FADING FORESTS

North American Trees and the Threat of Exotic Pests

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Preface

An intense debate currently rages over management of North American forests. Curiously, the impact of exotic (introduced or alien) pests on forest ecosystems has largely been ignored in the past, despite widespread damage. Already, numerous tree species are seriously affected. Furthermore, between 1991 and 1993, at least four new exotic pests have been discovered. Advocates of forest utilization, whether for consumptive or nonconsumptive use, need to recognize the potential threat of exotic pests to forest composition, health, and longevity. The interest in restoring the health of North American forests represents a common ground among contending interest and consumer groups.

This report documents the extensive impact that exotic organisms have had on North American forests by using examples of affected tree species. Economic and ecological consequences are presented. The mechanisms for prevention of exotic organisms entering the U.S. and control of existing exotic pests are discussed. Two United States Department of Agriculture (USDA) agencies are primarily responsible for pest prevention and pest control. The USDA Animal and Plant Health Inspection Service (APHIS) is responsible for inspection and, if necessary, quarantine or denial of entry, of animals and plants imported into this country. The responsibility for control of introduced pests, and associated research, has been shifted to the USDA Forest Service and cooperating state agencies and universities.

In addition, this report relates the current challenges and problems of importing pest-free wood materials, particularly from Siberia, New Zealand, and Chile. An increase in raw wood importations will raise the probability of new, exotic pest infestations. At present, the USDA-APHIS is considering alternatives in pest mitigation procedures to exclude or minimize exotic pest introductions. We recommend that APHIS develop and apply reasonable, uniform mitigation procedures for different wood materials, e.g., chips or logs, regardless of the species or country of origin. Development of such procedures should have input from all forest user groups.

Finally, this report suggests that a comprehensive national pest management program needs to be developed within the framework of existing agencies. The growing number of exotic pests and the corresponding damage to the ecosystem dictate that a nationwide strategy be devised. Current budgetary levels will not support all facets of a comprehensive program, so additional funding will be required. The burden of such funding should be borne by all user groups, rather than only those groups that generate revenue from wood utilization.

Introduction

The current debate over forest land use has involved citizen groups, local, state, and federal governments, and private companies. Land uses advocated range from complete, permanent preservation to various utilization options, including timber harvesting by clearclutting. From the broad constituency involved in environmental issues, it is evident that wise stewardship of natural resources is very important to most Americans. Basic American values, such as landowner rights, national heritage, right-to-work, and appreciation of natural beauty, are reflected in articles, debates, and other communications on North America's environment. Confrontations between groups having consumptive versus nonconsumptive viewpoints regularly occur, both in personal exchanges and in courtrooms. In contrast, the maintenance of forest health is one particular area where there is a general agreement among all concerned citizens. Regardless of how the forest is used, a forest in poor health–*e.g.*, a forest with a high proportion of dead and declining trees–is relatively unproductive. Declining forests have relatively low production rates of timber and mast (nuts, fruits, and berries), which affect wildlife populations, and are not aesthetically pleasing.

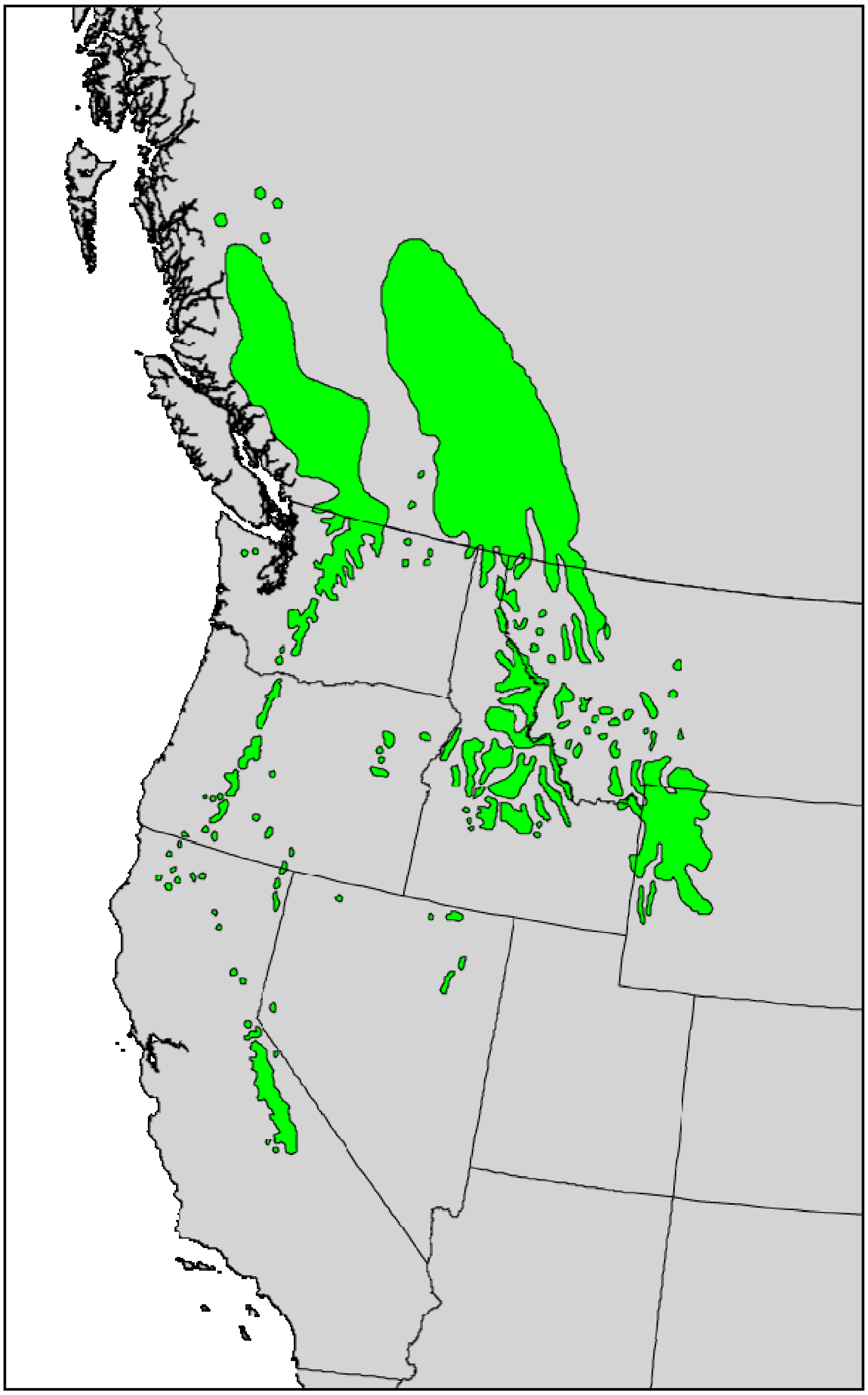
Many reasons explain unhealthy forests. Some problems are related to the increasing industrialization of the world. Other problems are caused by biological agents or "pests" that feed upon forest plant species. A widespread pest infestation, *e.g.*, gypsy moth (*Lymantria dispar*),[1] can permanently alter a forest in terms of plant and animal species composition. Forest-dwelling animals, as well as forest vegetation, are affected by pest-caused devastation. In the eastern forests, the loss of American chestnut (*Castanea dentata*) to an exotic fungal blight probably drastically reduced populations of black bears and turkeys (Pelton, personal communication). Reductions in whitebark pine (*Pinus albicaulis*) populations due to another exotic fungus have impacted grizzly bear and Clark's nutcracker populations in western forests (Kendall and Arno 1989).

Interestingly, many publications on forest problems and history do no mention or emphasize the destruction caused by forest pests (MacCleery 1992, USDA Forest Service 1984). The effects of forest fire, air pollution, logging, farming, grazing, and homesteading are discussed, yet devastation from major pest infestations is virtually ignored. Pests have altered entire forest ecosystems in eastern North America and have had a major impact on western forests in certain localities. Exotic pests from other continents have proven to be more destructive than endemic insects and diseases. Native insects, other arthropods, and fungi are part of the natural forest ecosystem. Native forest trees have evolved with native pests, and have developed defense mechanisms. Over the long term, these mechanisms keep the essential balance of the natural ecosystem intact. However, when alien or exotic insects, arachnids, saprophytic plants, fungi, and diseases are introduced into the forest, extensive damage or mortality can occur. Natural controls for introduced pests are usually absent. Native trees, without a history of natural interaction with exotic pests, often have little or no resistance mechanisms. As a result, native

[1]Appendices B, C, and D provide the common and Latin names of species mentioned in this report.

species can be seriously damaged or eventually eliminated.

Exotic insects and diseases have damaged North American forests for more than 100 years (*cf*. Crandall *et al*. 1945). In a recent forest health survey for the Northeast, Burkman *et al*. (1993) found that forest types covering more than 60 percent of the total forested area (which covers about 165 million acres) have been seriously damaged by introduced insects or pathogens. While the true economic costs of forest damage caused by all forest pests are difficult to calculate, lost timber revenue alone amounts to $2 billion annually (Pimentel 1986). The impact on industries that are connected with recreational forest use is more difficult to estimate. Industries associated with hiking, hunting, fishing, and other outdoor activities can be seriously affected if the forest is no longer suitable for a particular recreational activity. The ecological cost, in terms of an altered forest ecosystem, cannot be adequately measured. According to Ledig (1992), "Introduction of exotic diseases, insects, mammalian herbivores, and competing vegetation has had the best-documented effects on genetic diversity [of forest ecosystems], reducing both species diversity and intraspecific diversity." Their impact has been greater than that of other, more widely recognized, human-caused factors, including forest fragmentation, changed demographic structure, altered habitat, pollution, and favoring of a certain "domesticated" species of trees. Exotic pests have virtually eliminated



The natural range of whitebark pine

important species such as the American chestnut and American elm (*Ulmus americana*) as viable components of eastern forests sand have radically altered the eastern forest ecosystem (Ledig 1992).

The majority of exotic forest pests in North America have been introduced on imported nursery stock or logs. Past problems with imported pests resulted in the formation of the Animal and Plant Health Inspection Service (APHIS) in the United States Department of Agriculture (USDA). Strict regulations on importation of nursery stock were implemented decades ago (Plant Quarantine Act 1912).[2] Until recently, however, there were no specific timber import regulations to insure protection against exotic pest introduction. APHIS relied on visual inspection of logs entering U.S. ports to detect insects and pathogens. Importers were required to eliminate any pests found prior to bringing the logs into the country for processing. This policy reflected the fact that log shipments usually were relatively small or from countries considered to be substantially free from pests that could damage American forests, *e.g.*, countries with a tropical climate. Now, however, the reduction of harvesting in U.S. National Forests and increasing controversy about logging in the United States, especially in old-growth forests of the Pacific coast, have created an interest in importing large quantities of logs from Siberia, New Zealand, Chile, and other countries with similar climates and forest types as in North America.

