Longleaf pine is the least susceptible of the southern pines to most insect and disease pests currently affecting southern forests, and its restoration on former longleaf pine sites currently forested with loblolly, slash, and shortleaf pine should lessen the impact of known insect and disease pests in those areas.

■ Because of land use history and the decimation of American chestnut by the chestnut blight, oaks probably represent a larger component of the southern forests today than at any time in the past.

■ Oak decline will continue to be a forest health issue in the region especially on national forest land, which has a higher frequency of attributes that are important in oak decline etiology (old trees, low soil fertility, and shallow soils). Among national forests, the George Washington and Jefferson have the highest incidence of this disease.

■ In central Texas, oak wilt has emerged as a major disease, causing significant damage to an environmentally restricted and vulnerable resource that is primarily valued for aesthetics.

■ The southern pine beetle will play anlñcreasingly important role in the future of the South's pine forests. Catastrophic population buildups will continue to occur, especially in overstocked, old, less vigorous forests.

■ For virtually all pests, stand age and density, tree size, and species composition affect pest behavior. Forest pest impact is greater in less intensively managed forests, and on small private tracts and public landholdings than on private industrial forests.

■ Integrated pest management, which employs silvicultural methods and various mechanical, manual, biological, and chemical tools, is the most successful strategy currently available for pest management.

■ Introduced insect and disease pests have the potential to permanently alter ecosystems in the South.

■ American chestnut has been eliminated from its niche by chestnut blight, caused by an introduced fungus.

■ Dogwoods are being eliminated from their native habitats above 3,000-foot elevation by dogwood anthracnose, caused by another introduced fungus.

■ Damage by the beech bark disease (caused by a complex of introduced insects and fungi) has only just begun in the South; barring an unpredicted natural barrier or research success, it is expected to spread throughout the southern range of American beech and permanently reduce it from a codominant tree species to a deformed mid- to understory species.

■ All eastern and Carolina hemlocks, except for treated trees and geographically isolated populations, could be killed by an introduced insect, the hemlock woolly adelgid.

■ Balsam and Fraser fir are now candidate species for listing under the Endangered Species Act due to the activity of the introduced balsam woolly adelgid.

■ The gypsy moth and the fungus causing butternut canker, both introduced species, are expected to significantly increase in activity in the South during the next 30 years, permanently altering the species composition of affected southern forests.

■ Data are not available on pest management (including silvicultural manipulation and pesticide use) on private land in the South.

■ Brown-spot disease has been estimated to reduce total annual growth of southern pines by 16 million cubic feet (0.453 million cubic meters). Existing management strategies could significantly reduce this loss.

■ Extensive planting of susceptible slash and loblolly pines since the 1930s has resulted in a continuing epidemic of fusiform rust. Damage appears to have reached equilibrium. At present, fusiform rust infects at least 10 percent of the slash or loblolly pines on over 13.4 million acres (28 percent of the host type) South-wide. Use of available, genetically improved, disease resistant seedlings, and intensively managing

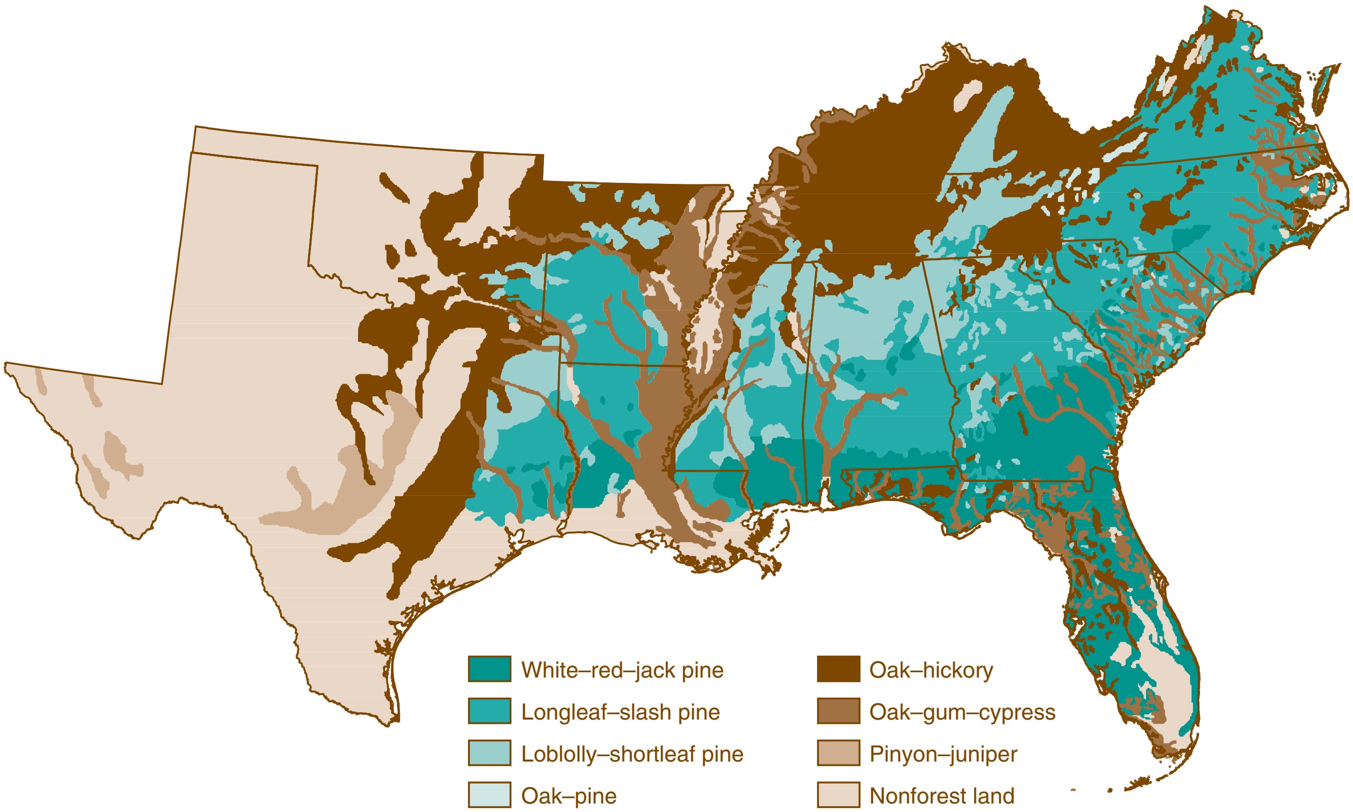

Figure 17.1—Location of major forest cover types in the Southern United States (based on Eyre 1980).

infected stands have the potential of reducing this damage.

■ Concern about exportation of oak wilt to Europe has caused the European Economic Community to impose a quarantine on the importation of oak logs from United States counties where oak wilt has been documented.

■ Reproduction weevils can cause 30 to 90 percent mortality in planted seedlings in the South

■ Average annual losses caused by the southern pine beetle in the Southern United States exceed 100 million board feet of sawtimber plus 20 million cubic feet of smaller sized growing stock. From 1991 to 1996, total value of trees killed by the beetle in the South was estimated at $493 million. Although yet to be tried on a broad scale, prevention strategies currently available to forest managers are believed to have the potential to reduce the damage caused by this insect.

■ Hardwood borers are estimated to cause more than $29 million in loss (timber value) per year. Periodic outbreaks of specific borers, such as the current epizootic of the red oak borer in northern Arkansas, cause significant damage to forest ecosystems and local economies.

Introduction

Any assessment of the region's forests would be incomplete without an evaluation of forest health. In this chapter, we provide such an evaluation for the forests of the South. We have restricted our discussion of forests to areas regenerated either naturally or through the intervention of land managers (fig. 17.1). We have excluded from our discussion specialized, small areas of forestry-related lands such as seed tree orchards or forest tree nurseries. While they are important to forestry, these areas are essentially intensively managed single species, juvenile forest stands. While no further specific mention is made of seed orchards and nurseries, it must be remembered that they are the primary production points for the genetically improved, pest-resistant plants discussed in Genetics. We have also restricted the discussion in this chapter to insect and disease pests that affect the overall health of the southern forests. Nonnative invasive plants that are major pests in the southern forest ecosystem and that have serious potential to disturb the overall health of those forests are discussed in the chapter on vegetation of the forests—chapter 2. All discussion of this extremely serious problem is found in that chapter.

"Forest health" is a concept that became popular in the 1990s and remains popular even though its precise meaning is open to debate. Often, damaging populations of forest pests are indicators of other predisposing factors such as overcrowding, over maturity, floods, drought, fire, or off-site plantings. Any analysis of the health of the forest reflects not only the well being of the ecosystem, but also the human expectations for that forest.

A healthy forest has the capacity to vigorously renew itself and to recover from a wide range of disturbances, while meeting current and future human needs for desired levels of values, uses, products, and services.

Methods and Data Sources

Information for this chapter is derived from two primary sources—published literature and the experience of the authors and their colleagues who are engaged in pest management. Experts in State and Federal agencies and in universities and other private organizations have provided information on specific pests.

A limited selection of articles is cited. Cited articles form only a small part of the extensive literature about pests of southern forests. Additional information about forest pests and their control is readily available from State and Federal forestry agencies or on the Internet (two good starting points are http://fhpr8.srs.fs.fed.us/ and http://www.na.fs.fed.us/spfo/pubs/fth_pub_pages/fidl.htm).

Results

We begin by describing pest problems in general terms and by recommending an approach to controlling pest-caused losses called integrated pest management (IPM). In this approach, pest management is viewed simply as one part of the job of managing a forest. Six common methods of pest control are described in general terms. Finally, we describe the 21 forest pests generally considered most important in the South. They are presented in four categories: native diseases, native insects, nonnative diseases, and nonnative insects.

Impact of Pests on Southern Forests

Insects and diseases can negatively impact forests in several ways. They can kill trees; reduce their growth; degrade wood and other products; cause dieback, decline and deformity; change the composition of the forest; reduce biological diversity; affect water quality and quantity; create safety hazards; increase fire risk; reduce the quality of the landscape; and cause other kinds of damage. Some of these types of damage may not be significant if they are not detrimental to the intended use of the forests.

It is important to note that pest outbreaks do not respect ownership boundaries. While the management strategies discussed below may lead to a measure of protection of forest lands from destructive insect or disease activity, failure of a landowner or land-manager to control pest outbreaks can (and often does) affect other owners lands. Passive management of forests can easily lead to pest population spillover and negatively affect forest resources of adjacent landowners.

Although impact can be expressed in many ways, it is usually measured in relation to number of trees killed, volume of timber lost, area of defoliation, or amount of growth loss resulting from pest activity. It has been estimated that forest insects account for 20 percent of the total negative growth impact on forest trees, while diseases account for 45 percent of it (Tainter and Baker 1996). Recently foresters have tried to express impact using values, such as quality of the landscape, water quality, biological diversity, and other values, that refer to the intended use of the forest ecosystem but are very difficult to assess objectively.

Native disease-causing organisms and insects are natural components of ecosystems. They often have a positive impact by contributing to biodiversity, improving habitat for various flora and fauna, and hastening decomposition and ecological succession of the forest (Coulson and Witter 1984).

Whether the effects of insects or diseases are perceived as positive or negative depends on the intended use of the forest. In a "natural" forest native insects and diseases are simply part of the ecological processes that maintain a mosaic of ages and stand conditions. Dead and dying trees contribute to the health of natural forests by contributing to the crucial processes that recycle elements from dead or downed trees. They also are among the mechanisms driving removal of the weakest and favoring the healthiest trees in any stand.

In an industrial plantation, where profit from wood is the primary objective, the presence of dead and dying trees is not generally considered a healthy condition. The more intensive the forest management, the more forest pests become potential threats for the intended use of the forest. However, with more intensive management this potential damage is generally precluded by management practices designed to forestall pest-caused damage. Impacts of insects and diseases can be even greater in urban forests, where buildings and other structures and peoples' lives are threatened by falling trees or branches.

Problems Caused by Invasive Nonnative Pests

As global trade and travel increases, so do the risks that nonnative forest pests will be introduced into the United States. They are often moved unintentionally as riders on plants, animals, personal property, or packing materials.

Nonnative insects and diseases have permanently changed southern forest ecosystems, and efforts to control them have cost hundreds of millions of dollars. Once established, populations of some imported insects and disease-causing organisms have quickly increased because natural control agents present in their native habitat were absent or ineffective in the new habitat. As a result, exotic pests have changed, and will continue to change, entire ecosystems by displacing native flora and fauna.

Early Forest Pest Control

Until the late 1940s, little was done in the South to control forest pests. They were viewed like wind, lightning, or other acts of God. It was believed that little could be done to control them.

After World War II, State and Federal agencies in the South began to recognize forest protection as a necessary part of forest management. Maximizing the production of wood and wood fiber in the South became desirable. Congress authorized funds to build the capacity to protect forests at the State and Federal levels. State forestry organizations hired forest protection specialists; and universities and colleges began to teach courses about protection of forests from fire, insects, and disease. State and Federal agencies as well as universities conducted research on forest pests. Through the 1950s, 1960s, and 1970s forest management was commodity or use driven, and some control methods used, though highly effective in generating product, were not environmentally friendly.

Emphasis was placed on chemical control, especially after the development of chlorinated hydrocarbon pesticides, such as DDT, BHC, and lindane. During this era, control of forest pests required intensive labor and, in many cases, was perceived by many people as being damaging to the environment as well as injurious to the people who applied the treatments. Rachel Carson's book, *Silent Spring*, decried the existing pattern of pesticide use, calling instead for a more intelligent use of these chemicals. The book catalyzed the environmental movement in the United States during the 1960s and 1970s. Public outcries against the use of chemicals in the forest resulted in the banning of several pesticides and challenged managers to use and researchers to develop additional environmentally friendly methods for controlling forest pests.

Integrated Pest Management

The best approach to managing pest problems is to combine prevention and control strategies to meet natural resource management objectives. This approach is called IPM.

Pest management should be a part of the overall management plan for a forest. The need for pest control can usually be minimized through wise, long-term forestry practices that promote healthy and vigorous trees. The control methods chosen will depend on the kind and amount of control necessary, the costs, and the benefits within legal, environmental, and other constraints.

The most important principle of pest control is to use a control method only when it will prevent the pest from causing more damage than is reasonable to accept. Even though a pest is present, it may not be necessary to control it. Both economics and ecology affect the decision to control or not. Exceptions are newly introduced nonnative invasive pests for which adequate data on potential spread and impact are unavailable.

The four main pest management strategies are: (1) prevention, making the forest more resistant to the invasion of pests or more resilient if attacked; (2) suppression, lowering unacceptably high pest populations to acceptable levels; (3) eradication, eliminating the pest from the ecosystem; and (4) exclusion, preventing the movement of nonnative pests into a new area. Ideally, managers will scientifically select the most effective, most environmentally friendly method (Thatcher and others 1986).

Control Methods

Silviculture—Silvicultural methods for controlling pests include practices that favor the appropriate species for the site or increase the vigor of the plants left on the site. During site preparation, thinning, or any other stand improvement activities, opportunities exist to favor the healthiest and most natural components of an ecosystem. Normally, vigorous, mixed-age and mixed-species forests are more resistant to devastation by native pests than are single-species plantations.

Genetics—Often, a portion of a population is less affected by a pest than is the remainder of the population. This ability to tolerate attack by a pest may result from inherent resistance in the population. When resistance is genetically based, favoring and propagating resistant individuals will add a measure of protection to the next generation. Breeding to enhance genetic resistance takes advantage of a natural process, augmenting it but not significantly altering it. However, as managers breed genetically resistant plants, pest populations adapt to attack the newly developed resistant host material. The process of genetic manipulation is, therefore, an ongoing process, not a permanent solution.

In recent years a new technology, genetic engineering (which involves altering the genetic structure of living organisms at the molecular level) has emerged. Pests can be engineered, altering their genes to make them less successful in reproducing or less aggressive in attacking potential host material. Alternatively, hosts can be genetically engineered to make them more resistant, or even toxic, to invading pests. Currently, little genetic engineering is being done with southern forest trees. The potential of this method is unclear because use of this method is currently very controversial. Genetic engineering is perceived by some as having the potential to accidentally kill beneficial organisms or even to create new pests.

Quarantine—State and Federal agencies often restrict the movement of live plants or animals across State or national boundaries unless they are declared free of pests. These quarantines have been fairly effective in reducing the spread of known pest organisms but have failed to stop many organisms that are not pests in their native environment but become pests when moved. As discussed elsewhere, quarantine restrictions have been ineffective in preventing the introduction of ornamental plants, which subsequently are shown to have no natural enemies in their new ecosystems. Plant quarantine to ensure the health of incoming vegetative materials and prevent the dissemination of infested or infected materials is a critical process for protecting the future health of the southern forests.

Sanitation—Sanitation involves removing infected or pest-infested materials from an ecosystem in an attempt to reduce or eliminate pest impact in response to pest outbreaks, or as a part of regularly scheduled stand maintenance activities. Affected trees or small blocks of trees are selectively removed, leaving the healthy vigorous ones. Sanitation can be highly effective if signs and/or symptoms are readily visible.

However, where symptoms are masked, large numbers of infected or infested trees may be left. Prescribed fire is often used to suppress pests either by killing them or destroying or modifying their habitats.

Chemical control—When properly applied, pesticides are very useful in suppressing or eradicating pest organisms. Pesticides used in the southern forests include insecticides, herbicides, rodenticides, and fungicides (U.S. Department of Agriculture Forest Service 1992).

Pesticides can suppress pest populations by killing the pests outright or by moderating their activity. They may be applied from the air or the ground. New pesticides have been developed that kill only the intended pest or affect a very limited number of target non-organisms. In southern forests a limited number of treatments (2 to 4) in the 40- to 120-year rotation may occur.

Despite an impressive record of success in controlling pests, and progress to improve their selectivity, pesticide use in the South has declined steadily in numbers of acres treated, as well as in rates of pesticide applied per acre. Data are not available on pesticide use on industrial and private land in the South. It is believed that the downward trend in pesticide use is not as marked on these lands as it is on national forests.

Biological control—Biological control involves the use of one organism to moderate or control the behavior of another organism. In biological control, the manager attempts to locate a natural enemy of a pest and augment its population to control unacceptable population levels of the pest. Viruses, bacteria, fungi, and insects have all been used in biological control (Stairs 1971). Apparent biocontrol of an epidemic population of gypsy moth by the fungus *Entomophaga miamiaga*, the use of a virus against sawflies, and the use of another fungus against the introduced pine sawfly are examples of successful biocontrol. Biological control, however, suffers from a problem very similar to genetic control. Often, this process has only provided short-term solutions. Natural enemies of a pest organism may fail to colonize the same niche as the pest, and either totally fail as biocontrol agents, or themselves become pests in the niche they do colonize.

Damaging Insect and Disease Agents

The following information on 21 of the most important forest pests in the Southern United States is provided by experts from universities, the private sector, and State and Federal forestry agencies.

Native Diseases of Conifers

Fusiform rust—Fusiform rust, caused by the fungus *Cronartium fusiforme* f. sp. *fusiforme*, occurs primarily on slash and loblolly pines. It is considered the most destructive disease of southern pines, causing cigar-shaped galls on the main stem that are generally fatal (Anderson and others 1980, Czabator 1971).

Extensive planting of susceptible slash and loblolly pines since the 1930s has resulted in an epidemic of fusiform rust. Infected trees can be found throughout the southern pine region (fig. 17.2), but losses are most serious on Coastal Plain sites from Louisiana to southeastern South Carolina. Several variables including weather, amount of inoculum, abundance of oaks (the alternate host), and susceptibility of the pine species govern incidence of the disease.

Nonindustrial private and industrial forest landowners own a majority of the pine host type in the South. Over 13.4 million acres Southwide have at least 10 percent of the slash and/or loblolly pines infected (Starkey and others 1997).

Control strategies designed to minimize the impacts of fusiform rust are documented in several publications. They include genetic selection, silvicultural manipulation, and chemical treatment (Anderson and others 1980, Belanger and others 1991, Dinus and Schmidt 1977, Matthews and Anderson 1979, Schmidt 1998, U.S. Department of Agriculture Forest Service 1971).

More intensively managed areas generally are at higher risk from fusiform rust. The more rapidly a tree grows, the greater its risk of becoming infected. Most practices that improve pine growth, therefore, favor rust development (Dinus and Schmidt 1977, Schmidt 1998).

The incidence and impact of fusiform rust is projected to remain stable or increase slightly in the future. A study by Starkey and others (1997) showed that there was a slight regional trend towards higher infection rates in slash pine and a slightly reduced rate for loblolly pine. In the long term, fusiform rust could be reduced by planting disease-resistant seedlings.

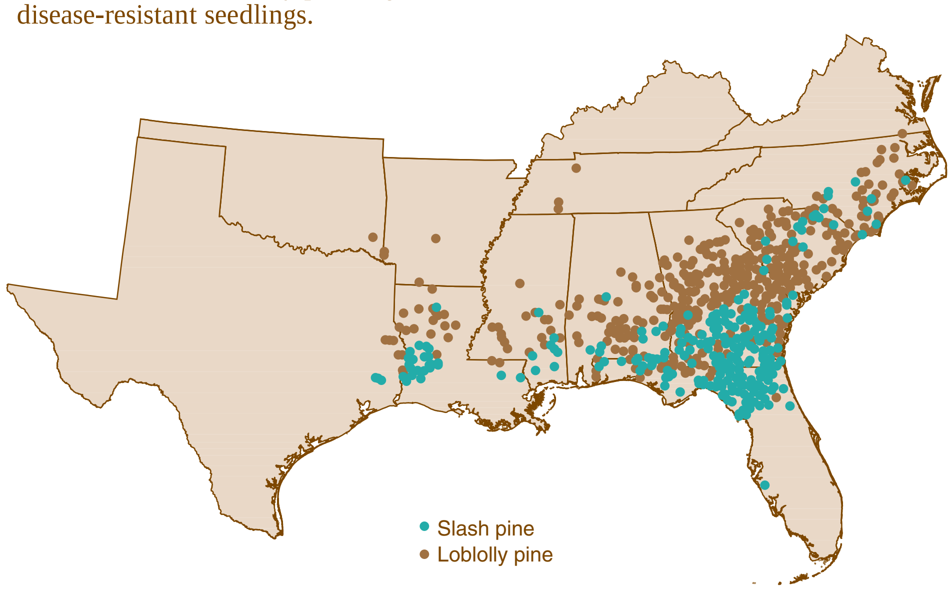

Figure 17.2—Incidence of fusiform rust on more than 10 percent of slash and loblolly pine on Forest Inventory and Analysis plots.

Annosus root disease—Annosus root disease (ARD), caused by the fungus *Heterobasidion annosum*, produces significant losses of conifers across the South. On sandy, well-drained sites, this disease causes growth loss or kills trees. It is most often associated with thinning of loblolly, longleaf, shortleaf, slash, and white pine plantations. Slash and loblolly pines are the most commonly planted species in the South and are both very susceptible to ARD (Robbins 1984, Stambaugh 1989).

A survey of ARD in the South documented 2 to 3 percent mortality and a 44 to 60 percent rate of disease occurrence in planted pine. Documented rates of radial and height growth are significantly less for diseased than for healthy pines (Applegate 1971, Froelich and others 1977, Morris 1970). The fungus enters a stand by infecting freshly cut pine stumps. It progresses into roots, and, thereafter, it grows from tree-to-tree via root contacts and grafts. First entry into a stand can be prevented by treating susceptible new stumps with borax.

The primary risk factors associated with ARD are the amount of host type available, the timing and degree of management activity, and the soil and site conditions. Risk of damage caused by ARD decreases as clay content in the surface layer of soil increases, giving us an effective risk mapping tool (fig. 17.3). In the Southeast, risk of ARD is high or moderately high on an estimated 163.5 million acres, not all currently forested (Hoffard and others 1995). Silvicultural and chemical controls can be used to minimize the impact of ARD on high-risk sites. A biological control that appears to be effective does not have EPA registration and is currently unavailable to managers.

Private industry generally favors intensive plantation management of loblolly and slash pine on short rotations of 30 to 35 years. Severity of ARD in this type of management is directly related to the number of thinnings in the stand and the proportion of sand in the soil. Industrial owners are more likely to use a full range of management options. Short rotations and intensive management generally result in low ARD caused mortality on industry lands.

On managed public land, the current trend is to restrict the amount of intensive plantation management in favor of longer rotations for watershed protection and recreation. Restoration of longleaf pine is being promoted. Of the southern pines, longleaf is considered the least susceptible to root disease, and its restoration on sites currently occupied with other pines will lessen the impact of ARD.

When pine stands managed on longer rotations have few intermediate cuts, the risk of ARD development is generally reduced. However, strategies that promote uneven-aged management with frequent cuts will likely increase incidence and severity of ARD. Management for red-cockaded woodpecker habitat, which requires frequent mid-rotation thinnings, may also increase ARD on high-risk sites (Cram 1994).

On public reserved land, where management activities are minimal, ARD will have little impact.

Private nonindustrial land, which includes 69 percent of the South's forest lands, is managed in a variety of ways, creating a range of risk for ARD. The Conservation Reserve Program (CRP), which has assisted private landowners to reforest thousands of acres of erodable cropland, has resulted in increased risk for ARD in the plantations it supports by favoring early thinning. Approximately 400,000 of the 2 million acres enrolled are on high-risk soils for ARD development (Anderson and Mistretta 1982).

Brown spot needle disease of longleaf pine—Brown spot needle disease, caused by the fungus *Scirrhia acicola*, is considered the most serious disease of longleaf pine. It causes seedlings to remain in the grass stage (an early growth stage of longleaf in which the seedling looks like a clump of grass) for an abnormally long time, delaying initiation of height growth and causing loss of potential wood production. Severely infected trees often die. Young longleaf trees become more resistant to this disease once they grow out of the grass stage.

This disease occurs from Virginia to Texas, primarily on the Atlantic and Gulf Coastal Plains. It is more severe in certain geographic areas (fig. 17.4). It has been estimated to reduce total annual growth of southern pine timber by 16 million cubic feet (0.453 million cubic meters).

At present, longleaf pine occupies only about 5 million acres of its former 60 million acre range. Difficulties in storing and handling longleaf pine seedlings have discouraged managers from planting this species.

Recent work has led to the production of healthier seedlings for planting; planting success has improved on sites where, historically, longleaf was the dominant species (Cordell and others 1989, Kais 1989). Several possible treatments are available for managers to limit the impact of this disease on their

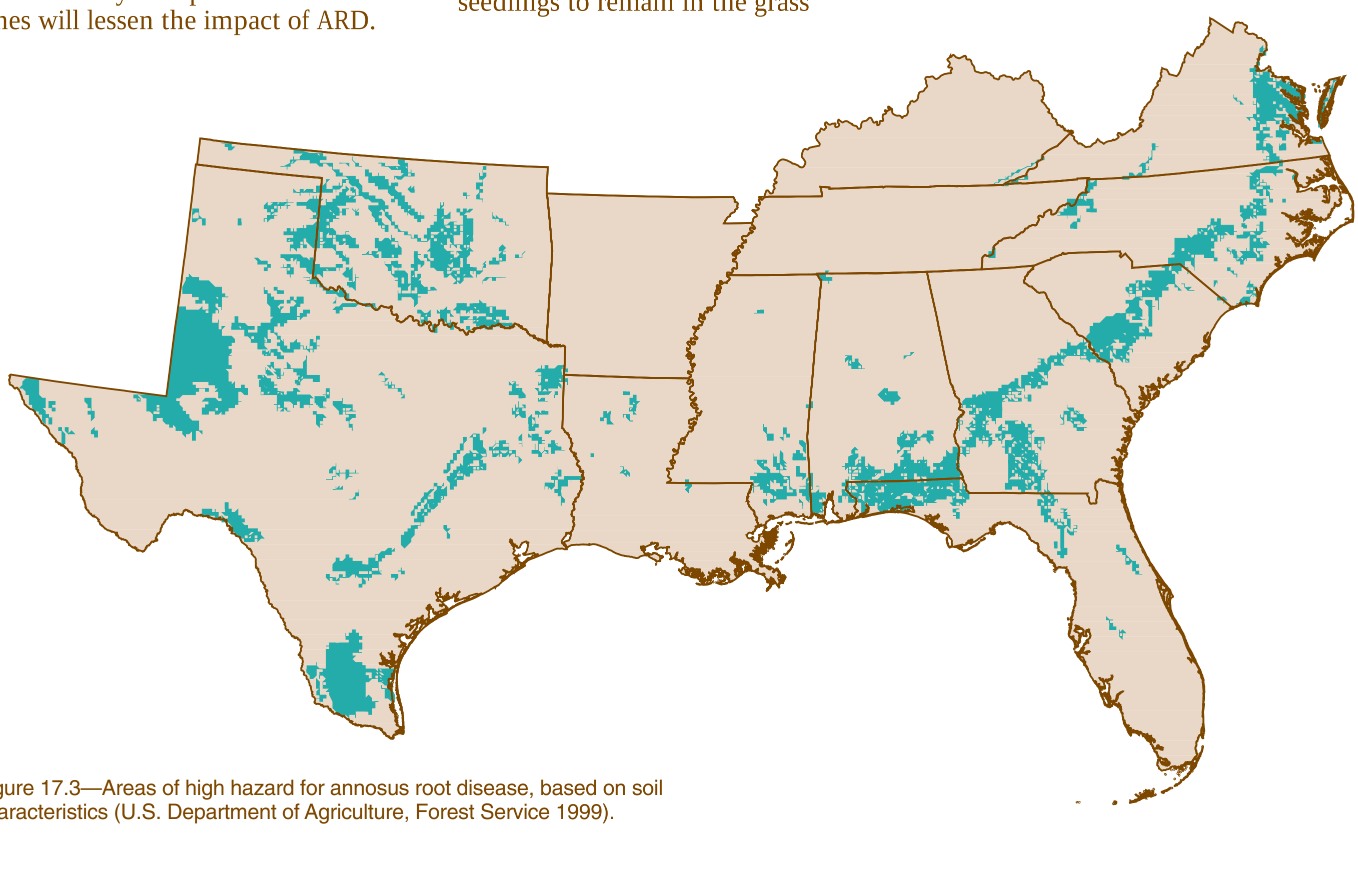

Figure 17.3—Areas of high hazard for annosus root disease, based on soil characteristics (U.S. Department of Agriculture, Forest Service 1999).