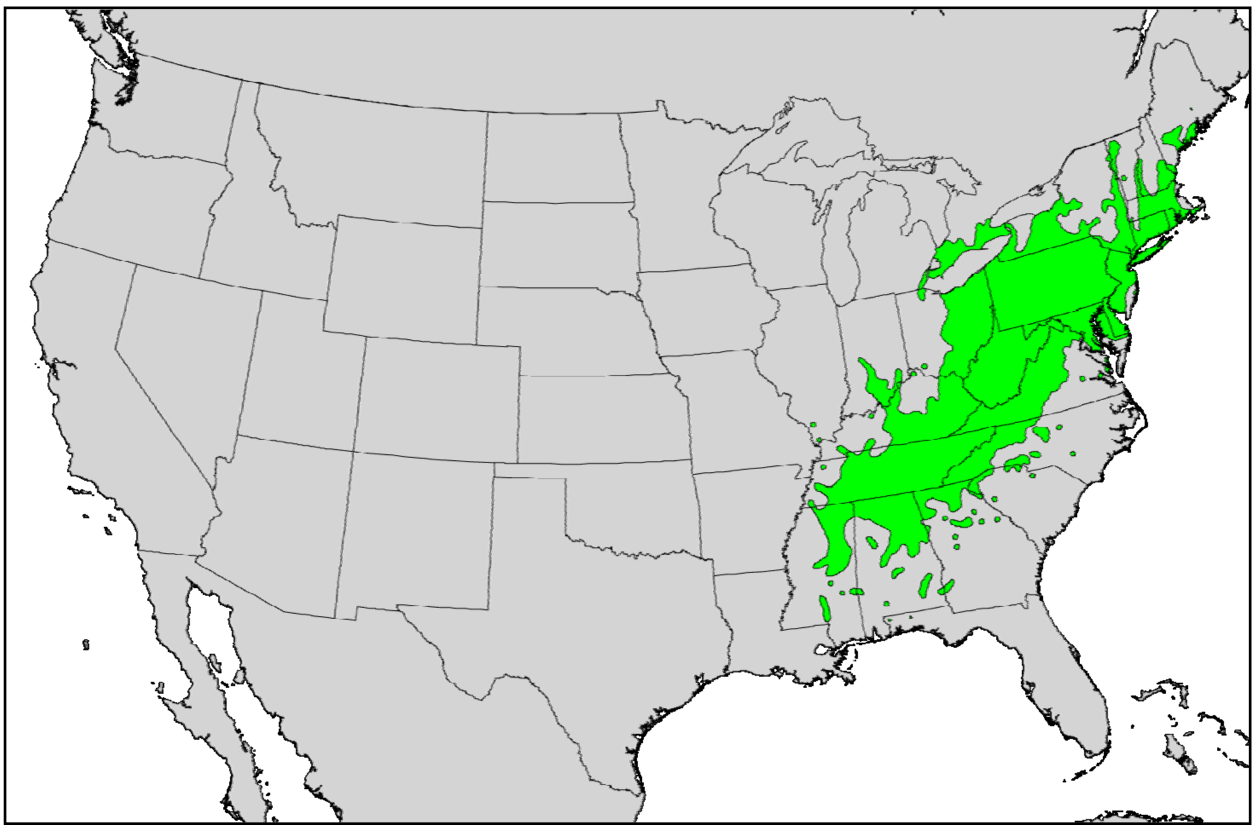
In the context of this paper, the most important question raised by such proposals is the possibility of introducing exotic pests into North America. Although USDA has begun to take steps to control or respond to the introduction of alien pests, their efforts to date are inadequate in the face of this serious threat. Pests could have extremely high economic and ecological costs if they became established in the widespread coniferous forest ecosystems of the American west. In 1961, Boyce predicted that "[a] virulent introduced parasite is infinitely more destructive to pure than to mixed stands, . . . no more potentially dangerous situation for disaster can be imagined than the extensive pure Douglas-fir forests of the Pacific Northwest or the far-flung pure stands of ponderosa pine and lodgepole pine in other parts of the West." Unfortunately, this prediction has been realized, as western forests are currently threatened by exotic pests such as Asian gypsy moth. Some examples of past and current exotic pest devastations are listed below to illustrate the magnitude of exotic pest problems.

[2] See Appendix A for summary of statutes governing exclusion and control of alien pest species.

Chapter 1: Examples of Exotic Pest Devastations in North America

American Chestnut Blight

The American chestnut was once the most important hardwood species in the eastern U.S. The species was found in vast stands from Main to Georgia before the turn of the twentieth century, accounting for one-quarter of all the standing timber in eastern forests (USDA Forest Service 1991b). In 1904, an introduced fungal disease, *Cryphonectria* (= *Endothia*) *parasitica*, changed the species composition of eastern North American forests. The disease was first observed on dying American chestnut trees in the Bronx Zoological Gardens. Introduced to North America in a shipment of Asian chestnut nursery stock, chestnut blight spread throughout the eastern hardwood forests at a rate of 24 miles per year (National Academy of Sciences 1975). By the 1950's virtually all mature American chestnuts had succumbed to the disease. American chestnut is now a minor understory component, existing as sprouts from old stumps and root systems (*cf*. Burnham *et al*. 1986).



Natural range of American chestnut in North America

The species provided timber, food, and tannin that were important to early European settlers. In recent years, the emphasis on utilization of American chestnut for wood products has overshadowed the importance of the species in wildlife food chains (Schlarbaum 1989). Annually, the tree would produce large crop of hard mast, unlike the oaks, hickories, and other trees that have replaced the chestnut. It is not known exactly how critical American chestnut was to wildlife populations. American wildlife biology was not well developed as a science in the late 1800s and early 1900s. No surveys were conducted before or during the demise of the chestnut that could document the impact on animal species (Pelton, personal communication). In addition, simultaneous widespread timber harvesting in eastern forests complicates efforts to assess the importance of chestnut to wildlife. However, historical accounts and old photographs clearly indicate that wildlife was much more abundant before the blight decimated the species.

Different approaches have been used in attempts to develop a blight-resistant American chestnut for eastern forests. These approaches include breeding within the species, hybridization with blight-resistant Asian hybrids and use of hypovirulent strains of the fungus (Diller and Clapper 1965, 1969; Thor 1976). Currently, a promising development involves the genetic engineering of the virus that induces hypovirulence (Choi and Nuss 1992). Regardless of the approach, the end result will be a tree that is resistant, not immune, to the chestnut blight. Resistant trees may be able to survive in present-day forest situations, but could be more susceptible to secondary attack from other pests.

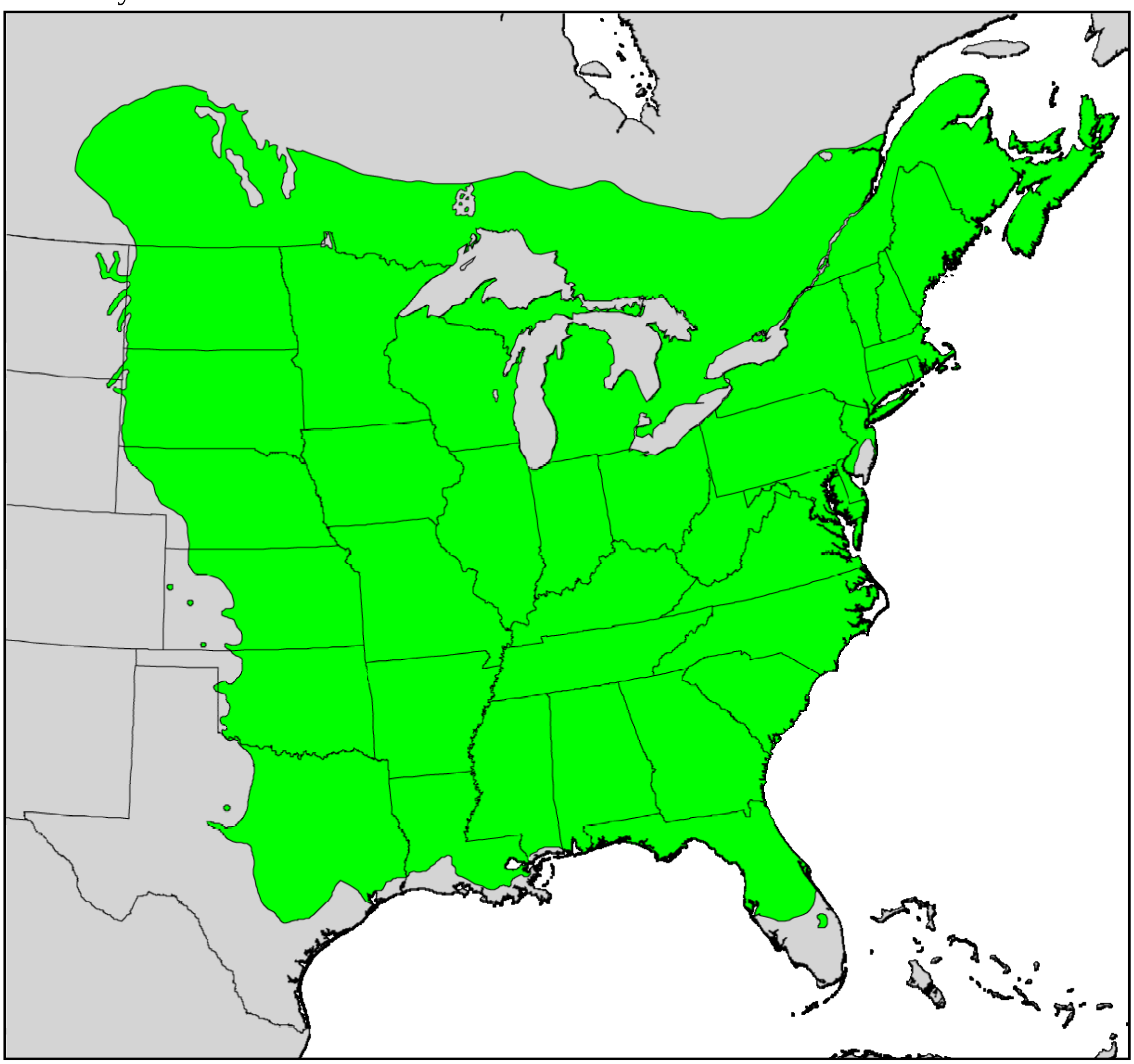
A chestnut in North American forests will have to contend with several exotic pests aside from chestnut blight. There is good evidence that an exotic fungus, *Phytophthora cinnamomi*, had infested southern populations of American chestnut and Allegheny chinkapin (*Castanea pumilla*) as early as 1824 (Crandall *et al*. 1945). The fungus attacks the roots and causes mortality or decline. Infestations by the chestnut gall wasp (*Dryocosmus kuriphilus*) were first reported in 1974 (Payne *et al*. 1975). Initially, this insect infested *Castanea* species in Georgia and gradually spread to adjacent states. Chestnut gall wasp larvae feed upon bud and flower tissue forming a characteristic gall. Mortality can occur with severe infestations.