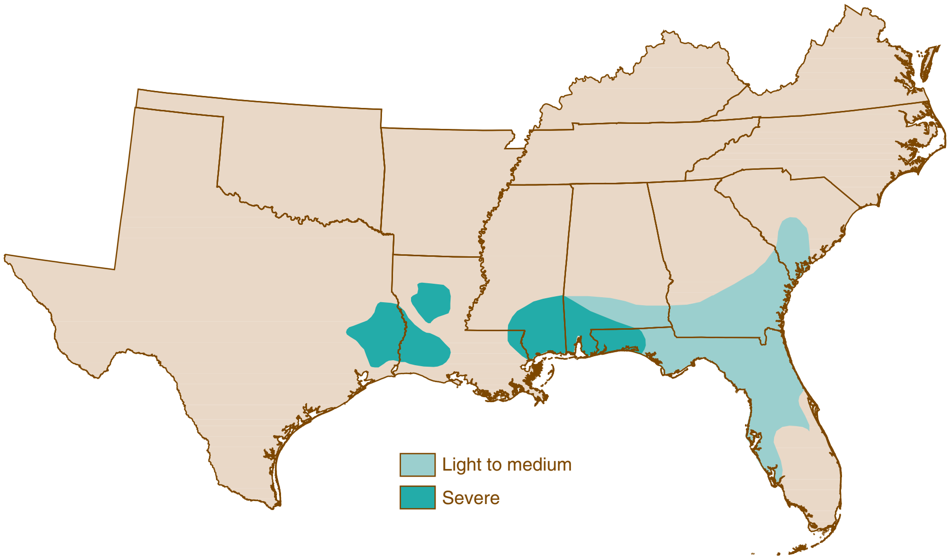

Figure 17.4—Brown spot disease range (U.S. Department of Agriculture, Forest Service 1999).

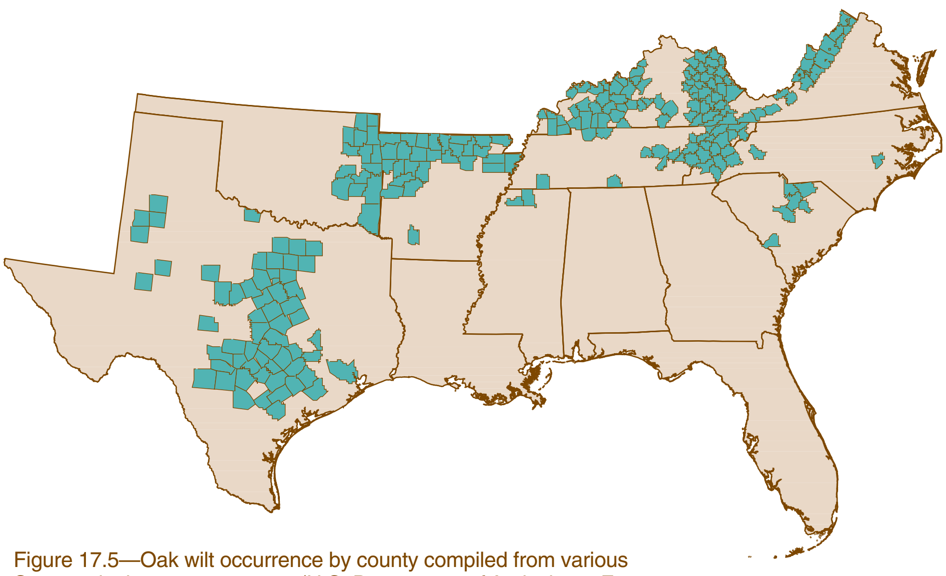

Figure 17.5—Oak wilt occurrence by county compiled from various State and other survey reports (U.S. Department of Agriculture, Forest Service 1999).

grass-stage longleaf pine seedlings. They include silvicultural, fire, and fungicidal options.

Chemical treatment of seedlings and prescribed burning are most likely to be used by managers of private industry land and managed public land. State forestry agencies are having success assisting private nonindustrial landowners in controlling brown spot; but there are a huge number of landowners to contact, and this effort is very slow.

It is expected that disease incidence will increase as attempts are made to return longleaf to its native range.

Native Diseases of Hardwoods

Oak wilt—Oak wilt is a vascular wilt disease of oaks that currently is found only in North America. The causal fungus (*Ceratocystis fagacearum*) was first identified in Wisconsin in 1942, but scientists believe the disease is native to North America and was present long before its discovery (MacDonald 1995, Tainter and Baker 1996). Oak wilt is known to occur in 21 States in the Central and Eastern United States (Rexrode and Brown 1983); 9 of the 13 Southern States are known to harbor the disease, but severe mortality is occurring only in central Texas (fig. 17.5).

Oak wilt causes affected trees to wilt and usually to die. All species of oak are susceptible, but species in the red oak group (northern red, scarlet, and black oak) are most readily killed. Oaks in the white oak group (white, post, and chestnut oaks) are infected but mortality occurs much less frequently and more slowly. Live oaks die at a rate generally intermediate between red and white oaks.

Infection centers develop when the fungus spreads to adjacent, susceptible trees via root grafts. Sap feeding beetles can carry spores to nearby healthy trees. Control strategies consist of cutting or killing infected trees and others nearby to prevent tree-to-tree spread (MacDonald 1995, Rexrode and Brown 1983, Tainter and Baker 1996).

Oak wilt control programs were implemented in a number of Eastern States in the 1960s and 1970s, but devastation of oaks never developed as originally feared. Evaluations of control programs seem to indicate that efforts had little effect on the number of infection centers or the number of oaks that died, and most control programs have been discontinued.

In central Texas, however, catastrophic losses, primarily in live oaks with lesser loss of Texas red oak, have generated much interest and concern since the 1980s (Appel and Billings 1995). Oaks in this area have little commercial value, but they are highly prized for shade, aesthetics, wildlife, and their contribution to watershed health. Both rural and urban trees are affected. An active control program has been in operation since 1988 (Cameron and Billings 1995). Control treatments successfully implemented in central Texas include trenching to sever root connections and fungicide injections to prevent mortality of individual, high-value trees.

Concern over the importation of oak wilt to Europe has resulted in an import quarantine being imposed by the European Economic Community countries on oak logs from United States counties where oak wilt has been documented. Oak logs exported from such counties must be fumigated and then be certified disease free.

Oak wilt will continue to affect the oak resource in its current range. Of greater concern is the possibility that the oak wilt fungus, having adapted to Texas oaks and their environment, may now spread throughout the southern range of oak.

Oak decline—Because of the history of woods grazing, widespread wildfire, exploitive logging for wood products, and the loss of American chestnut to chestnut blight, oaks probably represent a larger component of the southern forest ecosystem today than at any time in the past (Millers and others 1990).

Oak decline in upland hardwood and mixed oak-pine forests is a disease complex involving environmental stressors, often drought, root diseases such as are caused by *Armillaria* spp., insect pests of opportunity such as the two-lined chestnut borer, introduced pests such as the Japanese beetle and Asiatic oak weevil, and physiological maturity of the trees (Staley 1965, Wargo 1977, Wargo and others 1983). Bottomland oak forests are also subject to oak decline but at a lower incidence. Stress agents of bottomland hardwoods also include seasonal, sometimes prolonged flooding.

Decline progression is measured in decades rather than months or years. Introduction of the gypsy moth into northern parts of the region has worsened oak decline because oaks are preferred hosts, and spring defoliation contributes to the chain of events that increase susceptibility. While decline development may take decades from inception to visible symptom expression, susceptible trees die within a few years after dieback exceeds one-third of the crown volume. Not all affected trees reach this point. Species in the red oak group (particularly black and scarlet oaks) are most susceptible. Hickories are the only non-oak species group commonly observed with symptoms in decline areas (Starkey and others 1989).

Forest workers have reported oak decline occurrences since the mid-1800s (Balch 1927, Beal 1926) and in every decade since the 1950s (Millers and others 1990). A severe drought in the 1950s may have led to the current cohort of trees being highly susceptible to oak decline (Dwyer and others 1995, Tainter and others 1990). Significant oak decline episodes continue to occur in the region (primarily in Arkansas and Virginia) where predisposing conditions, inciting events, and

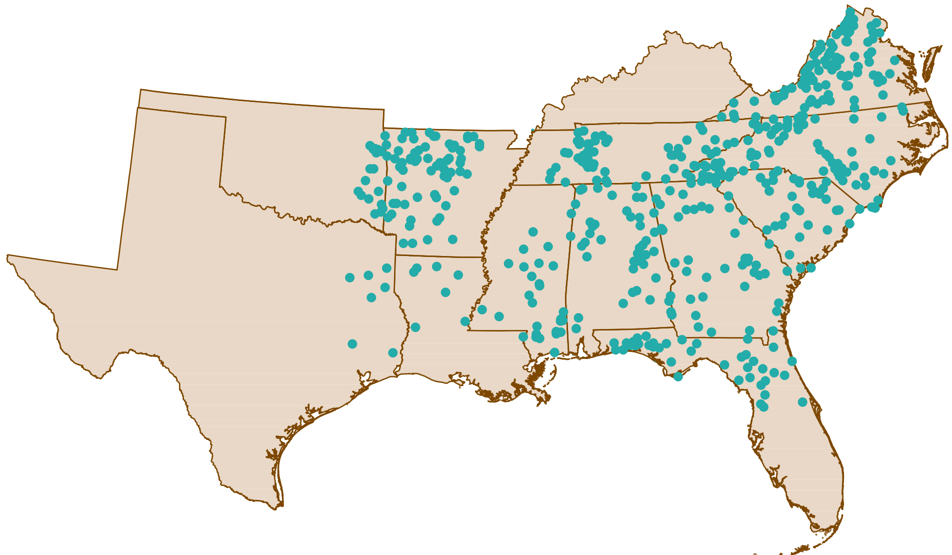

Figure 17.6—Forest Inventory and Analysis plots affected with oak decline (U.S. Department of Agriculture, Forest Service 1999).

contributing factors are coincident (Starkey and others 2000).

Not all oak forests are equally affected (fig. 17.6); Virginia, North Carolina, and Tennessee have the highest incidence. Among physiographic subregions, the Southern Appalachian and Ozark-Ouachita Mountains are most affected. Species in the red oak group suffer greater impacts than those in the white oak group (Gysel 1957, Oak and others 1988).

Although most of the decline-affected area is on privately owned land, national forests have by far the highest incidence of this problem because they have a higher frequency of stands with the attributes that favor this disease (older aged oaks predominate, oak species composition favoring susceptible species, and average to low site productivity) (Oak and others 1991, 1996). Among national forests, the George Washington and Jefferson have the highest incidence of oak decline.

The relative importance of oak is both a biological and a social question, but the cumulative impacts of the loss of American chestnut, continued oak decline, and ongoing defoliation by the gypsy moth indicate that special efforts must be made if the oaks are to maintain their prominence in the forest. Risk rating models have been developed to aid in this process (Oak and Courter 2000, Oak and Croll 1995, Oak and others 1996).

Oak decline will continue to be a forest health problem, particularly on national forest land. Oaks will not be eliminated from affected areas, but their numbers and diversity will be reduced. Red maple, blackgum, and other relatively shade tolerant species are likely to replace the oaks. As this change occurs, forest structure becomes more complex, the quantity of standing trees and woody debris increases, and overall susceptibility to oak decline and gypsy moth is reduced.

Subsequent decline in hard mast production is another serious impact of this problem.

Native Insect Pests of Conifers

Southern pine beetle—The southern pine beetle (SPB) (*Dendroctonus frontalis*) is the most destructive insect pest of pine forests in the South (Thatcher and Conner 1985). Populations build rapidly during periodic outbreaks and kill large numbers of trees. Average annual losses may exceed 100 million board feet of sawtimber and 20 million cubic feet of growing stock. From 1991 to 1996, total value of trees killed by SPB in the Southern United States was estimated at $493 million (Price and others 1998). However, during endemic periods, SPB populations may be so low that it is difficult to locate a single infested tree or capture beetles in pheromone traps (Thatcher and Barry 1982, Thatcher and others 1980).

The SPB, which attacks all species of pines, prefers loblolly, shortleaf, Virginia, pond, and pitch pines but

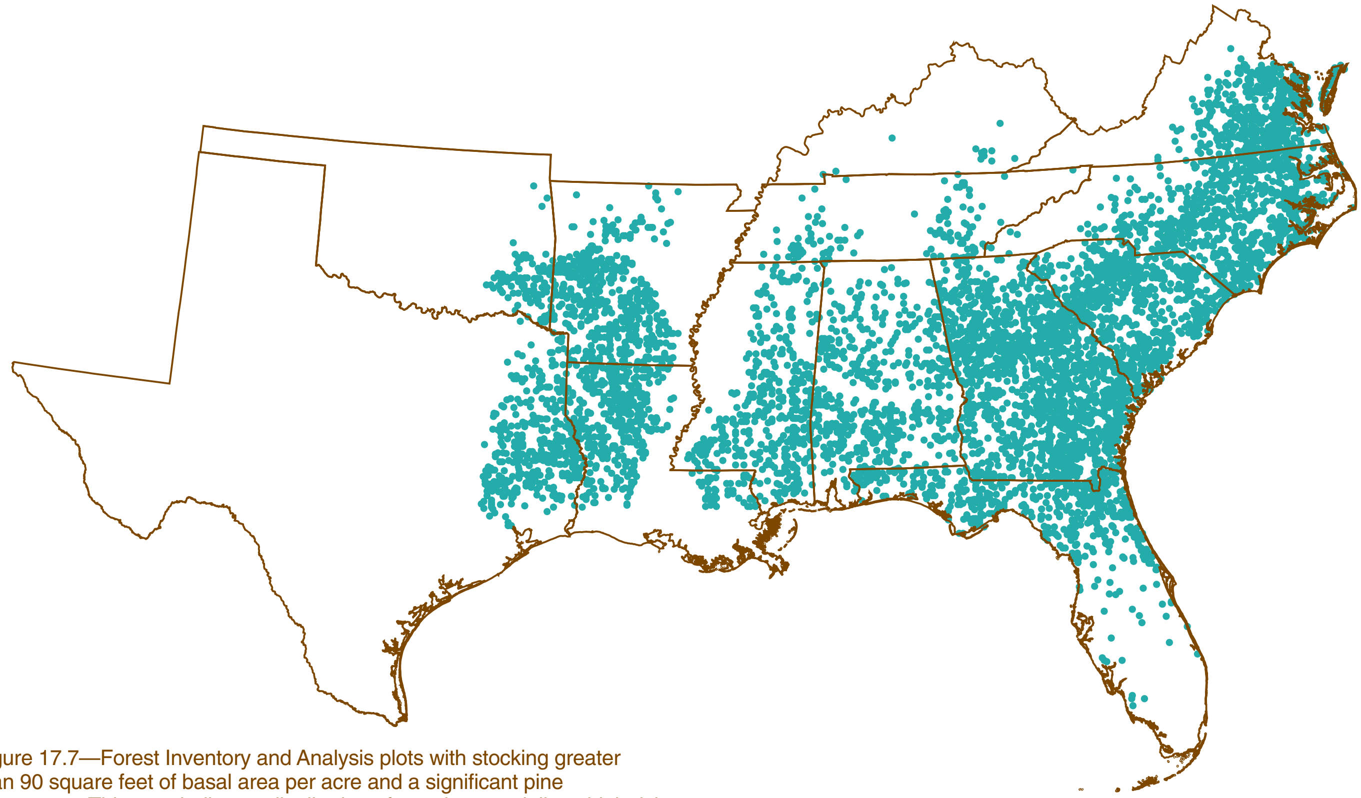

Figure 17.7—Forest Inventory and Analysis plots with stocking greater than 90 square feet of basal area per acre and a significant pine component. This map indicates distribution of stands potentially at high risk of attack by southern pine beetle.

seldom attacks longleaf pine. Recently, SPB has been observed to successfully infest white and Table Mountain pines. Mature trees in pure, dense stands have long been considered most susceptible to SPB attack (fig. 17.7), but in recent years unthinned pine plantations have increasingly supported SPB infestations. Trees less than 5 years old or 2 inches in diameter are seldom attacked.

During outbreaks, SPB activity peaks in early summer in the Gulf States and in late summer and early fall farther north.

Figure 17.8 shows a summary of SPB outbreaks as reported by Price and others (1998). Since 1960, a SPB outbreak has occurred somewhere in the South almost every year. Outbreaks, which may last 3 to 6 years, have been most severe and persistent in southeast Texas and southwest Louisiana, central Mississippi, the Piedmont of Alabama, Georgia, and South Carolina, and the Coastal Plain of Georgia, and North and South Carolina. Currently a catastrophic infestation of SPB is threatening pines in Virginia, Kentucky, Tennessee, North Carolina, and Georgia. Ridgetop pine ecosystems for which control options are extremely limited are of special concern to ecologists and forest managers.

Natural enemies, including diseases, parasites, and predators, can help maintain beetle populations at low levels. However, they seem to have little effect in preventing periodic outbreaks.

The primary suppression method is to salvage infested trees plus a buffer of green trees to stop spot expansion. Cutting and leaving infested trees, under appropriate conditions, also protects the residual stand (Swain and Remion 1981).

While chemical treatments are available, chemical insecticides are seldom used on a large scale to suppress SPB. They are most often used to prevent attacks of SPB and associated bark beetles on individual

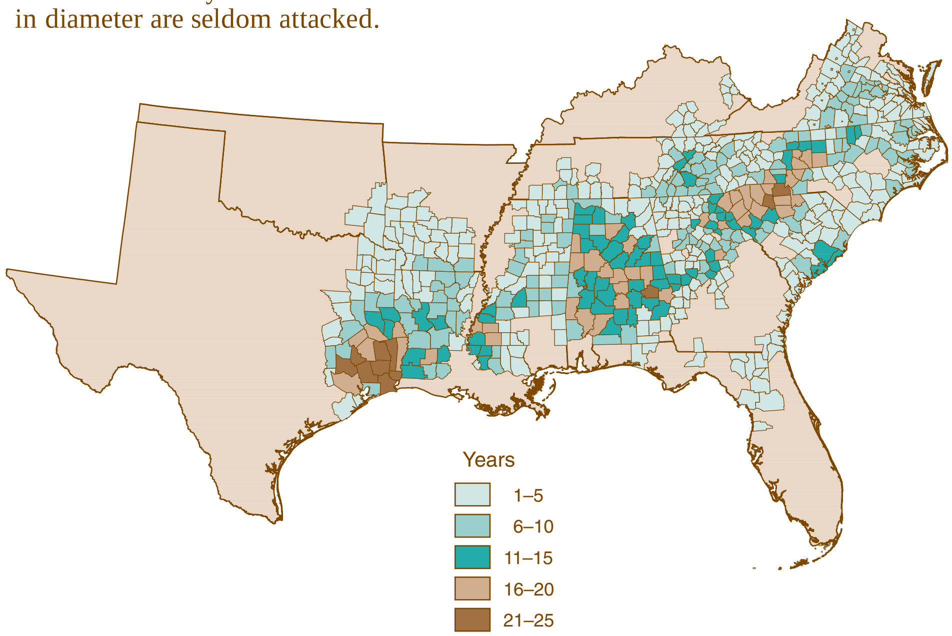

Figure 17.8—Counties in outbreak status for southern pine beetle; a 40-year summary (U.S. Department of Agriculture, Forest Service 1999).

trees of high value. A new semiochemical is being tested to protect trees from SPB attack.

The most practical way to minimize timber losses and avoid costly, short-term suppression projects is to maintain forests in a vigorous, healthy condition. Several practical hazard-rating systems have been developed to help managers to prioritize SPB prevention activities. Thinning and harvesting are extremely important prevention tools since outbreaks are generally less likely in actively managed forests, where management is designed to enhance health and vigor of the residual stand.

SPB outbreaks affect pine forests on all ownerships. The severity of loss tends to be greatest on Federal forests due to the preponderance of mature pine sawtimber in dense stands. Areas set aside for wilderness or preserves have proven especially prone to SPB outbreaks, due largely to the advanced age, high density of the stands, and the policy of not controlling SPB on these areas.

In the last five decades, large acreages of pine plantations have been established in the South. Even-aged, single-species plantations become increasingly susceptible to SPB infestations as they age. Precommercial and commercial thinning to promote rapid growth in these plantations should reduce their susceptibility to future SPB outbreaks. Nevertheless, the SPB is expected to play an increasingly important role in the future of the South's pine forests.

Impacts vary with ownership. Federal land supporting an abundance of overmature loblolly pine forests is expected to be particularly vulnerable to extensive outbreaks. Industrial forests are likely to suffer SPB problems primarily in young, unthinned pine plantations. Short-rotation pine plantations receiving intensive management (periodic thinning, fertilization, etc.) should have minimal problems with SPB. Small private forests will face SPB problems in inverse proportion to management intensity.

SPB will continue to play a major role in the health of the southern forest. Catastrophic population buildup will continue to occur periodically. When this occurs survivor species will assume a higher profile in the residual forest. In some cases, total loss of the pine component in the forest may result.

Bark beetles other than southern pine beetle—Although the southern pine beetle is the most damaging insect in southern pine forests, it is only one of five species of pine bark beetles of concern for forest managers in the South. The other species are the six-spined engraver (*Ips calligraphus*), the southern pine engraver (*Ips grandicollis*), the small southern pine engraver (*Ips avulsus*), and the black turpentine beetle (BTB) (*Dendroctonus terebrans*). These beetles are usually considered secondary pests because they normally infest only stressed, weakened, damaged, or downed pines. They also colonize pines that have been attacked by SPB or another species of bark beetle. Host species in the South include loblolly, shortleaf, slash, longleaf, pitch, sand, eastern white, and Virginia pines. Both pure pine and mixed pine-hardwood stands may be affected (Conner and Wilkinson 1983, Smith 1972, U.S. Department of Agriculture Forest Service 1985a).

Adult BTBs are the largest of the southern pine bark beetles. Although BTB attacks may continue for several months, infestation is not always fatal, and multiple attacks around the entire circumference of the tree are required to cause mortality (Smith 1972, U.S. Department of Agriculture Forest Service 1985a).

The small southern pine engraver is the smallest of the *Ips* spp. in the South; the southern pine engraver is midsize; and the six-spined engraver is the largest. The small southern pine engraver and the six-spined engraver are the most aggressive and may kill small groups of trees. Losses may be extensive during periods of drought (Conner and Wilkinson 1983, U.S. Department of Agriculture Forest Service 1985a).

In the past, the secondary bark beetles played a vital role in shaping forest structure. They attacked individual weakened or severely stressed trees, or older trees reaching senescence. Large infestations developed only occasionally, usually in the aftermath of widespread environmental stress, drought, storm damage, or wildfire. Overall, their action served to thin the pine forests, reducing competition, leaving the stronger trees, and decreasing the risk of SPB outbreaks. Over time, they may have had a greater impact on regulating pine stands than SPB (Clarke and others, in press; Paine and others 1981; Thatcher 1960a).

Today, the impact of these other bark beetles depends largely on management activities (Coulson and others 1986). On unmanaged land they function much as they did in the past, attacking single trees or small groups of pines, and reducing pine basal area. They provide openings for pine reproduction or for established hardwoods to grow. The effects are often not noticeable except during periods of extended drought, after storm damage, or at the end of SPB epidemics.

On managed land, outbreaks of secondary bark beetles occur infrequently, and primarily impact dense, unthinned young pine stands. Infestations temporarily increase after burning or thinning. Increases in beetle activity are usually short-lived, and the long-term benefits of thinning and prescribed burning outweigh the temporary, negative effects. Black turpentine beetles may attack pines scored for the production of naval stores. *Ips* bark beetles quickly infest pines downed by storms, and often introduce blue stain fungi that invade the wood.

Secondary bark beetles are important killers of individual, high-value pines in urban or recreation areas. There they create hazard trees that are expensive to remove.

In the past, secondary bark beetle infestations were often aggressively controlled, usually by felling and then spraying the affected trees with insecticides. This tactic was expensive and killed the natural enemies of the beetles. It was determined that such treatments were generally not cost effective, and today few infestations are controlled. When large infestations develop after drought or wildfire, prompt salvage of the currently infested trees may limit the spread of the beetles and allow time for uninfested, stressed trees to recover. Populations of secondary bark beetles infesting storm- or fire-damaged pines rarely move into healthy trees.

Prevention is the key to reducing losses to secondary bark beetles. Maintaining healthy pine stands and minimizing damage during management activities keep impacts low. If infested trees in high-value areas cannot be removed, the at-risk pines may be sprayed with insecticides to prevent attacks. Only the lower bole should be sprayed for BTB, but the entire bole must be treated to keep out *Ips* bark beetles.

Secondary bark beetle activity and damage are expected to continue at natural levels into the future. Periodic significant outbreaks will also continue to occur.

Pine reproduction weevils—The pales weevil (*Hylobius pales*) and pitch-eating weevil (*Pachylobius picivorus*) are two of the most serious insect pests of pine seedlings in the Eastern United States. In the South, they are found wherever pine occurs (fig. 17.1). Adult weevils of both species are attracted to freshly harvested pines, where they breed in logging slash, stumps, and old root systems. Seedlings planted in freshly cut areas are injured or killed by adult weevils that feed on bark. It is common to have 30 to 60 percent weevil-caused mortality among first-year seedlings in the South, and mortality of 90 percent or more has been recorded (Thatcher 1960b). A third species, the eastern pine weevil is generally less common but is known to kill terminal and lateral branches and to girdle the stems of small trees (Doggett and others 1977, Nord and others 1984).

In the South, pales weevils prefer loblolly, shortleaf, pitch, and white pines and almost never attack longleaf pine. Rare instances of pales weevil feeding on hardwoods also have been recorded. The pitch-eating weevil is reported to feed on similar hosts, whereas the eastern pine weevil prefers cedar but will also attack most southern yellow pines. Pales and eastern pine weevils may serve as vectors of various pathogenic fungi.

In the South, weevil control is unnecessary after winter or spring cuts because all weevils are gone before the next winter's planting. On the other hand, after summer or fall cuts, control will probably be necessary because the weevils remain onsite and attack newly planted seedlings during the spring (Corneil and Wilson 1980, Grosman and others 1999, Speers 1974). Weevils are not a problem when plantations are established on areas formerly covered with nonconiferous vegetation (for example, old fields and hardwoods) or on land where stands are allowed to regenerate naturally.

Only a few biological control agents that affect reproduction weevils have been reported. Very little is known about their effect in regulating field populations. Silvicultural and chemical strategies are available to reduce losses to reproduction weevils. A hazard rating system is available and should be used before scheduling pine planting.

Forest managers who harvest, prepare the site, and plant on a schedule that allows stumps to stale after cutting and prior to planting do not often experience high weevil-caused seedling mortality. In contrast, nonindustrial private landowners who often plant during the spring after late-year harvests often experience greater than 20 percent weevil-caused seedling mortality (Grosman and others 1999).

Reproduction weevil impacts may increase in the future. Current trends suggest that forest industry will continue to shorten rotations and may be less willing in the future to delay replanting to avoid the weevils. This trend could lead to an increased risk of weevil-caused damage or an increased need for proactive control strategies. Informed land managers can effectively reduce or eliminate the risk of weevil-caused damage, so education is a key to future prevention of this problem.

Nantucket pine tip moth—The Nantucket pine tip moth (*Rhyacionia frustrana*) is one of the most common forest insects in the Southeast (Berisford 1988). Although it is usually considered a southern pest, its range includes most of the eastern half of the United States.

Most hard pines are susceptible to attack by the Nantucket pine tip moth, but there are considerable differences in relative susceptibility. Among the southern pines, shortleaf, loblolly, and Virginia pine are highly susceptible, while slash and longleaf pine (with the exception of very young nursery seedlings) are highly resistant.

Damage, while potentially serious, is normally transitory or negligible in forest stands. Tip moth damage (loss of growth and deformation) is most severe on seedlings and saplings, usually under 5 years old. Deformation is particularly important on ornamentals and Christmas trees, which may become virtually worthless if tip moth attacks are not controlled. Experts disagree about the long-term impact of Nantucket pine tip moth attacks.