Dutch Elm Disease

Dutch elm disease is the most devastating shade tree disease in the U.S. (Karnosky 1979). The American elm was once the primary ornamental tree in eastern and mid-western cities. The species was noted for fast growth and a vase-shaped form that made it an ideal choice for shading houses and streets. From the eastern forests, American elm provided lumber for boat building, cooperage, furniture, and agricultural implements. After 1930, however, use of American elm in urban landscapes and as a forest product dramatically decreased due to an exotic fungal disease. Dutch elm disease was first recorded in Cleveland, Ohio in 1930, and rapidly spread throughout eastern North America from three different infestation centers (May 1930; *cf*. Stipes and Campana 1981). The disease, caused by an introduced fungus, *Ophiostoma* (= *Ceratocystis*) *ulmi*, was brought into the country on different shipments of unpeeled raw veneer logs from Europe (USDA Forest Service 1991b). By 1977, the disease had spread to most of the contiguous 48 states. In the Northeast U.S. alone, 75 percent of the elms had died by 1979 (USDA Forest Service 1991b). Cities with large elm populations have suffered more than an aesthetic loss. The removal of dead and dying elms has cost up to an estimated $100 million per year nationwide (Mazzone and Peacock 1985). The disease has also virtually eliminated American elm as a timber species (Burkman *et al*. 1993). The five other species of native elms, *e.g.*, red or slippery elm (*Ulmus rubra*), are also vulnerable to infestation, but appear to have more resistance. Since arriving in America, the disease has evolved more aggressive strains which now are adding to the threat in Europe as well (USDA Forest Service 1991b).

Fungal infection usually occurs in wounds made by insect vectors and may be lethal in a small tree within a single year. Dual efforts have been made to control the disease, targeting the fungus and its primary vector, the introduced European elm bark beetle (*Scolytus multistriatus*). The removal of dead and dying elms and any dead wood left on the ground is essential to an effective long-term control program. This approach is feasible only in urban plantings, due to the expense of removal of the dead materials. Unfortunately, the disease also can be spread by root grafts are usually frustrated by transmission of the disease by beetles (Swank and Smith, personal communication). Pesticides and fungicides have been used only in urban settings and have had variable success in preventing the disease or arresting existing infestation.

Hybridization between American elm and disease-resistant Asian elms has been prevented by differences in chromosome numbers (Dermen and May 1966). Intraspecific and interspecific hybridizations have been made among selections of resistant Asian species and among American species (Townsend and Santamour 1993). Over 20 pure American elm clones have been identified with good resistance to *O. ulmi*, and a number of hybrid elms and Asian selections have been released for urban plantings. Evaluations of resistant American elms in forest settings have not yet been conducted.



Natural range of American elm

Gypsy Moth

The European gypsy moth has the broadest host range of all exotic pests in North America. The larval stage (caterpillar) defoliates a wide variety of woody plants, although it prefers hardwood trees. Oak species, which have dominated upland forests since the chestnut blight epidemic, are a preferred food source. Understory species important for mast production, *e.g.*, hazelnut, serviceberry, and hawthorn, are also favored food of gypsy moth larvae (*cf*. Gottschalk 1993). When preferred food sources are not available, older larvae feed on a variety of other wood plants including coniferous species of pine and spruce, arbor-vitae, and hemlock.

The insect was deliberately imported in 1869 to the U.S. in an attempt to establish a domestic silk industry. Gypsy moth was first observed as a forest pest in Massachusetts within 10 years of the original importation date. The pest has slowly spread throughout the northeastern states in subsequent years. By 1991, gypsy moth had infested 200,000 square miles of the Northeast, with additional outbreaks in North Carolina, Tennessee, Arkansas, Ohio, Michigan, and Wisconsin. Infestations of gypsy moth have also been reported in Washington, Oregon, California, and British Columbia, as well as in the Rocky Mountain states.

Gypsy moth infestations are cyclical. In 1978, 643,000 acres were defoliated, but in 1981, defoliation affected 12.9 million acres. An estimated 125 million acres were infested nationwide in 1991, of which 4.1 million acres (3 percent) were defoliated (Burkman *et al*. 1993). On the advancing front, the moth is perpetually at high population levels (USDA Forest Service 1991b).

Defoliation induced trees to drain energy reserves in attempting to refoliate. A healthy tree can usually withstand several consecutive defoliations of greater than 50 percent. Extensive feeding by gypsy moth larvae affects timber and recreational industries and alters the complexion of existing ecosystems. Mortality from defoliation can be as high as 90 percent where gypsy moth populations are at an epidemic level (Herrick and Gansner 1987). Although defoliation may not always result in tree mortality, diameter and volume growth will decline (Baker 1941, Twery 1987) and wood quality can be affect (Twery 1990).

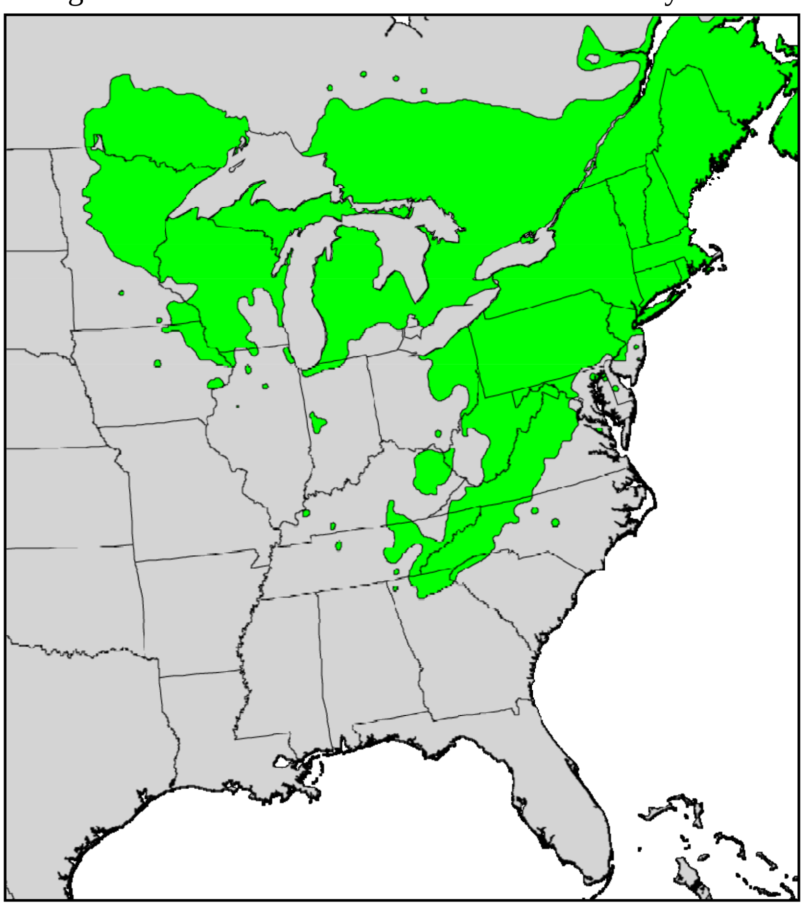
Gypsy moth defoliation will alter the species composition of the flora and fauna in a forest ecosystem by causing more nutritional resources to reach the remaining trees and plants in the over- and understory (Allen and Bowersox 1989). A change in the composition of plant species often affects certain wildlife populations and ultimately wildlife food chains. Water yield and quality in forest rivers, streams, ponds and lakes can be affected by gypsy moth activities. Water yield within a watershed increases after defoliation (Corbett and Lynch 1987). The decomposition of additional detritus on the forest floor increases the amount of nitrogen and other nutrients entering a water system and can alter water quality (Swank *et al*. 1981).

Gypsy moth infestations have an adverse influence on recreational use and associated industries. Alterations in plant and animal populations and water quality will have an influence on forest use for hunting and fishing. Heavy defoliation will reduce the aesthetic quality of the forest as a whole (Hollenhorst *et al*. 1993) and can result in a 20 percent reduction in recreational use in the infested area (Goebl 1987).

Various approaches have been used to control gypsy moth infestations. Pesticide spraying and silvicultural treatments have proven to be effective in controlling or minimizing gypsy moth damage, but have not stopped the spread of the pest into new areas. The Forest Service spent approximately $10.6 million on gypsy moth suppression and eradication efforts in fiscal year 1993. It is currently employing biotechnological methods to engineer more effective control agents to curtail the gypsy moth. Although the gypsy moth has encountered many native North American enemies, native predators and parasites have not been able to stop the spread of infestations. Naturally occurring *nuclear polyhedrosis* virus (NPV) is specific to the gypsy moth and has proved devastating to its survival. Unfortunately, the specific NPV has relatively limited natural occurrence. A solution containing the virus has been developed into a spray and is being tested under operational conditions (Cunningham *et al*. 1993). Over 50 exotic parasites and predators have been released over the years to control the pest (Burgess and Crossman 1929, Campbell 1975, Drost and Carde 1992). In 1989, an exotic fungus, *Entomophaga maimaiga*, caused high mortality in gypsy moths in New England (Andreadis and Weseloh 1990, Hajek *et al*. 1990). This fungus was originally introduced to control the gypsy moth in 1920, but previously has not had a significant impact. Research is currently being conducted to examine the efficacy of this fungus as a biological control agent (Hajek and Roberts 1992, Weseloh and Andreadis 1992).

White Pine Blister Rust

White pine blister rust is a disease that infests five needle pines (*Pinus* subgenus *Strobus*) throughout North America. The disease is caused by an exotic fungus, *Cronartium ribicola*, that was introduced to the continent on imported nursery stock in three separate locations: Kansas (1892), eastern Canada (1906), and western Canada (1921) (Mielke 1938, *cf*. Garrett 1986). From eastern Canada, it quickly spread throughout eastern white pine (*Pinus strobus*) populations in the Northeast and Great Lakes region, followed by southward migration to high-elevation populations in North Carolina. In the Pacific Northwest, the disease spread throughout the ranges of its host trees, moving southward through California and into New Mexico (USDA Forest Service 1991b). Western white (*P. monticola*), sugar (*P. lambertiana*), whitebark (*P. albicaulis*), southwestern white (*P. strobiliformis*), and

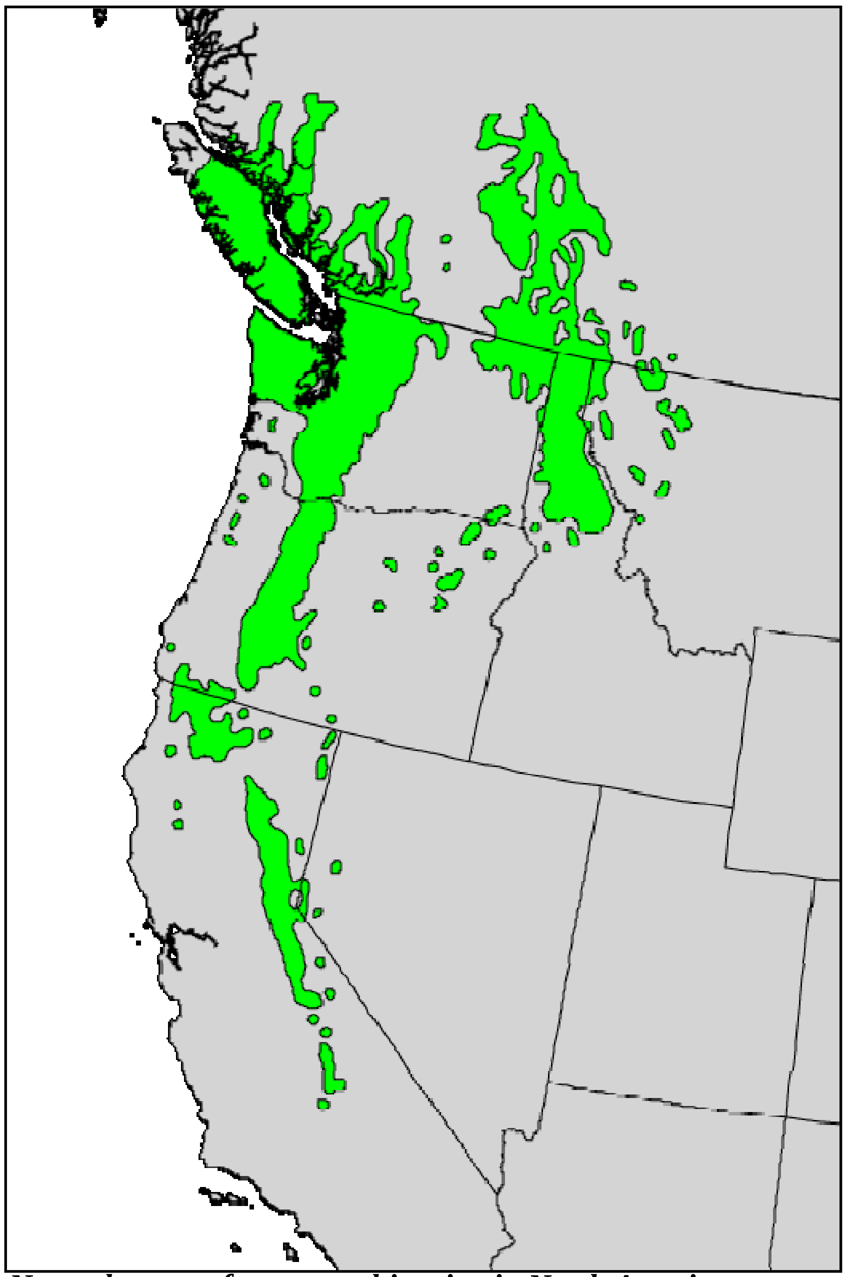


Natural range of eastern white pine in North America

bristlecone (*P. aristata*) pines are subject to infestation from this pathogen (Hoff and Hagle 1989).

Damage to eastern white pine has been comparatively less than damage to western white pine populations. The majority of eastern white pines grow in low-rust-hazard areas. In addition, the species is less susceptible to blister rust than western white pine (Bingham 1983). Western white pine stands can have as high as 94 percent mortality caused by the disease (Hirt 1948).

Different approaches have been utilized to control blister rust. The alternate hosts for *Cronartium ribicola* are species in the genus *Ribes, e.g.*, gooseberry, and blister rust control prescriptions have recommended the removal or eradication of *Ribes* bushes removal has been shown to be a successful control mechanism in high-rust-hazard areas (Ostrofsky *et al*. 1988). In the western forests of Washington, Idaho, Montana, and Wyoming, almost 470 million *Ribes* bushes were removed from 1923 to 1965 (Hoff and Hagle 1989). This practice was discontinued, however, due to the limited and, often, absence of success in controlling blister rust. Chemical control using antibiotics was tried briefly, but was abandoned after limited success (*cf*. Bingham 1983).



Natural range of western white pine in North America

The damage to western white pine populations was so extensive that operational planting of the species had been generally discontinued by 1968 (Ketcham *et al*. 1968). However, planting of western white pine has resumed using blister rust-resistant seedlings. Forest geneticists identified resistant trees in natural populations of western white pine, as well as other white pines species, and instituted screening/breeding programs (Riker *et al*. 1943, Bingham 1983). Genetic resistance to blister rust was found to differ among species (*cf*. Garrett 1986). Blister rust resistance is polygenic in eastern white pine, controlled by a single dominant gene in sugar pine, and at least two separate, recessive genes confer resistance in western white pine. Tree improvement programs have developed seed orchards for eastern and western white pines that produce seed with blister rust resistance.

Most of the five needle pine species are harvested commercially, particularly eastern white and western white pines. These two species are particularly valuable in forest ecosystems, as they often dominate forest stands over significant areas within their respective rangers (USDA Forest Service 1991b). Other species of white pine are not commercially important, but occupy critical ecological niches. Some white pines produce large seeds that are extremely nutritious and important in wildlife food chains. For example, whitebark pine seeds in the Rocky Mountains serve as a major food source for grizzly bear, black bear, red squirrels, and Clark's nutcracker (Kendall and Arno 1989).

Balsam Woolly Adelgid

True firs of the genus *Abies* in North America are attacked by the balsam woolly adelgid (*Adelges piceae*). The adelgid was introduced into New England in 1908 on European nursery stock (Kotinsky 1916). The adelgid can cause physical damage by feeding, although chemically induced injury is the major cause of mortality. The salivary secretions of the adelgid change the balance of growth hormones and inhibitors and cause abnormal development of tissues in trees (Balch *et al*. 1964). The tissue is killed by a combination of factors associated with salivary secretions (*cf*. Hay 1978) and the infected tree can die within 2-7 years (Johnson 1980).

In the East, the balsam fir (*Abies balsamea*) is infested from northern New York into the Canadian Maritime Provinces and the Gaspe region of Quebec (Mitchell *et al*. 1970). Severe damage of balsam fir populations can occasionally occur. West coast fir populations became infested in approximately 1928 from a separate European source (Annand 1928). All western fir species have been infested, to varying degrees, with the possible exception of the unique bristlecone fir (*Abies bracteata*) (*vide* Hay 1978). As in eastern North America, damage to western fir species can be extensive.

The eastern infestation has spread south, along the Appalachian mountains. The northern bracted balsam fir (*Abies balsamea* var. *phanerolepsis*) has been almost eliminated by adelgid infestation. This variety of balsam fir has a very limited distribution and was restricted to two mountaintops in northern Virginia (Langdon, personal communication). Presently the only mature population covers less than one acre. Mature populations of Fraser fir (*Abies fraseri*) also have been severely affected. This species is endemic to mountaintops in the southern Appalachians. It is the codominant species with red spruce (*Picea rubens*) that together constitute the spruce-fir ecosystems found only at high elevations in this region. Adelgid infestations have eliminated mature trees from many locations. Although immature trees still persist in significant numbers, these will be attacked with increasing severity as they age. Therefore, the reproductive potential of the species may have been destroyed.

The North Carolina State Park Service tried intensive insecticide spraying at Mount Mitchell shortly after the detection of the adelgid in 1957. This technique proved effective in protecting individual trees but was ill-suited for use on a forest-wide scale. Until recently, the National Park Service in the Great Smoky Mountains National Park deployed an environmentally safe detergent spray to control the insect. This spray also proved too costly and labor intensive to be employed on a large scale (Langdon, personal communication).

Extensive research has been conducted to locate a biological control for the adelgid, but no effective biocontrol agents have been found. All apparently suitable insects were field-tested in eastern Canada over a 35-year period. No single predator or group of predators was found to be effective (Schooley *et al*. 1984). While some fungal diseases are known to attack the adelgid, greenhouse and field studies in Quebec have not identified a successful control. The potential for control organisms from other locations is unknown (Schooley *et at*.1984).

Scleroderris Canker

Scleroderris canker is caused by the fungus *Ascocalyx abietina* (= *Gremmeniella abietina*) and infests various coniferous species in North America, Europe and Asia (Skilling *et al*. 1986). The fungus usually causes tree mortality by producing cankers that girdle a large number of branches. Two strains of the fungus are known in North America. One, called the "North American" strain, has caused extensive damage in the Lake States since at least 1950 (*cf*. Skilling *et al*. 1986). This strain is thought to be native to the Rocky Mountains, where it causes minimal damage to coniferous species, *e.g.* lodgepole pine (*Pinus contorta*) (Dorworth 1984). It attacks nursery stock and young plantations of red pine (*Pinus resinosa*), jack pine (*P. banksiana*), eastern white pine and the exotic Scots or Scotch pine (*P. sylvestris*). The fungus was spread by planting infested nursery stock and affected approximately two-thirds of National Forest plantations in Michigan and Wisconsin by 1965. Approximately 40 percent of the seedlings planted were killed. Fungicide treatment of nursery stock and silvicultural procedures have now reduced the disease to manageable levels (Skilling *et al*. 1986).

In 1975, *Gremmeniella abietina* was observed in New York, killing red and Scots pines of all ages (Setliff *et al.* 1977). Isolates were serologically identical to fungal isolates found in Europe (Dorworth *et al.* 1977); hence the strain was called the "European strain". Studies have shown that this strain has a wider range of hosts than the North American strain and could infest fir (*Abies*) and spruce (*Picea*) species as well as pine. The European strain presently occurs in northeastern North America and appears to be spreading (LaFlamme and LaChance 1987, Moody 1992). Intermediate strains, with the ability to attack trees of all ages, have been identified (Skilling et al. 1986).

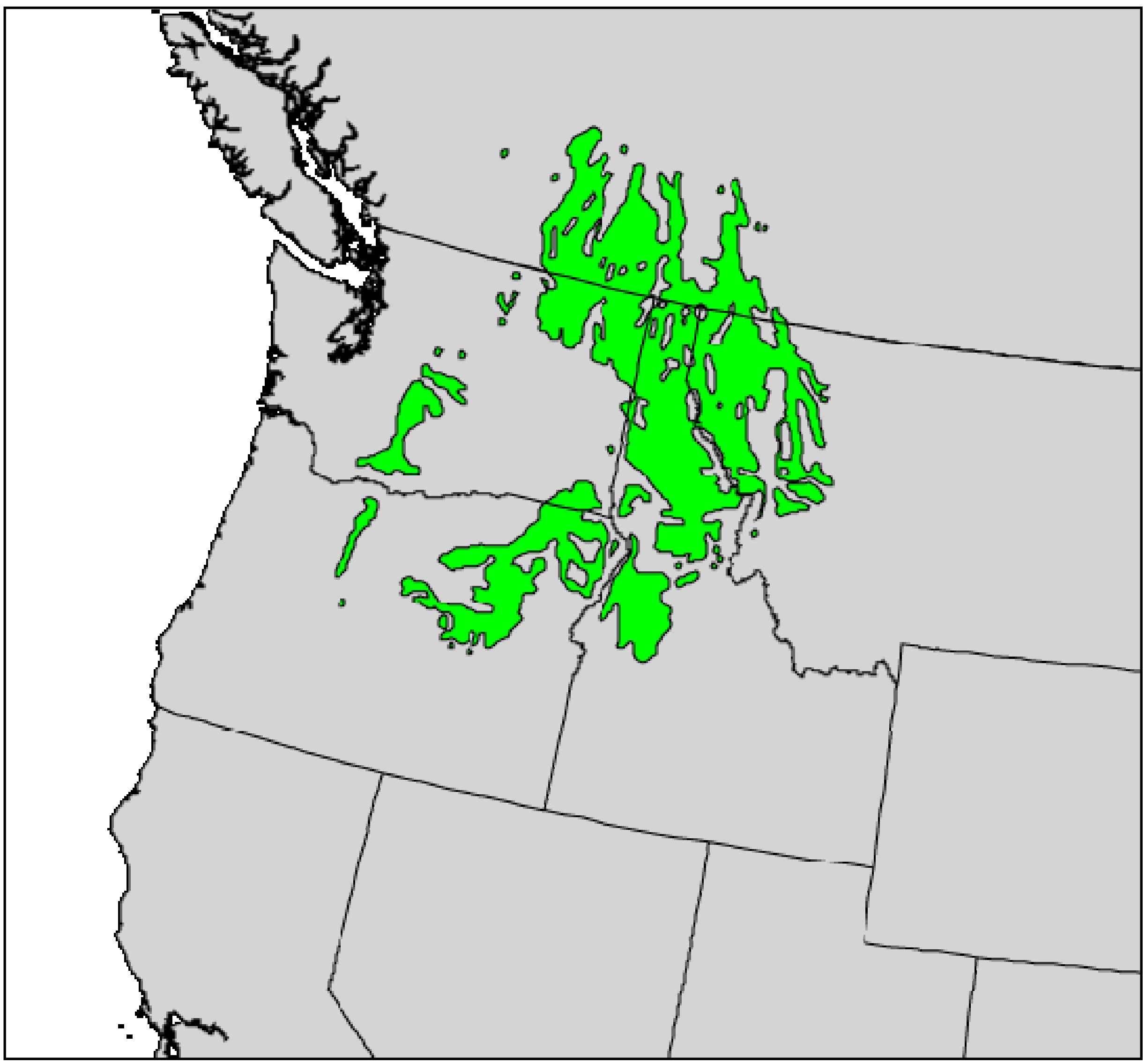
The European strain can be controlled in nurseries by spraying fungicides and young plantings by silvicultural practices. This strain, however, has the ability to attack mature trees, so silvicultural control is less effective than with North American strain infestations (Skilling *et al*. 1986).