The abundance of the Nantucket pine tip moth is strongly affected by the availability of preferred hosts that are in susceptible age classes. Colonization of pine plantations is often rapid (Clarke 1982). Highest tip moth populations and damage tend to occur in even-aged, low-diversity stands (Berisford and Kulman 1967). Intensive stand management techniques including mechanical site preparation, or the application of herbicides or fertilizer, increase tree growth, but often favor increased tip moth damage (Nowak and Berisford 2000). The primary effect of ownership on this disease is a secondary effect of choice of management intensity. Naturally regenerated stands or plantations that are not managed intensively generally do not suffer enough damage to offset the cost of control.

Reliable sampling methods have been developed for determination of tip moth populations. However, the necessary links between population estimates and damage predictions have not been established.

The biology of the Nantucket pine tip moth as it relates to control is described in a variety of publications (Berisford 1974, Fettig and Berisford 1999, Haugen and Stephen 1983). Nantucket pine tip moth has a significant complement of natural biocontrol agents (Eikenbary and Fox 1965, 1968; Warren 1985). While several are being evaluated for use, none are commercially available. Insecticidal control can be used if damage is severe. There are a number of insecticides registered for tip moth control and for aerial application.

Tip moth infestations in loblolly pine stands are generally regarded as inevitable. However, as the acreage of intensively managed pine plantations is predicted to increase, this tip moth should become a more common pest problem in the future.

Baldcypress leafroller (formerly fruittree leafroller)—The baldcypress leafroller, *Archips goyerana*, periodically defoliates baldcypress in Louisiana. It has also recently been found in Mississippi. Kruse's publication (2000) describes the baldcypress leafroller, summarizes its biology and its effects on baldcypress, and lists relevant publications.

The baldcypress leafroller was first recorded in 1983 in Louisiana, where it feeds almost exclusively on baldcypress. Since 1983, it annually has defoliated the baldcypress component of the bottomland hardwood/cypress forest (about 35,000 acres).

While this insect is mainly a pest of flooded baldcypress, it can move into drier upland and urban settings during periods of heavy infestation. Baldcypress trees of all sizes display canopy dieback and significant reductions in diameter growth because of repeated annual defoliation. Pole-sized to small sawtimber-sized baldcypress trees growing on forest edges or in dense stands are most severely affected. In areas where chronic saltwater intrusion is a problem, trees die after as little as 2 consecutive years of defoliation.

Most defoliation caused by baldcypress leafroller occurs on unmanaged private, nonindustrial wetlands. Although several parasitoids and predators attack *A. goyerana*, the general lack of natural enemies in forested wetlands leads to persistent high populations of this leafroller. Lacking economic incentives, little or no direct control is applied. A bacterial spray is available, but is seldom used. Starvation is the major factor causing local reductions in caterpillar populations. One potential future control tactic involves planting genotypes of baldcypress, cultured originally for salt tolerance, which may minimize caterpillar development and limit female fecundity.

High populations of *A. goyerana* are expected to continue in the forested wetlands of southern Louisiana and Mississippi. The insect may spread and become a problem in other areas of the Gulf Coast, but movement has been slowed by breaks in the baldcypress forest type (mapped as oak-gum-cypress) and the obstacles presented by large bodies of water. Dieback and mortality of baldcypress trees will increase.

Texas leaf-cutting ant—The Texas leaf-cutting ant, *Atta texana*, is a serious pest in first- and second-year pine plantations in east Texas and west-central Louisiana. In areas where the ants are abundant, it is nearly impossible to establish pine plantations. Pine seedling mortality due to the Texas leaf-cutting ant occurs on nearly 12,000 acres annually and control and seedling replacement costs average $2.3 million per year (Cherret 1986, Texas Forest Service 1982).

The Texas leaf-cutting ant is generally confined to well-drained, deep sandy soils (Moser 1984, Vilela 1986). Figure 17.9 shows the range of the Texas leaf-cutting ant in Texas and Louisiana.

The impact of this insect appears to be unaffected by management intensity or ownership (Waller 1986).

Currently, only one chemical is registered to control Texas leaf-cutting ants, and it is scheduled for phase-out by the year 2005. A new baited formulation containing a slow-acting insecticide has been highly effective in field trials but is not yet registered for use.

Untreated colonies will remain a source of reinfestation and future losses.

Native Insect Pests of Hardwoods

Forest tent caterpillar—The forest tent caterpillar (FTC) (*Malacosoma disstria*) occurs throughout most of the United States and Canada, where it defoliates a variety of hardwoods (Batzer and Morris 1978, Fitzgerald 1995, U.S. Department of Agriculture Forest Service 1985b). In the South, it heavily defoliates water tupelo, sweetgum, blackgum, and various oak species. The most persistent and extreme outbreaks in the South occur in bottomlands, forested wetlands, and riparian areas. However, when FTC populations reach epidemic levels, the caterpillars often spread to urban and suburban areas where they defoliate a variety of shade trees and ornamental plants. Outbreaks in recreation areas may adversely affect business due to the nuisance created by migrating caterpillars and the presence of completely defoliated trees during the tourist season.

Outbreaks of the FTC occur in several Southern States, where well over 500,000 acres can be defoliated in a single season; FTC defoliation does not cause significant amounts of tree mortality. However, it does cause significant loss of tree growth. Repeated, heavy defoliation of stands may cause significant amounts of dieback.

Impacts of FTC occur mainly in the bottomland hardwood-cypress forest types (mapped as oak-gum-cypress and elm-ash-cottonwood), but they are occasionally a problem in upland northern hardwood forest types (mapped as maple-beech-birch, oak-hickory, and oak-pine). Most FTC defoliation occurs on forest lands that are not managed. Neither ownership nor intensity of management influences the impact of this pest. However, a number of chemical and biological treatments are available (Harper and Abrahamson 1979).

Future impacts of FTC on southern forests are likely to be much the same as in the past.

Hardwood borers—Insect borers are important pests of hardwood trees throughout the South. They tunnel in the bark, trunks, terminals, and roots,

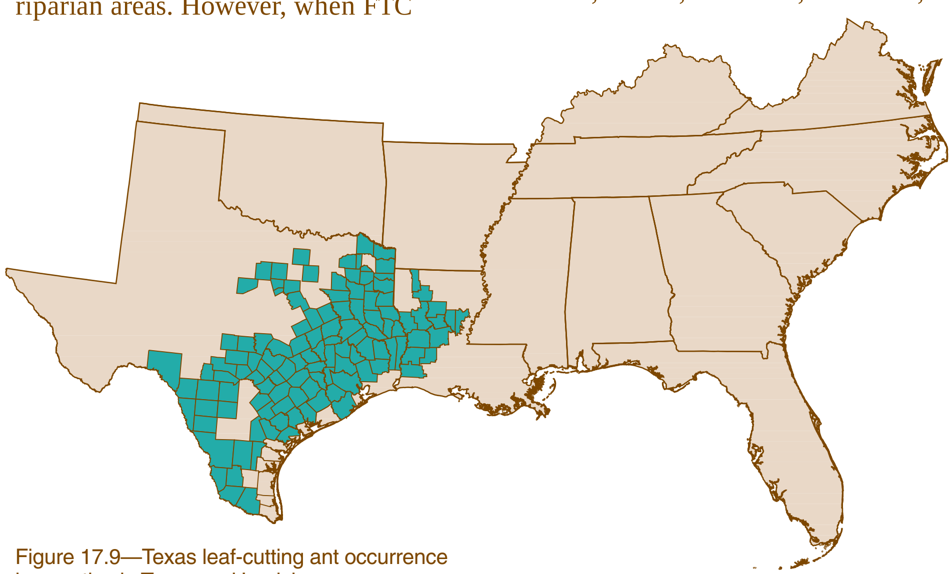

Figure 17.9—Texas leaf-cutting ant occurrence in counties in Texas and Louisiana.

causing a variety of defects in wood, deformation of stems, reduction of seed production, and tree decline.

Some of the major damaging borers in the South are the carpenterworm, red oak borer, white oak borer, ash borer, poplar borer, oak timberworm, Columbian timber beetle, and ambrosia beetle (Solomon 1995). Borers, endemic to an area, do not normally cause dieback and mortality, but in abnormally large numbers they do contribute to tree decline. Severely affected stands can be seriously degraded. Excessive numbers of growth defects caused by borers are reported to affect between 25 and 88 percent of all hardwood logs. The most recent loss estimate available (based on timber values) is slightly more than $29 million in 1998.

Prevention and control of borers in living trees are difficult and often are not economically feasible. Nevertheless, there are several options available to managers. Chemical control of woodborers is feasible only for high-value trees. Synthetic sex pheromones, available for some borer species, are useful to survey and monitor borer populations, and to establish optimum timing for insecticide application. Silvicultural treatments and practices that favor good tree health, while slow to take effect, are the most enduring controls (Graham 1959). Silvicultural controls are based on the fact that intensively managed hardwood stands on productive sites generally sustain less borer damage than those with little or no management. Ownership, except as it may affect intensity of management, has no direct effect on the activity of borers.

Recently, prolonged droughts have caused a decline in the vigor of oaks across the northern portion of Arkansas. This decline has permitted the development of a massive red oak borer outbreak. While not the primary cause of the oak mortality being experienced in that area, the borers have proven to be the most destructive agent to date in the decline complex. They have reduced salvage value to virtually nothing due to the extensive damage they have caused to the wood of dead and dying trees.

Most of the major insect borers are endemic across the South and will continue to impact hardwood stands in the future. Atypically high populations of woodborers will continue to occur periodically.

Nonnative Diseases of Conifers

Littleleaf disease—Littleleaf disease is the most serious disease of shortleaf pine in the Southeast. It is caused by a complex of factors including a nonnative fungus, *Phytophthora cinnamomi*, low soil nitrogen, eroded soils, a plow pan (from farming), and poor internal soil drainage (Campbell and Copeland 1954). Often, native microscopic roundworms called nematodes and native species of the fungal genus *Pythium* are associated with the disease. Infected trees have reduced growth rates and commonly die within 12 years of symptom expression. Growth reduction and death generally occur only in older stands where competition for root space (and, thus, for water and nutrients) has become significant. Once trees are affected, there is little likelihood of recovery, but it is possible to delay tree death for a few years by thinning and applying fertilizer.

While shortleaf pine is the most seriously damaged host, loblolly pine is damaged to a lesser extent. Littleleaf disease has also been reported on Virginia, pitch, slash, and longleaf pines. Historically this root rot complex was also responsible for significant losses of American chestnut trees.

Affected pine stands are found on the Piedmont Plateau from Virginia to Mississippi. Additional scattered pockets of disease occur in eastern Tennessee and southeastern Kentucky. The disease has its greatest impact in Alabama, Georgia, and South Carolina (fig. 17.10).

Management strategies based on the work of Campbell, Copeland, and others have been extensively implemented throughout the range of the disease. Primary strategies are silvicultural (Anderson and Mistretta 1982; Mistretta 1984). Overall, the most used management strategies are to regenerate littleleaf sites with the more resistant loblolly pine, or to allow the site to revert to a predominantly hardwood cover with the expectation that the hardwoods will break the plow pan.

Generally, the level of management significantly affects the occurrence and severity of this disease. Intensively managed stands are regenerated before losses become serious. Less managed stands are likely to suffer serious loss and appear as generally unhealthy stands.

Ownership affects management of this disease. Industrial stands managed for short rotation products are essentially unaffected by this disease, while public land managed for older age timber or for old-growth aesthetics are vulnerable. Extensively managed, nonindustrial private land is susceptible to this disease, while intensively managed private land avoids the loss. Many managers of public land are implementing the strategy of converting to loblolly pine to avoid damage by this disease.

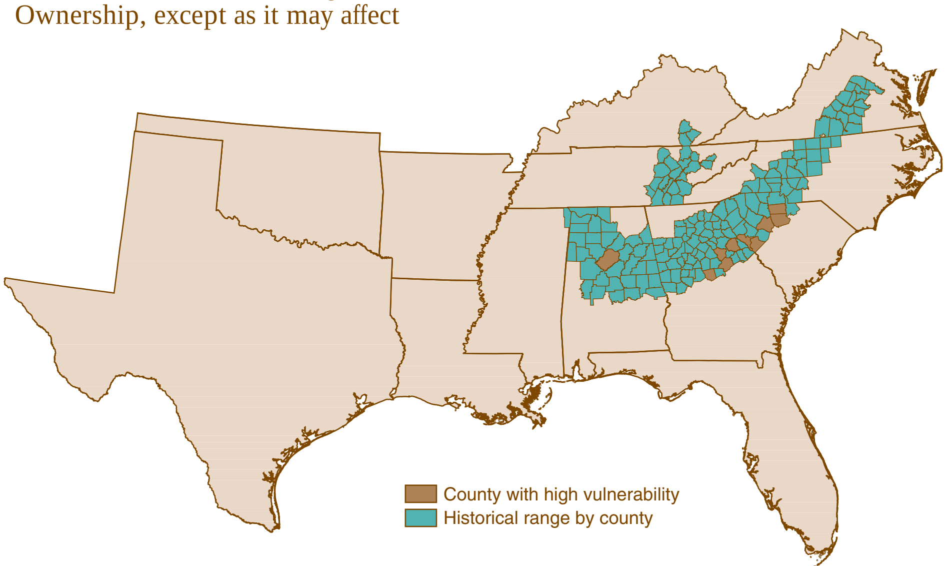

Figure 17.10—Historical range of littleleaf disease by county. Counties shown as highly vulnerable have soil and site characteristics that favor littleleaf disease.

According to one estimate (Mistretta 1984), littleleaf disease was present in 35 percent of the commercial range of shortleaf pine and was severe enough to be a factor in timber management on about 4 million acres. Losses attributed to littleleaf disease exceed $15 million per year. However, because of appropriate management, there appears to have been a reduction in the amount and severity of littleleaf disease during the last several years.

As time passes, this disease will become less significant. However, it is difficult to project the ecological effects that will result from converting large acreages of shortleaf pine to loblolly pine.

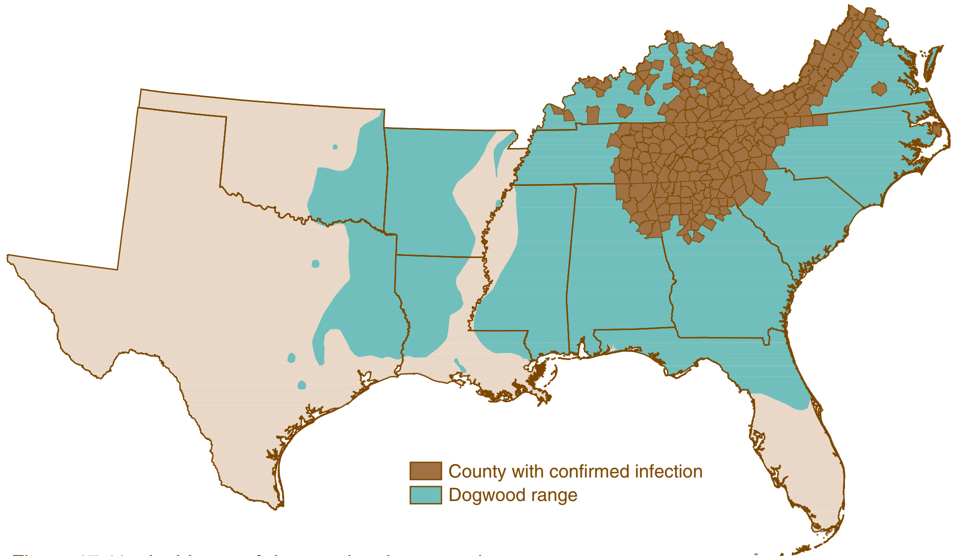

Figure 17.11—Incidence of dogwood anthracnose by county superimposed on the range of dogwood in the South (U.S. Department of Agriculture, Forest Service 1999).