Larch Casebearer

Eastern larch or tamarack (*Larix laricina*), and western larch (*Larix occidentalis*) are infested with larch casebearer (*Colephora laricella*). The moth was introduced into Massachusetts in

1886, probably on imported nursery stock from Europe (Tunnock and Ryan 1983, Otvos and Quednau 1984). Initially infesting tamarack, the casebearer spread throughout the northeastern U.S. and southeastern Canada, reaching the Great Lakes region in the 1950s. By 1970, it was present in southeastern Manitoba (Otvos and Quednau 1984). In the West, the insect was discovered infesting western larch in Idaho in 1957 and was considered to be the species' most serious pest (Denton 1979). An outbreak occurred in British Columbia in 1966 (Otvos and Quednau 1984), and by 1982, all the U.S. range and most of the southern Canadian range of the western larch was infested (Tunnock and Ryan 1983). The mouth larvae feed on the internal needle tissue causing defoliation. Five years of defoliation can kill a tree or reduce potential growth by as much as 97 percent (Tunnock *et al*. 1969). Younger trees growing in the open or along the edges of openings suffer the highest mortality (Tunnock and Ryan 1983).

Control strategies relying on a combination of natural factors and introduced parasites have been successful in eastern and central Canada and the northwestern U.S. (Otvos and Quednau 1984,



Natural range of the western larch in North America

Graham 1949, Ryan *et al*. 1987). The control organisms used include two introduced European parasites, the braconid, *Agathis pumila* and eulophid, *Chrysocharis laricinellae*. In western North America, however, biological control using *Agathis pumila* was not satisfactory. Other parasites, including *Chrysocharis laricinellae,* were released from 1971 into the 1980s (Ryan *et al*. 1987). Long-term studies are under way to evaluate the effectiveness of the parasites (Ryan 1990).

European Larch Canker

European larch canker disease infests species of the genus *Larix* and the Chinese monotype, *Psuedolarix amabilis*. This disease is caused by a fungus, *Lachnellula* (*Dasyscypha*) *willkommii*, and was first reported in North America in 1927 (Spaulding and Siggers 1927). The disease was effectively eradicated from Massachusetts by 1965 (Tegethoff 1965), but a new infestation was found in Canada in 1980 (Magasi and Pond 1982). Subsequently, infestations were observed in the coastal areas of eastern Maine (Miller-Weeks and Stark 1983). In those areas where the disease is present, the canker has infested and damaged 50 to 100 percent of the larch in plantations or young managed stands (USDA Forest Service 1991b). The severe impact of the canker on larch in parts of Europe and its potential impact on North American species has prompted Environment Canada, the USDA Forest Service, and the Maine Forest Service to issue public-information flyers urging extreme caution in transporting cuttings and seedlings (USDA Forest Service 1991b).

Pear Thrips

Pear thrips (*Taeniothrips inconsequens*) are native to Europe and were introduced to North America approximately 1900 (*cf*. Carey *et al*. 1992). The insect was first described as a pest on fruit trees in California (Foster and Jones 1915), but recently has become a serious pest of sugar maple (*Acer saccharum*) (Parker *et al*. 1988). Pennsylvania foresters first observed defoliated trees in 1979, and pear thrips were identified as the casual agent. A subsequent inspection of survey records indicated that pear thrips were present in central Pennsylvania during the mid 1970s (Quimby 1990).

Pear thrips infestations are found in New England and the Great Lake States and are spreading to the midwestern region. Scientists cannot yet explain why pear thrips, formerly known as pests of fruit trees, have switched host preference to sugar maples and other forest tree species. Damage is highly variable by year and geographic location. For example, Pennsylvania found 100,000 acres of heavy defoliation in 1982, virtually none in 1983 and 1984, and 110,000 acres of heavy defoliation in 1985 (Laudermilch 1988).

Control methods have not been developed yet. All pear thrips identified in the U.S. are females and are believed to reproduce by parthenogenesis (Laudermilch 1988).

Winter Moth

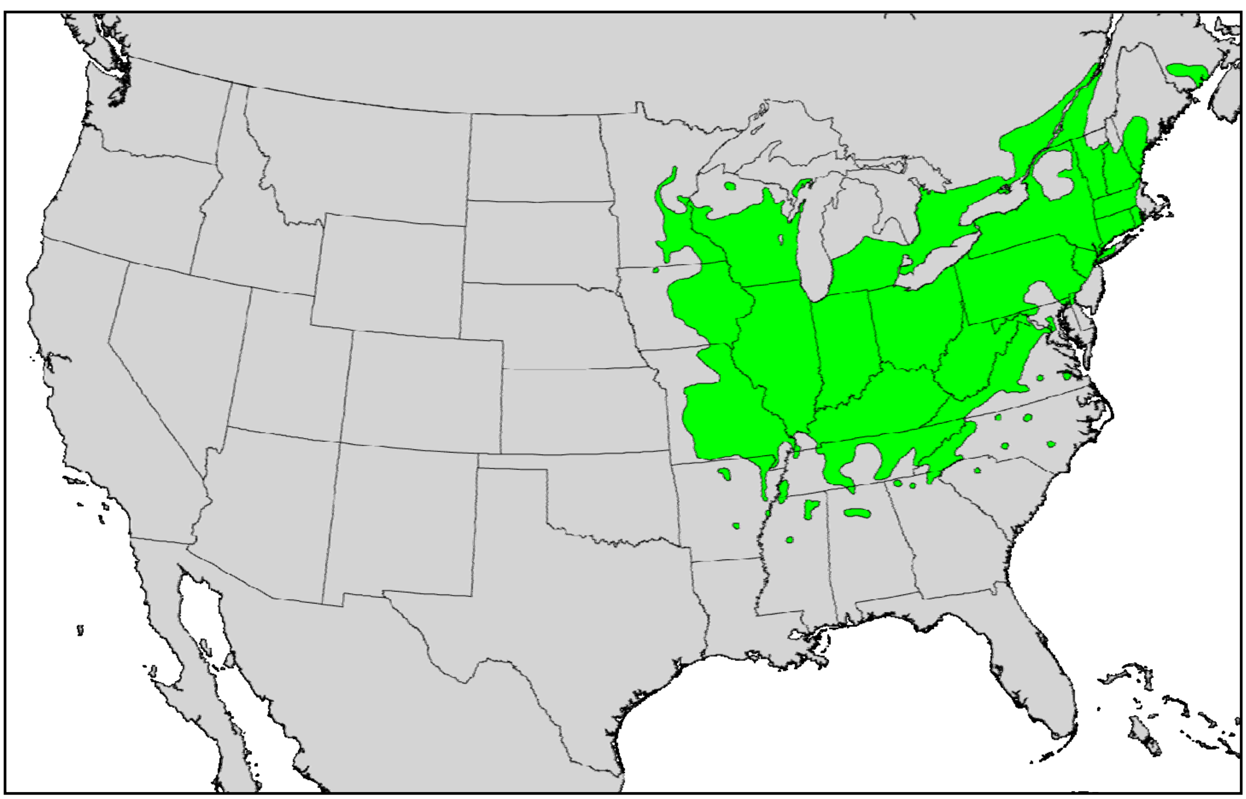
The winter moth (*Operophtera brumata*) feeds on various broadleaf trees, including maples, hawthorns, cherry, poplar, oaks, apple, and willow, in the Canadian Maritime provinces sand U.S. Pacific Northwest forests. The moth was accidentally introduced into Nova Scotia, probably in the 1930s (Embree and Otvos 1984). By 1952, is had become a serious pest over much of Nova Scotia. Hardwood forests, particularly those containing northern red oak and wild apple, were severely defoliated. Two exotic parasites, *Cyzenis albicans* and *Agrypon flaveolatum*, were released from 1955 to 1959 and moth populations subsequently collapsed (Embree 1991). Moth populations in native forests of the Maritime Provinces now appear to be controlled by a combination of life history factors and the two introduced parasites (Embree and Otvos 1984; Embree 1991). Sporadic outbreaks are now associated with early-leafing tree and shrub species, with little infestation of oak species (Embree 1984).

The winter moth was first reported in western North America in 1976 (Gillespie *et al* 1978), but evidence indicates it had been established in Oregon for many years (Kimberling *et al.* 1986). It is unknown whether western infestations were due to a migration from eastern Canada or to a separate introduction from Europe (Kimberling *et al*. 1986). The distribution rate of the insect in Oregon has been slow, unlike the experience in Nova Scotia. The reason may be the lesser abundance of host plants of which leaf buds open sufficiently early for the moth to take best advantage (Kimberling *et al*. 1986). It is still too early to determine whether the parasites will be effective in British Columbia and Washington State (Kimberling *et al*. 1986).

Winter moth has a broad host range and is adaptable to different temperature regimes. It is widespread in Europe and will probably continue to expand its range in North America.

Butternut Canker

Butternut or white walnut (*Juglans cinera*) is highly valued hardwood species. The tree is closely related to black walnut (*Juglans nigra*), but can grow on a poorer, drier site. Butternut is harvested for veneer and lumber for furniture and carvings. The heartwood of butternut is lighter



Natural range of butternut in North America

than black walnut and has a beautiful grain. Butternut is a hard mast species, producing nuts that are a component of many wildlife species' diets. The nut is palatable for human consumption, and 21 cultivars have been selected for orchard production (Millikan and Stefan 1989).

Butternut populations have been infested by the fungus *Sirococcus clavigignenti-juglandacearum*, that causes multiple branch and stem cankers. Cankers produced on the main stem will eventually girdle the tree and cause death. The disease was first discovered in 1967 in southwestern Wisconsin (Renlund 1971), but is believed to have originated from the eastern coast (Anderson and LaMadeleine 1978). Butternut canker has spread throughout much of the species' range. The 1991 Forest Insect and Disease Conditions in the United States survey (USDA Forest Service 1992) reports new infestations in Vermont and emphasizes that "[butternut canker] disease has eliminated most of the butternut in the Southern region." Unlike chestnut, butternut will not sprout from the root crown when the top is killed by cankers. Seedlings and young sprouts are killed by the disease in addition to mature trees (Prey and Kuntz 1982). Therefore, when butternut canker destroys a population, that particular gene pool is lost forever as there is no possibility for reproduction.