Nonnative Diseases of Hardwoods

Dogwood anthracnose—The eastern flowering dogwood is a small tree that is valued as an ornamental and for its beauty in both forest and urban landscapes. It is also an important source of soft mast for over 100 different species of wildlife that feed on its berries (Kasper 2000). It is typically an understory tree found growing mixed with other hardwoods such as oak and hickory. The southern range of this disease is presented as figure 17.11.

Dogwood anthracnose is caused by an introduced fungus, *Discula destructiva.* It was first reported in the United States on flowering dogwood in 1978 and on western flowering dogwood in 1979.

For the past two decades, flowering dogwoods have been declining at an alarming rate. In some areas, they have been all but eliminated from the forest ecosystem above 3,000 feet in elevation.

Dogwood anthracnose affects all ages and sizes of dogwoods. The impact is most severe on fully shaded, understory trees, which are normally killed in 2 to 5 years. The most characteristic symptom of dogwood anthracnose is the yearly twig and branch death beginning in the lower part of the canopy (Britton and others 1993, Daughtrey and others 1988).

In the South, the most severe hazard for infection and mortality is at elevations above 3,000 feet and on shaded north-facing slopes. At lower elevations, the hazard is most severe in shaded, moist, and cool areas. Trees growing in full sunlight or on southern or western facing slopes at elevations below 3,000 feet sustain little damage from the disease.

Ornamentals are often disfigured without being killed, particularly if they are growing on open, sunny sites. In the last 10 years, the popularity of this tree as a landscape ornamental has declined because of the sudden destructive outbreak of dogwood anthracnose (Daughtrey and others 1996).

There is no known control of the disease for dogwoods growing in the forest, but vigorously growing trees tend to suffer less damage than weakened or stressed trees. Stress factors such as drought and winter injury appear to increase susceptibility (Anderson and others 1994). High-value trees can generally be protected by mulching, watering during droughts, and applying a fungicide.

While there is no practical control strategy for this disease in forest settings, hotter, drier climate in the southern and western portions of dogwood's range may limit its spread. Neither ownership nor intensity of management has had any significant effect on this disease.

A few disease-free trees have been found in the native population of dogwoods in areas of high dogwood mortality. An anthracnose-resistant flowering dogwood was introduced into the marketplace in the fall of 2000 (Windham and others 1998). Planting resistant trees in high-value areas is practical and wildlife may ultimately spread anthracnose-resistant seeds throughout the forest. However, the native population of dogwood is expected to continue to decline.

Beech bark disease—Beech bark disease is caused by a complex of two or more agents working in concert. The beech scale attacks the bark of American beech, creating infection courts subsequently colonized by the fungus *Nectria coccinea* var. *faginata*. This fungus causes cankers that coalesce and girdle host trees.

While the beech scale is now a common pest of the American beech, it is nonnative, having been introduced through Nova Scotia (Canada) in the late 1800s. There is speculation that the fungus was also introduced. Discussion on that point is somewhat pointless since a native fungus, *Nectria galligena* is also capable of inciting cankers and killing hosts after entering through scale-damaged bark. The scale must be considered the pivotal introduction that allowed the invasive spread of this disease complex (Houston and O'Brien 1983, Southern Appalachian Man and the Biosphere 1996). This disease complex was first identified in southern forests in the early 1990s.

The disease range continues to spread along a broad front. In the early phase of the disease cycle, more than 50 percent of the American beech trees 10 inches or larger in diameter at breast height are killed. Openings created by death or removal of the beech result in dense stands of root-sprouts, which

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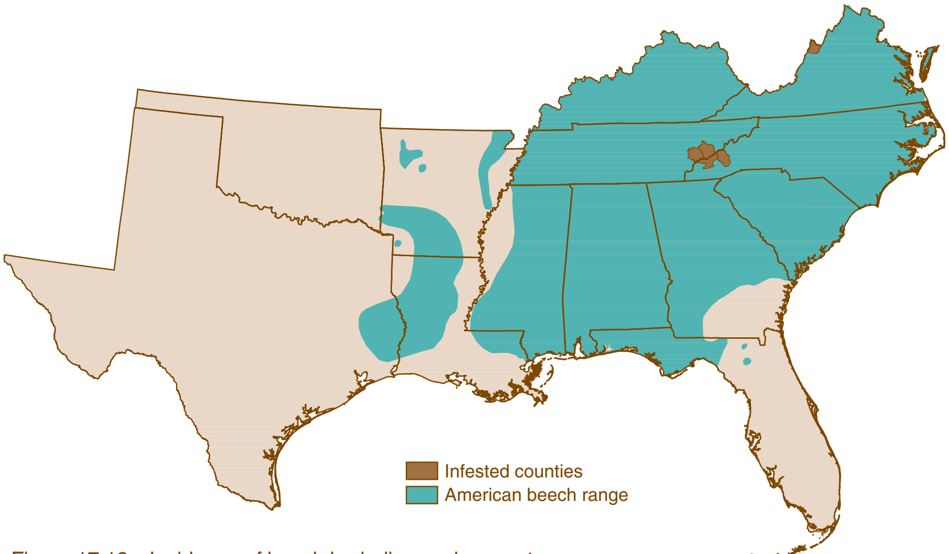

Figure 17.12—Incidence of beech bark disease by county superimposed on the range of American beech in the South (U.S. Department of Agriculture, Forest Service 1999).

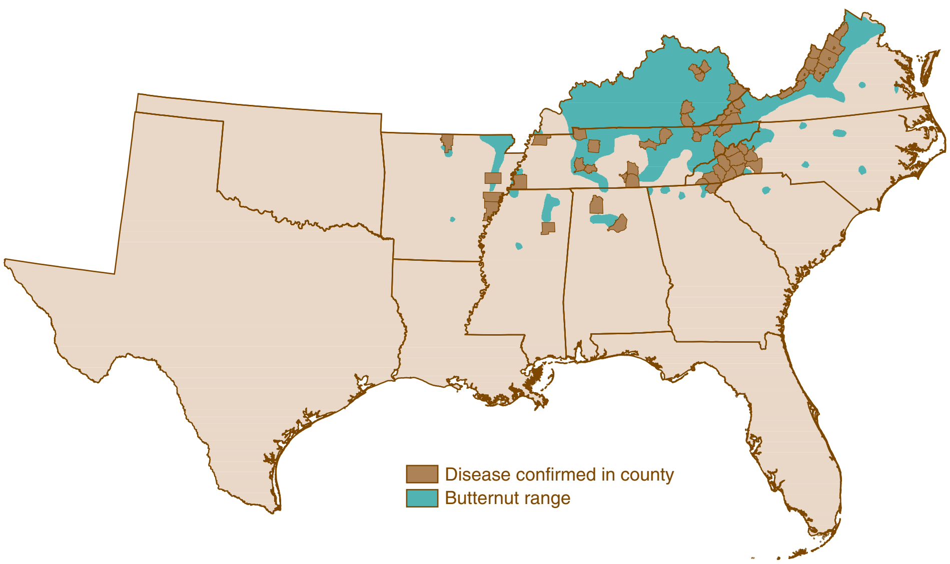

Figure 17.13—Incidence of butternut canker disease by county superimposed on the range of butternut in the South (U.S. Department of Agriculture, Forest Service 1999).

in turn yield stands abnormally rich in beech and deficient in its normal associates. In the second phase of the disease cycle, revegetated beech stands are attacked less severely, resulting in diseased survivors rather than in extensive mortality. Trees infected in this phase are rarely girdled, but they are generally severely deformed.

Since this disease complex affects only American beech, there is a direct relationship between the amount of beech in a stand and the intensity of the disease. Houston (1997) reports that "stand age and density, tree size, and species composition affect disease severity, especially in forests affected for the first time." The disease is expected to spread throughout the range of the host (fig. 17.12).

Silvicultural, chemical, and genetic strategies are available to manage this disease. Owners who depend on extensive (low intensity) management are expected to suffer significantly more quality (and value) loss than those who manage more intensively. Favoring genetic resistance is more effective in intensively managed forest stands.

Progeny from breeding programs designed to increase resistance have not been tested in field outplantings. They appear to hold promise, however, because some disease-free trees are known in most areas devastated by the disease. There is also some hope for biological control since a fungus and an insect are reported to attack the scale. High-value trees are sometimes protected with insecticides, but this method is impractical and uneconomical in the forest.

Damage to the South's beech resource has only just begun. Explosive buildups of scale population have not yet occurred in many places where the scales are known to be present. We anticipate significant additional mortality and deformation from this disease before prevention strategies are developed for use in forests.

Butternut canker—Butternut is a small to medium sized tree. Butternut typically is mixed with other hardwoods, such as black walnut, in the upland northern hardwood forest types (mapped as maple-beech-birch, oak-hickory, and oak-pine). Primarily found in riparian areas, this species was a significant producer of mast for wildlife. It hybridizes with other *Juglans* spp., such as heartnut, Japanese walnut, English walnut, little walnut, and Manchurian walnut. Although butternut is seldom found growing in great numbers, there is a strong desire to maintain a viable butternut population to preserve biodiversity (Clark 1965).

Butternut is being killed throughout its range in North America by a fungus, *Sirococcus clavigignenti-juglandacearam*. The fungus causes multiple cankers on the main stem and branches. Butternut canker has been found in 55 counties in the Southern United States (fig. 17.13). Butternut numbers have been dramatically reduced and it is now a candidate for listing under the Endangered Species Act.

Detailed examination of cankers indicates that butternut canker has been present in the United States since the early 1960s. Its origin is unknown but its rapid spread throughout the butternut range, its highly aggressive nature on infected trees, the scarcity of resistant trees, the lack of genetic diversity in the fungus, and the age of the oldest cankers (40 years) support the theory that it is a recent introduction.

Inventory data from FIA show a dramatic decrease in the number of live butternut trees in the United States. Surveys reveal that 77 percent of the butternut trees have been killed in North Carolina and Virginia.

Butternut canker kills trees of all ages. Trees in all settings and ownerships appear to be equally affected, except in urban settings that have been fertilized. (Fleguel 1996, Nicholls 1979).

Since butternut makes up less than 0.5 percent of the trees in the South, the overall impact of its loss to the forested ecosystem is considered by some to be minor. However, as butternut trees die, they are replaced by other species with a subsequent loss of biodiversity. The long-term outlook for butternut is not good; there is no known control for butternut canker. It appears the species will continue to decline and die, making up less and less of the forest population over time. At this time, the only hope for restoration is genetic selection and breeding.

The primary potential for control of the butternut canker is genetic. Disease-free trees are rare but have been found (Orchard and others 1981; Ostry and others 1994, 1996).

Chestnut blight—No event in the history of American forests is better known or sadder than the introduction of the chestnut blight fungus, *Cryphonectria parasitica*, from Asia, probably in the middle to late 1890s. The effects of this introduction will be felt for all time. The American chestnut tree was lost not only as a valuable timber species but also as the most important producer of hard mast for wildlife. The fungus continues to survive on infected sprouts from old chestnut rootstocks, various oaks, and some other hardwoods (Boyce 1961). Thus, there is virtually no hope the disease will be eradicated or that the American chestnut will naturally recover its preeminent position in eastern forest ecosystems.

Species associated with chestnut, including oaks, filled voids in forest stands left by the death of chestnut (Hepting 1974, Oak 1994). Unfortunately within about 60 years in the Southern Appalachians, the oaks that replaced the chestnut began to decline and die back (see Oak Decline) due in part to stressed growth on sites better adapted to chestnut.

No forest management practice of any intensity could overcome the ravages of

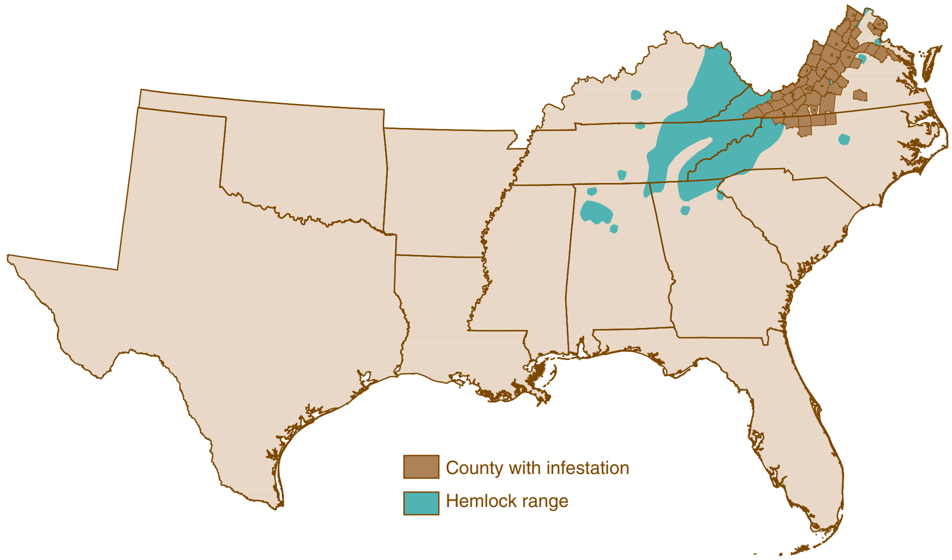

Figure 17.14—Incidence of hemlock woolly adelgid by county superimposed on the range of hemlock in the South (U.S. Department of Agriculture, Forest Service 1999).

chestnut blight nor did ownership affect disease progression. No control was found to stop the rapid devastation caused by this blight. Current attempts to cross American chestnuts with oriental varieties and then backcross to the American parent appear to offer a viable method of maintaining resistant chestnut in the forest (Schlarbaum 1988). Chromosome and gene manipulations now employed with other plants and animals may provide new avenues for resurrecting the American chestnut. Research into hypovirulence, the discovery of reduced pathogenicity because of a disease of *C. parasitica* itself, showed early promise as well (Anagnostakis 1978). Genetic engineering of the virus that causes a hypovirulent reaction has the potential to increase the efficiency of spread of hypovirulence in the fungal population and is currently being field-tested. Neither method has yet provided the needed answers but research is ongoing.