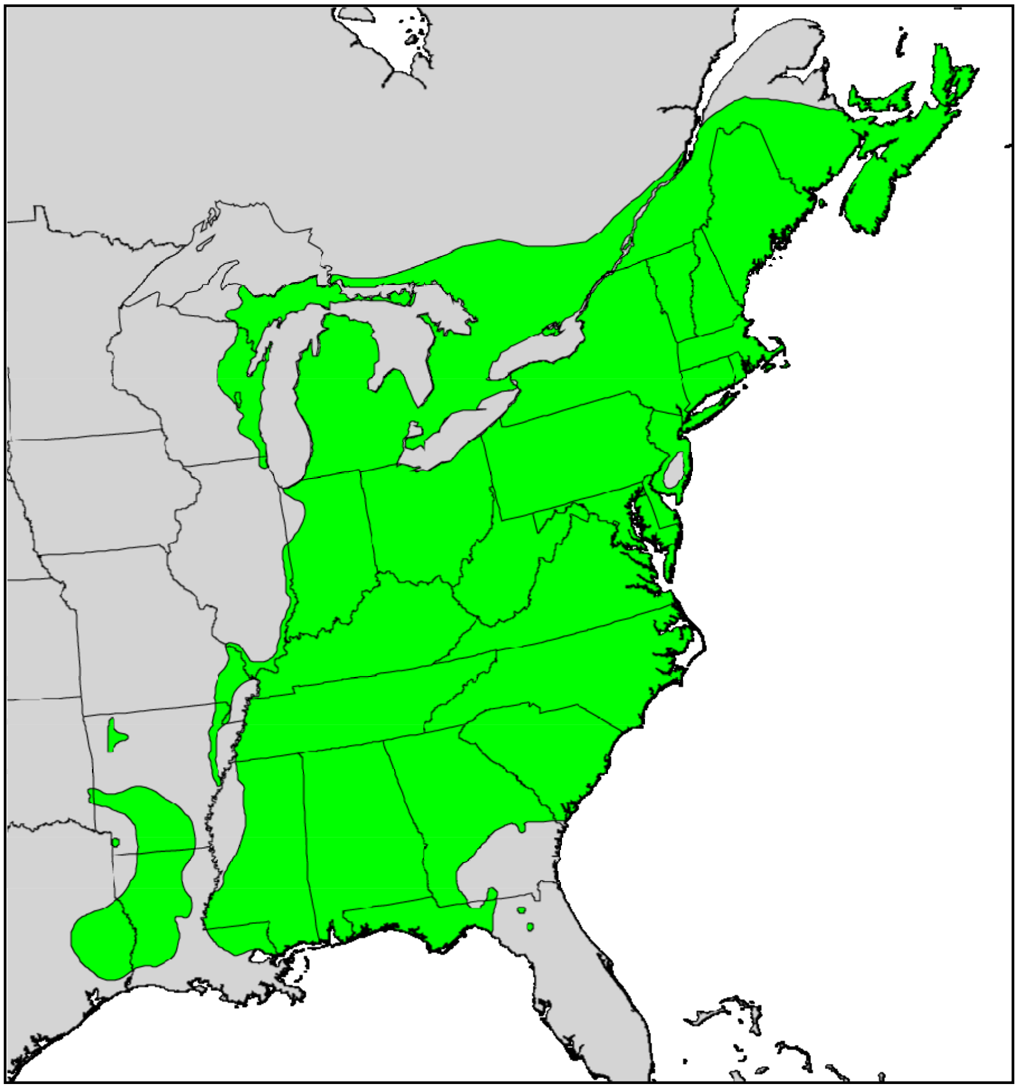
The devastation of butternut is occurring so rapidly that the species is currently a Federal Category 2 candidate for listing under the Endangered Species Act. In the northern National Forests (Forest Service, Region 9), it has been listed as a sensitive species. In southern states (Forest Service, Region 8), the National Forests in Mississippi consider butternut a sensitive species, and other southern National Forests have recommended the tree for sensitive species status.

No known cure exits for the disease. Research to develop a disease-resistant tree began in 1989, years after the first infestation was documented. A few putative resistant trees have been found in various locations and are presently being evaluated (Anderson, personal communication).

Beech Bark Disease

American beech (*Fagus grandifolia*) is an important species in climax forests of eastern North America. The tree is utilized for lumber and pulp, and provides hard mast for wildlife species. Beech populations in the northeast have been infested with a disease complex that has caused extensive mortality or reduced productivity. This disease has now been found as far south as the Great Smoky Mountains National Park (Rhea, personal communication). The disease complex is composed of the exotic beech scale (*Cryptococcus fagisuga*) and fungi of the *Nectria* genus, *N. galligena* and/or *N. coccinea* var. *faginata*. The fungi enter the tree through holes in the bark caused by scale infestation. The resulting cankers can kill or disfigure the infested tree (Houston and Valentine 1988).

The beech scale was inadvertently imported into North America on European beech (*Fagus sylvatica*) nursery stock (Hawbolt 1944). By 1932, a survey in Maine revealed that many forests were infested (Ehrlich 1934). In many northeastern stands, the disease has killed more than 50 percent of the beech population (USDA 1985). Along the "killing" front (*sensu* Shigo 1972), the disease is causing extensive mortality. Beech bark disease also kills sprouts from disease-killed trees (Burkman *et al*. 1993).



Natural range of beech in North America

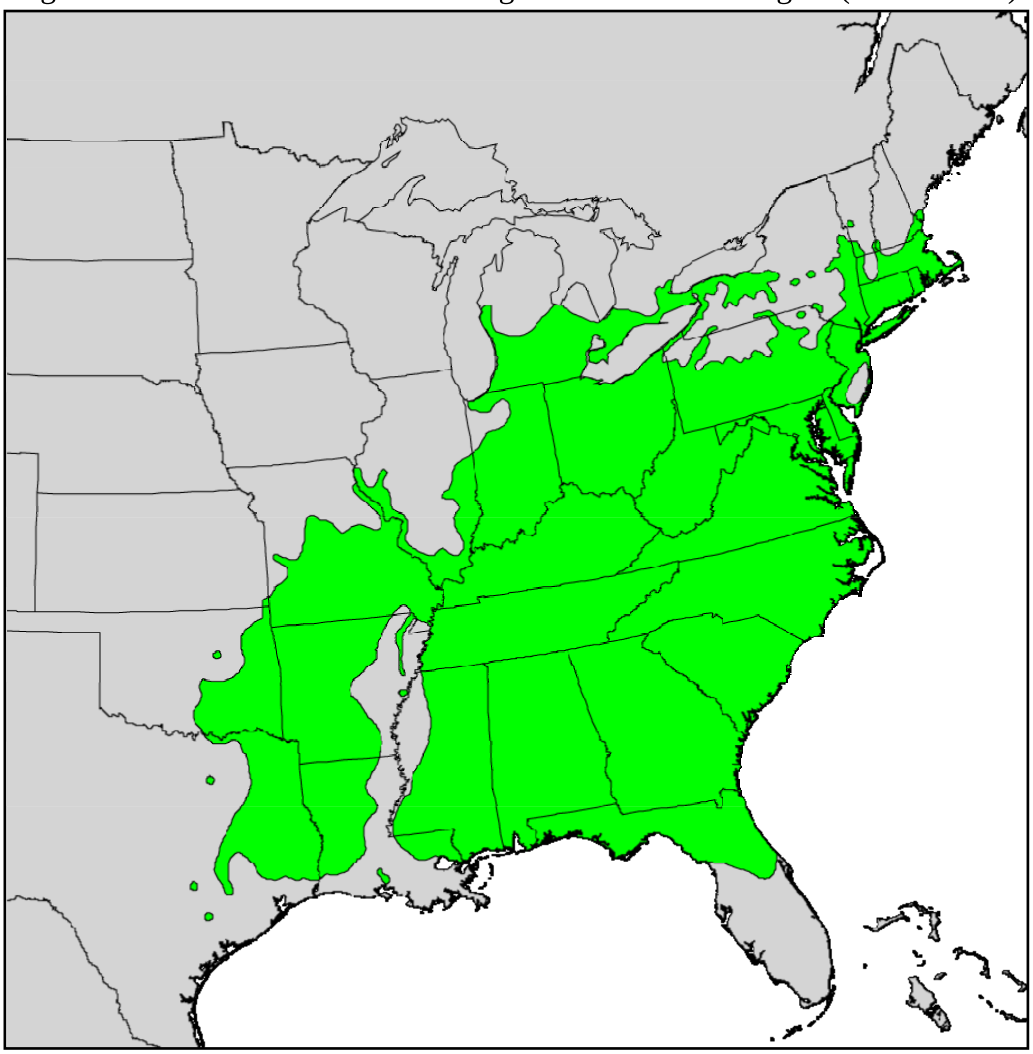
Chemical controls and detergent scrubbing have effectively controlled the scale on individual trees, but such measures are cost-prohibitive in forests. The scale has several natural enemies, the most prominent of which is the ladybird beetle (*Chilocorus stigma*). A fungus, *Nematogonum ferrugineum*, is a natural parasite of the *Nectria* fungus. The efficiency of this fungus, however, in curtailing the spread of the disease has not been adequately evaluated. Some beech trees are resistant to scale infestation (Shigo 1964, Cammermeyer 1993) and can be integrated into breeding programs.

Dogwood Anthracnose

The flowering and Pacific dogwoods (*Cornus florida* and *Cornus nuttallii*, respectively) are highly valued aesthetic components of eastern and western forests. Although dogwoods (*Cornus* species) are not important as a timber species, they are important as a mast supply for mammals and birds (*cf*. Mitchell *et al*. 1988). The fruit is high in protein and is a valuable food source for many migratory birds. The leaves and twigs of the dogwood provide browse for many herbivores, including deer. Fallen leaves from the dogwood contain a large amount of calcium and act as a major soil builder (Hepting 1971). In addition, the springtime floral display has not been ignored by the commercial nursery industry. Dogwood cultivars are extensively used in landscape plantings.

The opportunity for viewing the natural beauty of forest dogwoods may be limited in some areas. An anthracnose disease is plaguing both the flowering dogwood in eastern forests and the Pacific dogwood in the Pacific Northwest. It has killed over 80 percent of the trees in some areas (US Forest Service 1991a). First discovered in Washington State in 1976 (Byther and Davidson 1979) and subsequently in New York in 1978 (*cf.* Pirone 1980), the disease has spread rapidly throughout eastern and western forests (Britton 1993). In southeastern North America, an estimated 5.7 million acres of forest were affected by 1990 (Chellemi *et al.*, in press). The fungus is most virulent in cool, continuously moist conditions, *e.g.*, high elevation dogwood populations proximal to water.

Dogwood anthracnose is a leaf and twig disease that is initially detected by leaf necrosis. The fungus *Discula destructiva* is now recognized as the causal agent (Redlin 1991). While the exact



Natural range of the flowering dogwood

origin of the fungus in North America is uncertain, many scientists believe that the disease was introduced as it was first discovered near large port cities. Once infested, a tree will eventually become defoliated and may take several years to die. Occasionally trees are killed by annual cankers that can girdle the stem. Studies by Anderson *et al*. (1993) suggest that acid rain may predispose dogwoods to infestation and increase the severity of the disease. Contrary to forest-dwelling dogwoods, well-maintained trees in landscape plantings with full sun exposure often can survive (Swank and Smith, personal communication).

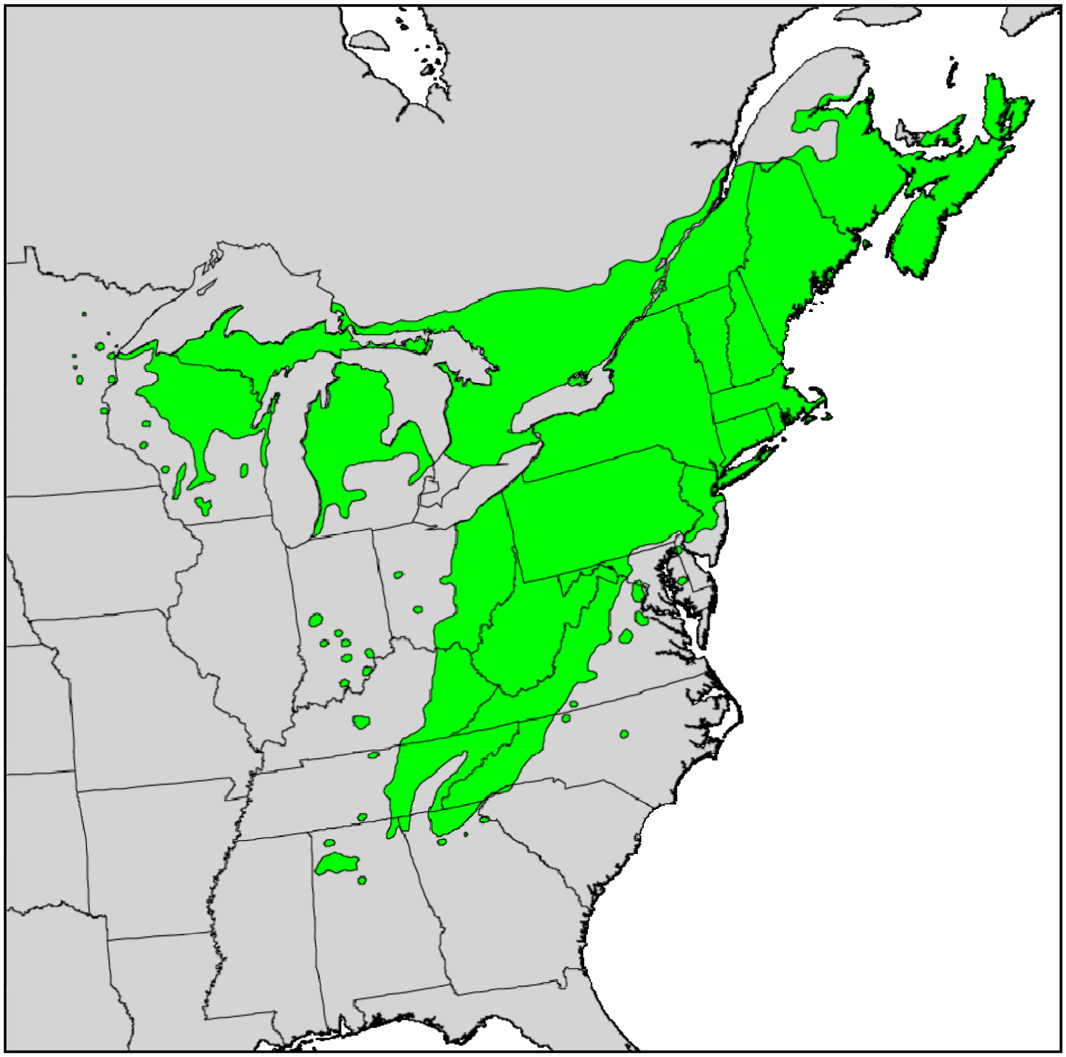
Public concern for the species' existence was increased when research failed to show resistance in population samples from 20 different states (Santamour *et al*. 1990). As a result, certain southern universities and the Forest Service has become extensively involved in assessing the spread, impact, and control of this pest. Surveys in Catoctin National Park have located putative resistant trees in areas where dogwood populations have been decimated (Langdon, personal communication; Windham, personal communication). Clones of these trees have shown varying degrees of resistant under greenhouse and field test conditions (Windham *et al*., unpublished) and have been integrated into a breeding program.

Hemlock Woolly Adelgid

The hemlock woolly adelgid (*Adelges tsugae*) attacks eastern hemlock (*Tsuga canadensis*), a commercially important species in eastern forests. The insect is believed to have been introduced into the U.S. from Asia (*cf*. McClure 1991) and was first reported in the Pacific northwest more than 65 years ago (Annand 1924). The insect was first observed in eastern forests approximately 40 years ago in Virginia. The hemlock wooly adelgid has spread north into southern New England. The adelgid thrives in colder temperatures and is, therefore, likely to infest eventually the entire Northeast and eastern Canada (McClure 1989). A rapid increase in infested acreage was reported in New York in 1990, and northern New Jersey has 26,000 acres of infested hemlock. Apparently it is not spreading south as rapidly, as it has not yet been found in North Carolina (Langdon, personal communication).

The adelgid probably injects the hemlock trees with a toxic saliva during feeding, as with the related balsam woolly adelgid (McClure 1991). Symptoms are foliage discoloration and dead branches. The tree usually dies within four years. All hemlocks are affected in a similar fashion, irrespective of age and size. Other introduced insects, the elongate and circular hemlock scales, have been found in conjunction with the adelgid (Burkman *et al* 1993). These insects were introduced from Japan. Both scales can weaken and kill hemlocks, although not as rapidly as the adelgid (Stevens, personal communication).

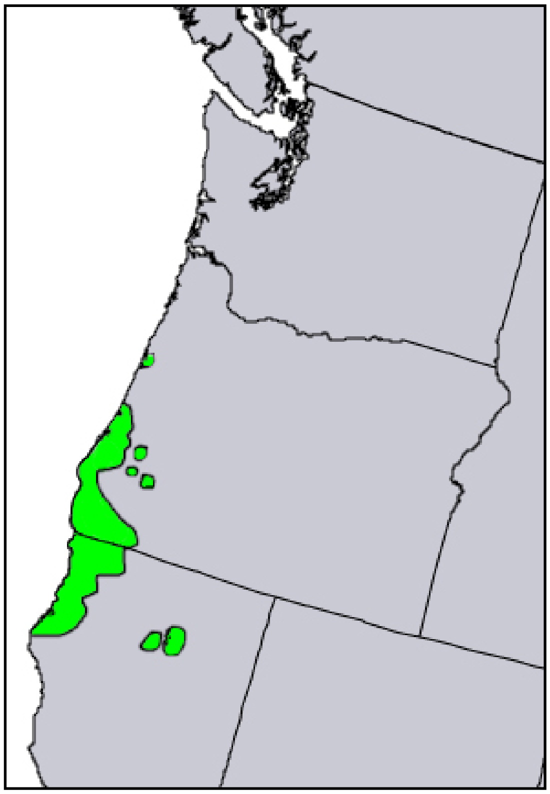
No resistance to the adelgid has been recorded in eastern hemlock nor has effective biological control(s) been found. Pesticides, horticultural oil, and insecticidal soap have been effective in controlling infestation in nursery and urban plantings (McClure 1987). However, these methods are not applicable to or only partially effective in forest settings. The National Arboretum is presently engaged in obtaining seed source collections of different hemlock species to evaluate for resistance to this pest (Garvey, personal communication).



Natural range of eastern hemlock in North America

Port-Orford-Cedar Root Disease

Port-Orford-Cedar (*Chamaecyparis lawsoniana*) is endemic to a limited range along the Pacific Coast from Coos Bay, Oregon to northern California. Port-Orford-Cedar-dominated forests are floristically diverse communities and are considered to be uniquely beautiful landscapes by recreational visitors. The species is valuable for its highly aromatic wood and is commercially widely used as a landscape plant. Native Port-Orford-Cedar populations have been decimated by a root disease caused by the exotic fungus *Phytophthora lateralis*. The disease was first reported in 1923 in a nursery near Seattle (Hunt in Zobel *et al*. 1985). The origin of *Phytophthora lateralis* remains unknown, although the partial resistance of Asian *Chamaecyparis* species has led some to speculate that it is Oriental in origin (Roth *et al* 1987). The disease initially infests fine roots by directly penetrating into succulent tissues, and eventually colonizes the entire root system. Mortality occurs in seedlings within a few days, while a large tree may take several years to die. The fungus grows only in living tissue and is not found independently in the soil (Ostrofsky *et al*. 1977).



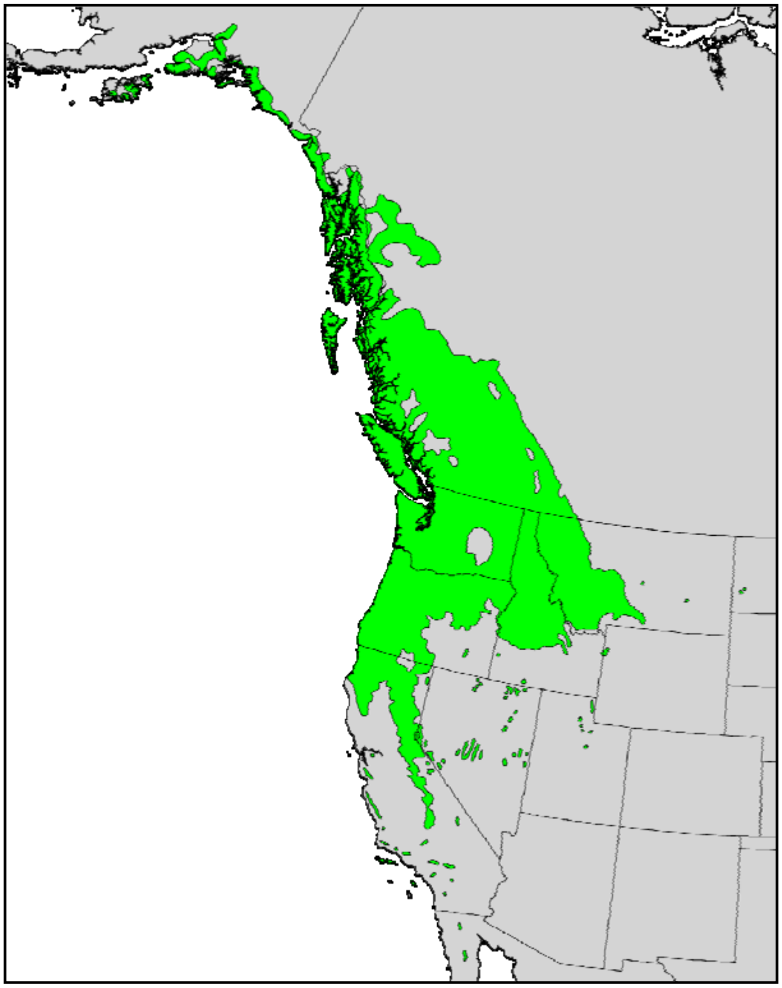
Natural range of Port-Orford-Cedar

By 1970, the disease had spread throughout the tree's range at lower elevations in Oregon (Kliejunas and Adams 1980). It is easily spread by movement of infested plant stock (landscape plants), including other species of *Chamaecyparis*. Zobel *et al*. (1985) conclude that the root disease "probably never would have emerged in epidemic form without the widespread planting of ornamental *Chamaecyparis* in northwestern Oregon and Washington." It is also spread through movement of spore-contaminated soil by machinery and animals. The spores germinate in water-saturated soil. Zobel *et al*. (1985) estimated that approximately 60 percent of the young regeneration has been killed by the disease. They concluded that without management techniques, or development of resistant stock, there is a limited future for commercial harvesting of Port-Orford-Cedar.