Nonnative Insects

Hemlock woolly adelgid—The hemlock woolly adelgid (*Adelges tsugae*), an insect species native to Asia, was first identified in the Eastern United States in the early 1950s in Richmond, VA. It has recently expanded into the Southern Appalachians and threatens to spread throughout the ranges of eastern and Carolina hemlock. In the South, it is currently established in the mountains around the Shenandoah Valley, and it is spreading southward along the Blue Ridge (fig. 17.14).

Eastern hemlock 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). The ecology of Carolina hemlock is less understood. It generally occupies more xeric sites on ridges and rock outcrops, but also probably provides cover and nesting sites for birds and small mammals.

Once infested by the adelgid, hemlocks are weakened, gradually defoliate, and become unable to refoliate or to produce cones. The adelgid causes mortality in all ages of both species. Mortality occurs after complete defoliation, generally within 5 years of initial infestation (McClure 1987).

Both eastern and Carolina hemlock are threatened. The adelgid could eliminate the limited population of Carolina hemlock within the next two decades.

There is suspected but unconfirmed genetic resistance to adelgids in both of the eastern hemlock species. Resistance is known to occur in hemlocks native to Asia and in the two species native to the Western United States. There are no known silvicultural strategies to prevent

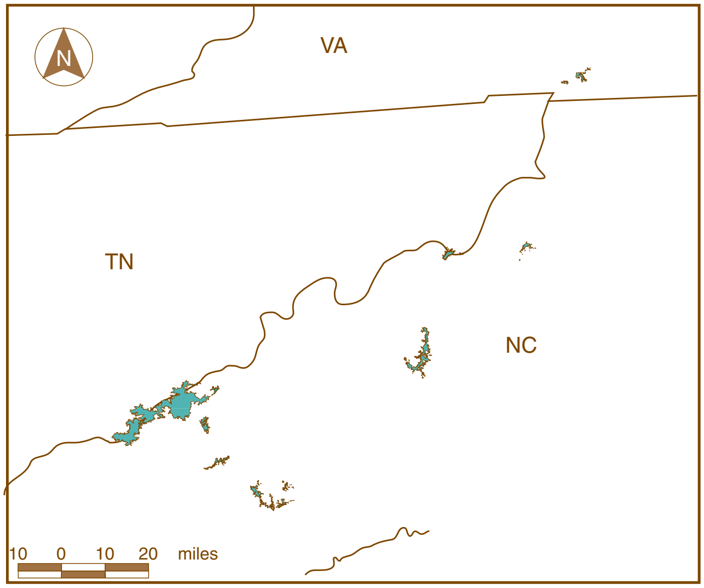

Figure 17.15—Location of spruce-fir type in western North Carolina, eastern Tennessee, and southern Virginia. Balsam woolly adelgid has colonized the entire host range (U.S. Department of Agriculture, Forest Service 1999).

adelgid-caused impact or mortality. Chemical spraying or soil treatment can protect individual hemlock trees, but such treatment is impractical for forest trees (Rhea 1996). Results of recent attempts at biocontrol of this pest are inconclusive. It appears that all untreated hemlocks, with the possible exception of small geographically isolated populations, could eventually be killed by the adelgid (Rhea 1996).

Balsam woolly adelgid in the Southern Appalachians—The impacts of balsam woolly adelgid (BWA) (*Adelges piceae*) were first documented in 1957 on Fraser fir in the Southern Appalachians. There are five major areas of spruce-fir forest in North Carolina, Tennessee, and Virginia (fig. 17.15). The majority of this forest type is on Federal land and is maintained for public use. These forests occur at high elevation and are highly valued scenic and recreation areas that attract several million visitors annually. The balsam woolly adelgid has infested Fraser fir in all five areas and impacts are evident.

Several laws have been enacted that direct the management of the Fraser fir and help resource managers make decisions dealing with the future of this tree. These laws help maintain the limited or threatened ecosystems and are key to the preservation of the spruce-fir forests. Fraser fir is under consideration for inclusion on the Federal endangered species list.

Several species of flora and fauna rely on mature spruce-fir habitat for survival. Many of these plants and animals are found only in this environment. Damage caused by the adelgid has put these species at greater risk.

The Fraser fir forests of the Southern Appalachians are declining (Dull and others 1988, Nicholas and Zedaker 1990). The BWA has eliminated 95 percent of the mature fir from the forest, fir mortality attributed to the BWA continues at a steady rate, and the residual fir population consists of trees generally less than 40 years old.

Ground-applied chemical controls have proven effective against BWA but none are economically or environmentally feasible in a forested situation. Aerial application of chemicals has proven ineffective.

Biological controls for the adelgid have been extensively studied, but so far no effective biocontrols have been found. In addition, natural enemies have had little effect on the thriving adelgid population.

Cultural control methods have also been attempted without success.

There is some speculation that BWA may ultimately eliminate Fraser fir by destroying its reproductive capacity. Reproduction of this species does occur but much less frequently than before BWA was present. Fraser fir survives to more than 40 years even when under pressure from the BWA, and at present it appears that the BWA will not eliminate spruce-fir forests at the high elevations of the Southern Appalachians. However, there remains the possibility that species dependent on mature fir canopies may be lost or that an additional stressor may cause the loss of the Fraser fir forest type.

Nonnative Insects of Hardwoods

Gypsy moth—The gypsy moth, *Lymantria dispar*, is native to Europe and Asia. In 1869, Leopold Trouvelot introduced the European strain of the gypsy moth into the United States. Since then, it has spread across the landscape of the Eastern United States, defoliating vast acreages of forest. The insect spread into northeastern Virginia in the early 1980s. By the middle 1990s, it had reached the eastern seaboard of North Carolina, and had infested much of Virginia. At the insect's current rate of spread, specialists predict that a significant portion of the Southeast will be infested in the next 30 years.

The gypsy moth causes its damage by feeding on and defoliating forest and shade trees during the caterpillar stage (Doane and McManus 1981, U.S. Department of Agriculture Forest Service and Animal and Plant Health Inpection Service 1995). Caterpillars feed on a wide range of trees and shrubs (Liebhold and others 1995, Zhu 1994) but prefer oaks.

Natural enemies, including small mammals and parasitic insects, often keep gypsy moth populations low (Elkinton and Liebhold 1990). Occasionally, however, populations increase above the capacity of these natural enemies to control. Then an outbreak occurs that can last for several years. Outbreaks culminate when populations collapse, either as the result of disease or starvation. The most important disease agents are the gypsy moth nucleopolyhedrosis virus and the gypsy moth fungus, *Entomophaga maimaiga* (Andreadis and Weseloh 1990, Hajek and others 1990).

Management of gypsy moth utilizes three strategies: eradication, suppression, and slowing the spread (Gottschalk 1993, U.S. Department of Agriculture Forest Service and Animal and Plant Health Inpection Service 1995). Eradication concentrates on the elimination of gypsy moth populations outside the quarantined area. Suppression concentrates on managing gypsy moth populations in the quarantine area to limit defoliation. Slowing the spread concentrates on limiting population spread along the leading edge of the quarantine area.

The gypsy moth is spreading into the South along a wide arc from the eastern shore of Virginia and North Carolina to the Appalachian Mountains in western Virginia. At this time, the impact of gypsy moth defoliation in the South is limited to Virginia and the northeastern shore of North Carolina (fig. 17.16).

The impact of repeated gypsy moth defoliation on the health of oak forests is significant (Campbell and Sloan 1977). Repeated severe defoliation of oaks weakens trees to such an extent that they may be attacked and killed by secondary pest organisms, such as the two-lined chestnut borer and Armillaria root rot (caused by *Armillaria mellea*). Extended drought intensifies the rate of death.

Species are attacked preferentially without respect to forest type. Highly favored species include northern red oak, basswood, and sweetgum. Species of limited suitability include maples, ash, beech, pine, and cherry. Species that are not favored or are avoided include yellow-poplar, blackgum, black locust, cypress, magnolia, and tupelo.

Increased intensity of management of forest stands may improve forest health, reduce susceptibility to defoliation by gypsy moth once stands are colonized, or remove individual trees and species that are vulnerable to damage. Overmature stands of red oaks, particularly scarlet and black oak, are highly vulnerable to loss after defoliation. Young, vigorously growing stands are thought to be less vulnerable to damage from gypsy moths. Alternatively, actively managed stands may be vulnerable to damage if they are defoliated soon after thinning. However, most silvicultural recommendations have not been experimentally verified at this time.

In a general sense, ownership does not influence impact. However, management objectives may limit treatment options for reducing outbreak populations of gypsy moth or they may limit opportunities to manage stand and species composition to favor nonpreferred species of trees.

Damaging populations of gypsy moths are managed by applying chemical or biological insecticides from the air and on the ground. Unfortunately, some treatments may adversely impact a nontarget species of crustaceans and insects, particularly rare species of moths and butterflies. Biological insecticides, including *Bacillus thuringiensis* var. *kurstaki*, a naturally occurring soil-borne bacterium, and Gypchek, a nucleo-polyhedrosis virus, are believed to have fewer negative environmental effects than other available treatments.

Very low-density populations of gypsy moths, particularly isolated populations, may be eliminated using a formulation of the sex pheromone of the female moth, or by mass trapping using the pheromone for bait. Insecticides are most often applied to residential areas where the caterpillar is considered to be a serious pest (U.S. Department of Agriculture Forest Service and Animal and Plant Health Inpection Service 1995). Treatment of uninhabited forests is generally only done to slow the spread of gypsy moths. Impact of this pest on the South's forests will increase as it continues to spread.

Outbreaks and their damage will be most conspicuous in the upland hardwood type, where oaks reach their greatest abundance. Bottomland hardwood and oak/pine forests will also sustain serious outbreaks.

How far south it will spread and how effective natural controls will prove to be are unknown.

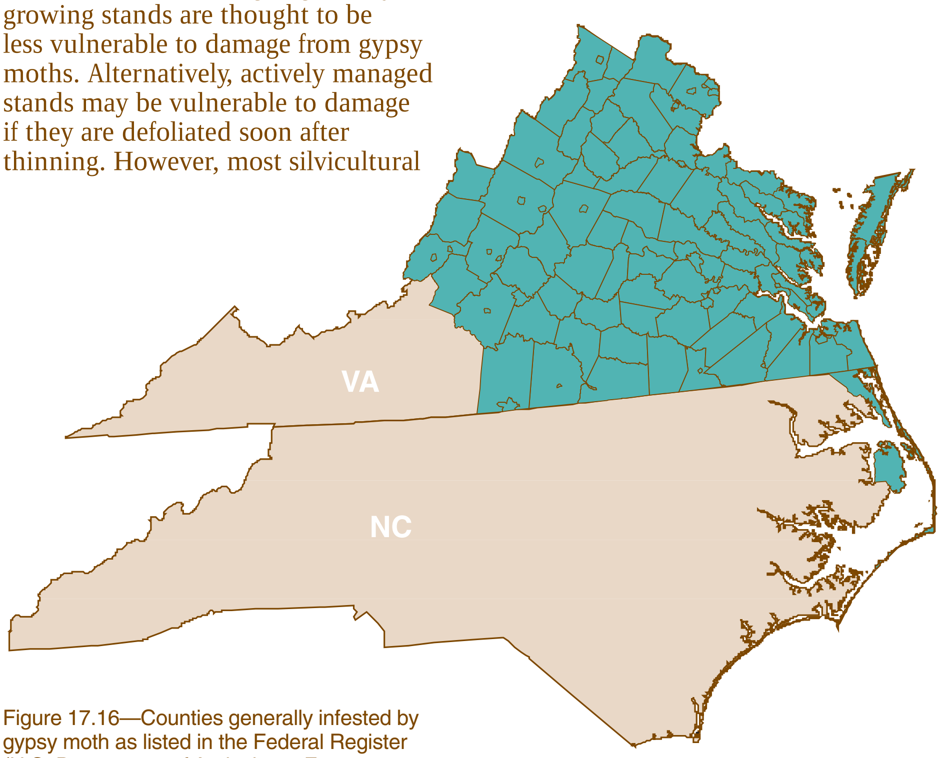

Figure 17.16—Counties generally infested by gypsy moth as listed in the Federal Register (U.S. Department of Agriculture, Forest Service 1999).

Discussion and Conclusions

Tables 17.1 and 17.2 summarize the current status of, current prevention and control strategies for, and likely changes in the amounts of damage that will be sustained from each of 21 forest pests in southern forests. We make no strong claims about the accuracy of these projections and provide them only as a useful summary.

Questions we have attempted to address concerning the health of the southern forests include:

- Are the effects of insect pests and diseases affected by forest type?
- What are the likely effects of large acreages of single-species plantations?
- What effect does intensive management have on insect and disease incidence?
- How will pest impacts differ among the major classes of land ownership?
- Will problems with nonnative insect and disease pests continue to increase?

Each of the pests discussed attacks a particular host or group of host species. Several of the pests discussed have the potential to eliminate their host species from the ecosystems in which they currently thrive.

Single-species planting, often called monoculture, is an economical way to produce wood or fiber of desired species rapidly. However, the concentration of single-species plantings over large areas offers great opportunities for forest pests that normally attack only the planted species or a small group of species that includes it. It

Table 17.1—Forest type listing with associated pest species

Forest type	Disease	Insect
White pine	Annosus root disease	Hemlock woolly adelgid
Hemlock	Annosus root disease	Balsam woolly adelgid
Spruce/fir	Annosus root disease	
Loblolly/shortleaf/ Virginia pine	Annosus root disease Fusiform rust Littleleaf disease	Bark beetles, not SPB Nantucket pine tip moth Pine reproduction weevils Southern pine beetle Texas leaf-cutting ant
Slash/longleaf pine	Annosus root disease Brown spot needle disease Fusiform rust	Bark beetles, not SPB Nantucket pine tip moth Pine reproduction weevils Southern pine beetle Texas leaf-cutting ant
Upland/northern hardwood	Beech bark disease Butternut canker Chestnut blight Dogwood anthracnose Oak decline Oak wilt	Forest tent caterpillar Gypsy moth Hardwood borers
Bottomland hardwood/cypress	Beech bark disease Dogwood anthracnose Oak wilt	Baldcypress leafroller Forest tent caterpillar Gypsy moth Hardwood borers
Oak/pine	Oak decline Oak wilt	Bark beetles, not SPB Forest tent caterpillar Gypsy moth Hardwood borers
Live oak	Oak Wilt	Hardwood borers

SPB = southern pine beetle.

seems obvious that populations of the pests that attack pine can expand and prosper in a pine monoculture. The fusiform rust fungus may be the outstanding example of a relatively minor pest becoming a major one because of plantation forestry.

Intensive forest management is a mixed blessing from the standpoint of pest management. While it is most commonly practiced in single-species plantations, and runs the risk of catastrophic losses to insects and diseases, it also offers great opportunities to minimize pest impacts. One of the primary objectives of intensive management is to keep individual trees vigorous, and such trees usually are less susceptible to pest damage than their slow-growing counterparts in unmanaged, less thrifty stands. In intensively managed stands it usually is practical to salvage trees that have been attacked by forest pests. In addition, healthy, intensively managed stands generally recover more quickly following a pest attack.

Risks of major losses to pests vary considerably by class of owner. Increasingly trees on public land are being grown in long rotations and in natural stands rather than plantations. Natural stands with mixed species composition have somewhat less risk of suffering catastrophic loss to forest pests. But susceptibility of individual trees increases as the trees age. Oak decline, for example, is taking a huge toll of aging oaks on public land.

When pest problems appear on industrial tracts, they are generally identified and dealt with promptly.

The same usually cannot be said for nonindustrial private land; the great diversity of owner objectives and management styles results in a variety of responses to pest problems. Most of the owners have little knowledge about pest problems and solutions, and many of their stands are not intensively managed. Commonly they are not even thinned before tree vigor starts to decline. In addition, desirable treatments often are not practical on the small tracts held by nonindustrial private landowners.

The greatest threat to the future health of southern forests is the introduction and spread of nonnative invasive pests. Once these pests are established, a lack of natural controls permits them to become extremely destructive and almost impossible to eliminate. Regulating the movement of plants and plant materials, and detecting and eradicating new pest introductions, are responsibilities of the USDA Animal and Plant Health Inspection Service (APHIS). The USDA Forest Service and State forestry organizations work closely with APHIS to prevent introductions and to eradicate them where they occur. Nevertheless, introductions continue to occur and eradication efforts often fail. The problem is not unique to the South or to the United States. It is an international problem of major proportions.

Among significant nonnative pests established in the South are the hemlock woolly adelgid, beech bark disease, dogwood anthracnose, the European gypsy moth, and the Formosan termite. Pests that are likely to be introduced include the Asian long-horned beetle, the pink hibiscus mealybug, and the Asian gypsy moth. Monitoring and suppression will continue to be important tools for preventing and managing these pests.

Risk assessment is one of the most important aspects of forest pest management. If the risk of a major loss is low, there is little point in spending a lot of money and disturbing environments to control a pest infestation. The USDA Forest Service has begun to evaluate areas at high risk from several pests. Areas are considered

Table 17.2—Summary of results of the individual forest pest analyses

Disease or pest	Native or nonnative pest	Type or species affected	Does impact vary with		Pest significance[a]		Are practical control strategies available?[b]	Research needs[c]
			Ownership?	Management intensity?	Past	Future		
Annosus root disease	Native	Pines in the pine types	Yes	Yes	5, 6	5, 6	PB, PC, PP, SC	
Baldcypress leaf roller	Native	Bald cypress in bottomland hardwood types	No	No	8	8	No	B, C
Balsam woolly adelgid	Nonnative	Fraser fir in the spruce-fir type	No	No	2	2	SC	B, C
Bark beetles (except southern pine beetle)	Native	Pines in the pine types	Yes	Yes	5, 6	5, 6, 7	SC	C
Beech bark disease	Nonnative	American beech in the northern hardwood types	No	No	NA	1	No	B, C
Brown spot needle disease	Native	Longleaf pine	Yes	Yes	5	5	PC, PP	
Butternut canker	Nonnative	Butternut in the northern hardwood types	No	No	1	1	No	C, G
Chestnut blight	Nonnative	Chestnut, oaks, and others in northern hardwood types	No	No	1	1	No	G
Dogwood anthracnose	Nonnative	Dogwoods in the northern hardwood types	No	No	1	1	No	G
Forest tent caterpillar	Native	Bottomland hardwood types	No	Yes	8	8	SB, SC	B
Fusiform rust	Native	Loblolly and slash pines in the pine types	Yes	Yes	5, 6	5, 6	PC, PG, PP, SC	G
Gypsy moth	Nonnative	Hardwoods—all types	No	Yes	1, 2, 4, 5, 6, 7	1, 2, 4, 5, 6, 7	PB, PC, PP, SP	B, G
Hemlock woolly adelgid	Nonnative	Hemlocks	No	No	NA	1	SP	B, G
Littleleaf disease	Nonnative	Shortleaf and loblolly pines	Yes	Yes	5, 6	5, 6	PC, SC	
Oak decline	Native	Oaks	Yes	Yes	1	1	PC	B, C
Oak wilt	Native	Oaks	Yes	Yes	2	1	SC, SP	C
Pine tip moth	Native	Hard pines	Yes	Yes	5, 6	5, 6	PC, SP	C
Pine reproduction weevils	Native	Pine	Yes	Yes	5, 6	5, 6	PC, SP	
Southern pine beetle	Native	Pines	Yes	Yes	3, 4, 5, 6, 7	3, 4, 5 6, 7	PC, SC, SP	C
Texas leaf-cutting ant	Native	Pine reproduction	No	No	5, 6	5, 6	SP	C, P
Woodborers	Native	Hardwoods pines	No	Yes	3	3	PC	C, P

[a] Pest significance: 1 = severe widespread ecological impacts, 2 = severe localized ecological impacts, 3 = significant tree mortality or decline, 4 = significant problem on reserved lands, 5 = significant problem on private and industrial forests, 6 = significant problem on unreserved public lands, 7 = significant problem in the urban/wildland interface, and 8 = moderate problem.

[b] Pest control strategies: prevention—PC = cultural practices, PG = genetic manipulation, PP = pesticidal tactics; suppression—SB = biological control, SC = cultural tactics, and SP = pesticidal control.

[c] Research needed: B = biocontrol, C = cultural tactics, G = genetic resistance enhancement, and P = prevention strategy.

to be at risk if tree mortality of 25 percent or more is expected during the next 15 years. Nationwide, some 59 million acres of forest are thought to be at risk from insects and disease-causing agents. Gypsy moths and southern pine beetles are the leading causes of risk in southern forests. Some 15 million southern acres are rated as high risk because of these insects (fig. 17.17).

The Forest Health Monitoring Program was established in 1990 to assess and report on the health of the Nation's forest ecosystems. It is a cooperative multi-agency effort. The Program provides for: (1) establishment of permanent plots throughout the Nation; (2) performance of aerial and ground surveys; (3) analysis of plot-based data from USDA Forest Service Forest Inventory and Analysis Units, national forest inventories, and forest health protection inventories; and (4) development of necessary methods to achieve assigned tasks.

Monitoring data support the conclusion that 85 to 90 percent of the trees in the South are healthy. These data also show that there are major concerns for the health of the forests in some areas (caused by oak decline, beech bark disease, and others), and also for some individual species of forest tree (eastern and Carolina hemlock, dogwood growing in specific conditions, and others).

Practical control methods for many pests are still lacking. Problems with treatment delivery, biology, public acceptance, economic practicality, adverse impact on nontarget species,

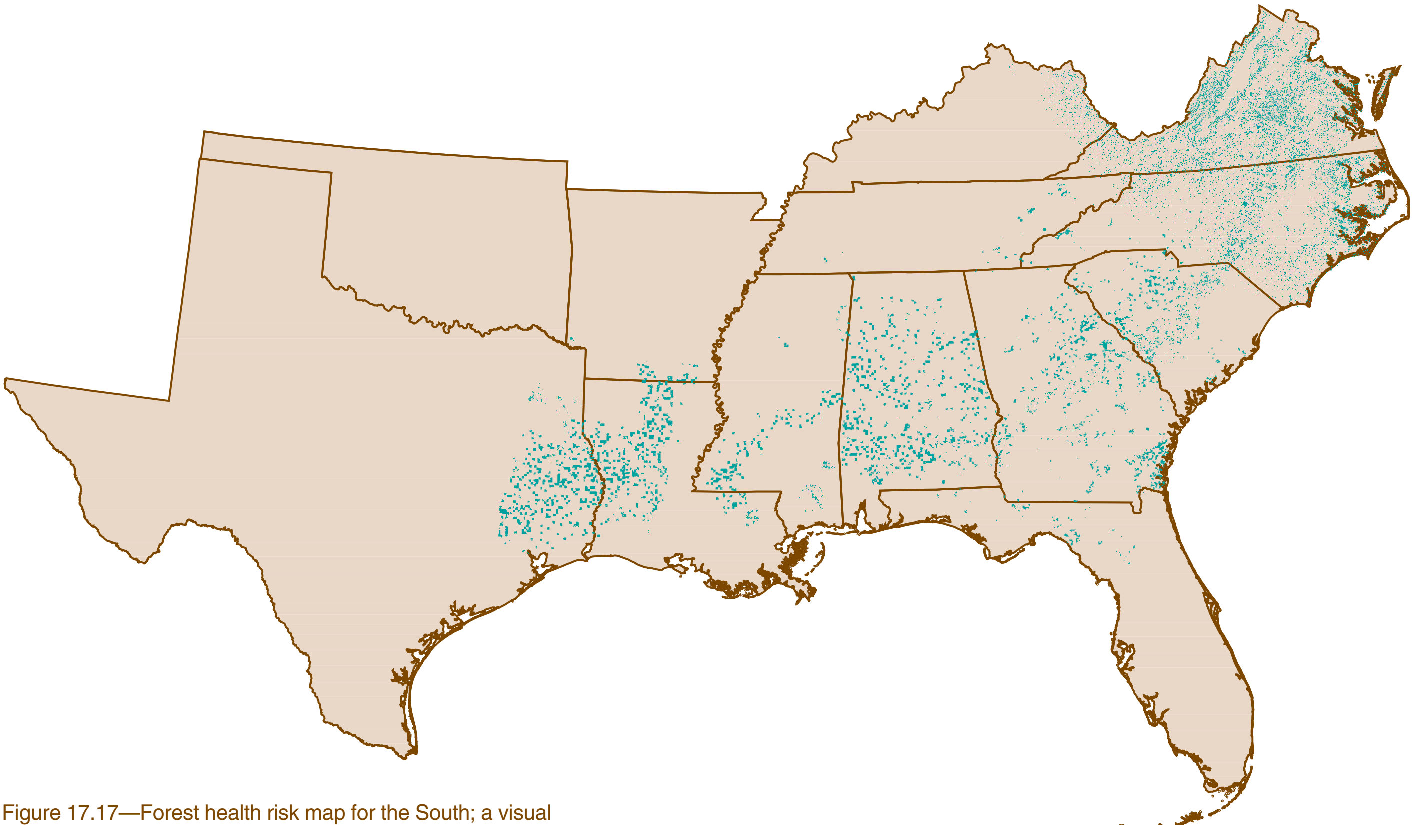

Figure 17.17—Forest health risk map for the South; a visual representation of risk of future tree mortality (Lewis 2000). The displayed results reflect intensity of risk and are not intended for site-specific analysis.

and many other obstacles affect development and deployment. The use of chemical pesticides in Federal forestry has declined due to the difficulty of procuring and maintaining EPA registration of products and also due to public pressure. Replacement silvicultural, genetic or biological strategies are often unavailable. Fragmentation of nonindustrial private ownerships makes it more difficult to implement control procedures there. Continued use of synthetic chemical pesticides will be necessary for the near future to keep pest problems manageable until alternative strategies become available.

IPM, the concurrent or consecutive use of a variety of tools or practices to control pests, is the overall process preferred by State and Federal agencies. Developing and implementing IPM for a particular pest is a complex process that requires considerable research. A systems model of IPM developed by Waters and Ewing (1974) (fig. 17.18) indicates the complexity of developing an IPM system for the southern pine beetle.

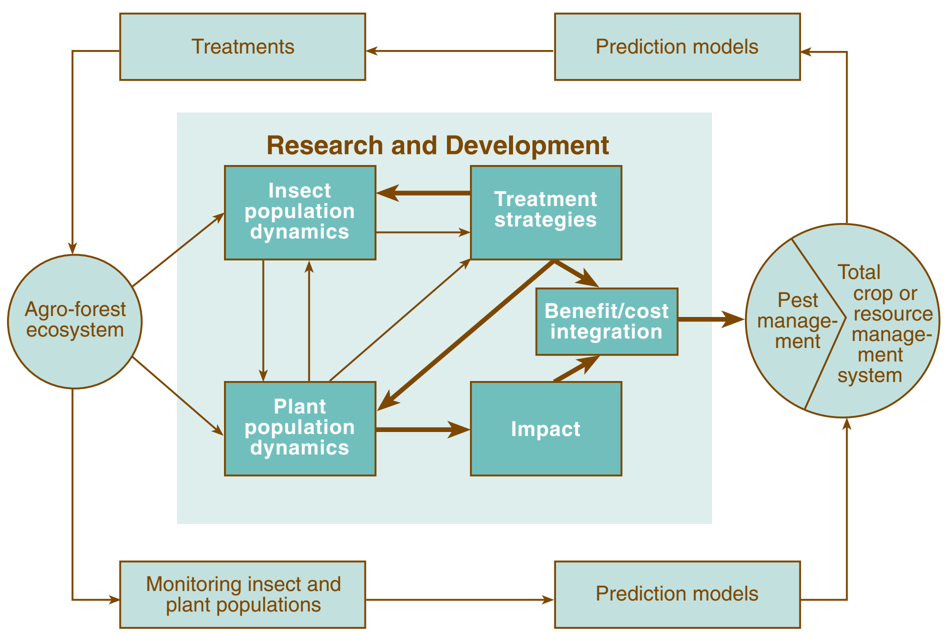

Figure 17.18—Waters and Ewing (1974) model of a potential IPM system for southern pine beetle control.

Research Needs

Significant data gaps were identified during preparation of this chapter. The most important pest management research needed includes:

- Continued investigation and development of tree resistance to butternut canker, chestnut blight, baldcypress leafroller, and several other pests.
- Continued development or enhancement of environmentally acceptable pest prevention and suppression treatments for all pests identified.
- Continued development of biopesticides and biological controls and prescription of their use in prevention and suppression programs for gypsy moth, SPB, ARD, and chestnut blight.
- Evaluation of the effectiveness of existing control measures, including “cut and leave” treatments for southern pine beetle control and silviculture for prevention of gypsy moth attack.
- Development of new hazard rating systems and validation of existing ones to identify areas that need treatment to prevent the occurrence of unacceptable losses to SPB, ARD, fusiform rust, and gypsy moth.
- Identification of potentially invasive species, along with the sites that are vulnerable to invasion.
- Development of methods for early detection of nonnative invasive species.

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The southern forest resource assessment provides a comprehensive analysis of the history, status, and likely future of forests in the Southern United States. Twenty-three chapters address questions regarding social/economic systems, terrestrial ecosystems, water and aquatic ecosystems, forest health, and timber management; 2 additional chapters provide a background on history and fire. Each chapter surveys pertinent literature and data, assesses conditions, identifies research needs, and examines the implications for southern forests and the benefits that they provide.

Keywords: Conservation, forest sustainability, integrated assessment.