The restoration and/or preservation of Port-Orford-Cedar has been addressed by several different approaches. A project to hybridize Port-Orford-Cedar with more resistant *Chamaecyparis* species has been initiated (Roth *et al*. 1987). Control strategies, such as cleaning soil off of logging equipment, have also been implemented. To minimize the spread of infestation, recommendations have been made for strict management of human and animal (including wildlife) access to Port-Orford-Cedar stands in addition to removing trees proximal to water courses, road edges, and moist sites (Kliejunas and Adams 1980; Zobel *et al*. 1985).

Larch-Poplar Melampsora Rust

Black cottonwood (*Populus trichocarpa*) and quaking aspen (*Populus tremuloides*) are important components of Pacific Northwest forests. These species and various poplar hybrids are planted for fiber and ornamental uses (Newcombe and Chastagner 1993a) and are considered as a potential source of biomass for conversion to energy (Abelson 1991). In 1991, rusts were observed in several hybrid poplar plantations in western Washington and Oregon. The rusts were identified as *Melampsora medusae* f.sp. *deltoidae*, a species endemic to eastern North America, and *Melampsora larici-populina*, a Eurasian rust not previously reported in North America (*cf*. Newcombe and Chastagner 1993a). By December 1992, *M. larici-populina* infestations had been identified in an area about 30 miles wide along the lower Columbia River (Chastagner *et al*. 1993) and from urban plantings and nurseries in many areas of California (Newcombe and Chastagner 1993b). The widespread nature of the infestation indicates that the rust has been present along the Pacific coast for years.



The range of black cottonwood is from Alaska to southern California, along the coast area

Melampsora larici-populina rust requires two hosts, a *Populus* species and a coniferous species, to complete it life cycle. In both hosts, poplar leaf rust can cause severe defoliation that reduces growth and may induce physiological disorders (Newcombe and Chastagner 1993a).

Other Exotic Pests

The preceding summaries of infestations represent examples of exotic pests that have caused notable destruction to a particular species or ecosystem. Forest Service staff have compiled lists of all exotic pests, insects, and diseases that have been introduced to North American trees, tree nurseries, and wood products. These lists now total over 300 species (Millers *et al*., unpublished manuscript and personal communication). Some of the pests cause as much damage as the examples presented in this paper, *e.g.*, European spruce sawfly (*Gilpinia hercyniae*). Other pests damage trees in a less obvious manner, reducing vigor through feeding/parasitism or providing an environment for a secondary pest to invade the tree. A good example of a pest that probably causes widespread, but not lethal, damage is the Asiatic oak weevil (*Cyrtepistomus castaneus*). Larvae of this pest overwinter in the ground, feeding upon root hairs of the host plant. Adults feed upon the foliage of the host plant after emergence. Ferguson *et al*. (1992) suspected that damage from Asiatic oak weevils may negatively affect oak regeneration.

New pests are continuously being imported, despite APHIS regulations and quarantines. The common (or larger) pine shoot beetle (*Tomicus* (= *Blastophagus*) *piniperdia*) was first discovered in July 1992 infecting Scotch (Scots) pine near Cleveland, Ohio (Kucera 1992). Since the initial discovery, infestations have been found in New York, Pennsylvania, Illinois, Indiana, and Michigan. This pest has attacked a variety of Eurasian and North American pine species. APHIS has quarantined movement of logs, Christmas trees, and nursery stock of coniferous species from the infested states.

Eleven specimens of another exotic pest, the spruce beetle (*Ips typographus*), were captured in pheromone traps near a dunnage pile in the port area of Erie, Pennsylvania in spring 1993 (Hofacker 1993). While the Siberian risk assessment states that this insect normally utilizes dead wood (USDA Forest Service 1991b), Smith (personal communication) states that "[t]his insect is one of the most destructive pests of spruce in Europe; one outbreak destroyed an estimated 30 million cubic meters of wood. The beetle also killed millions of trees in Japan." APHIS and the Forest Service have placed numerous additional traps to document the spread of this pest and are searching for potential breeding areas to determine whether the beetle has become established in the area (Hofacker 1993).

Chapter 2: Potential Future Introductions

The increased controversy over cutting America's remaining old-growth forests has affected North American timber supplies in western forests and generated interest in importing logs from foreign countries. The dissolution of the Soviet Union and associated trade restrictions have opened the forests of Siberia to utilization by western nations. Other countries, such as New Zealand and Chile, also have raw materials available for the North American market, In relation to this paper, the most important question raised by importation of logs are the possibilities of introducing new exotic pests into North America and reintroduction of existing exotic pests at new locations.

Siberian Importations

In response to pressure by scientists and politicians, APHIS requested the Forest Service to conduct an assessment of the risk of importing pests on logs from Siberia in 1991. The assessment team consisted of 43 forest scientists from federal and state agencies and universities. The team concluded that "the close similarity between [Siberia and similar latitudes of North America] promises to produce many taxa from Siberia that will find suitable hosts in various parts of the forests of Western North America...Some species are likely to become serious pests" (USDA Forest Service 1991b). Siberian larch (*Larix siberica*) was assumed by the team as the primary species to be imported. The assessment team determined that 175 species of arthropods, nematodes, and fungi were associated with Siberian larch. They identified and reviewed 36 "representative" species from each of three groups that could be imported on logs with attached bark: pests residing on the outer bark, found inside the bark, or within the wood (USDA Forest Service 1991b).

An economic analysis predicting revenue losses was conducted, based on the assumptions of infestation by the above 36 representative species. The analysis estimated the net present value of potential losses at between $24.9 million (best-case scenario) and $58 billion (worst-case scenario). These figures represented only the potential impacts to commercial timber species in the western U.S.; they did not consider ecosystem damage, impacts to nonconsumptive industries associated with forested land, or harm to agriculture.

Six of the "representative" pest species were examined in detail. The findings of these six pests are briefly summarized below.

Asian Gypsy Moth

The Asian strain of the gypsy moth (which belongs to the same species-*Lymantria dispar*-as the European insect) feeds upon more than 500 species of plants (Gibbon 1992), including many conifers and hardwood species. The Asian gypsy moth has a "moderate" potential to kill keystone hardwood tree species in healthy forests, and a "high" potential in stressed forests. The potential for extensive infestation of conifer forests is largely unknown but probably ranges from moderate to high (USDA Forest Service 1991b). Furthermore, unlike the European gypsy moth, the female Asian moth can fly up to 24 miles, carrying 600 to 700 eggs (USDA Forest Service 1991b, Gibbon 1992).

The Asian gypsy moth reached various Pacific port cities in North America in 1991 as egg masses on ships transporting grain. The United States and Canada immediately implemented an emergency control program. Aggressive spraying of the biopesticide, *Bacillus thuringiensis* ("Bt"), near the affected ports has apparently controlled the infestations. Meanwhile, Canadian authorities banned all ships that had visited potentially infested Siberian harbors from Canadian waters during the spring months when the eggs were likely to be hatching (Oliver, personal communication). The United States has relied on a voluntary agreement along the same guidelines. Both countries are monitoring gypsy moth population cycles near Siberian and North American ports. Asians gypsy moth infestations, however, would probably become extremely difficult to control if infestation repeatedly occurs at various Pacific ports.

An outbreak of gypsy moths in North Carolina in July 1993 was found to include Asian and European types, but predominantly hybrids between the two. This time, the insects had arrived on military equipment being shipped from Germany. Germany and other European countries are experiences heavy infestations of gypsy moths this year, which apparently include hybrids. Shipments of all types of cargo from Europe could carry the insects to the United States (USDA Forest Service and APHIS 1993).

Nun moth

The nun moth (*Lymantria monacha*) is similar to the Asian gypsy moth in habits, development, and host utilization. If introduced, it is likely to attack all western conifers except pines. Tree mortality "is likely to be high." The potential area affected is 172 million acres in the United States and additional areas of Canada (USDA Forest Service 1991b).

Pine wood nematode

Several Asian species of pine wood nematode, including *Bursaphelenchus mucronatus* and *B. kolymensis*, are believed to pose the greatest threat to the Jeffrey and ponderosa pines (*Pinus ponderosa*) and other hard pines (USDA Forest Service 1991b). Ponderosa pine occupies nearly 5.7 million acres from British Columbia south into Mexico (Lattin, personal communication; Skilling *et al*. 1986).

Larch canker

If introduced in the west (it is already present in eastern Canada and Maine), larch canker (*Lachnellula willkommii*) "could have a major impact on the 2 million acres of western U.S. forest with 50 percent or more larch cover." While the western larch's natural range is far from ports of entry, the canker might be spread on ornamental larches (USDA Forest Service 1991b).

Annosus root disease

Some Annosus root diseases are already causing damage on dry areas in western North America. If an exotic strain were to be introduced, it would have "a high potential to infest extensive areas of true fir and dry pine forests. Mortality in infested areas would probably be high." Other trees would suffer additional stress, becoming more vulnerable to other introductions or stresses (USDA Forest Service 1991b).

Spruce bark beetle

During epidemics, the spruce bark beetle (*Ips typographus*) spreads from dead or fallen spruce to standing spruce and sometimes pines and larches. The beetles carry various fungi, some of which are extremely pathogenic. The risk of introduction would be high in areas with spruce lumber or naturally dead spruce near coastal ports. Once introduced, the beetles could disperse by flight, eventually throughout the Pacific Northwest (including Alaska) and east along the boreal spruce forests to the Atlantic. If the beetle were accompanied by a more virulent fungus, such as *Ophiostoma polonica*, and native beetles also spread the fungus, "it could...be as disastrous to North American spruce as the Dutch elm disease was to elms." (USDA Forest Service 1991b).

In analyzing the threat posed by the potential introduction of Asian and Siberian tree "pest" organisms, the authors of the Siberian assessment stated,

> ...It is impossible to state the probability of extensive infestation.... However, since the risk of spread of these pests is high, large-scale infestations and tree mortality are likely to occur... Loss of a significant proportion of living trees within stands would trigger complex changes in food supply and habitat... Detrital food chains– fueled by dead organic matter–would be favored, while food chains that depend on living trees would collapse unless the system recovered very quickly...(USDA Forest Service 1991b).

The Risk Assessment authors predict that mycorrhizal fungi, several species of voles, flying squirrels, and spotted owls could not make the transition to a detrital food chain. Deer and elk would be further limited by the increased scarcity of closed-canopy forests, which provide winter forage and shelter. Western yew, accipiter hawks, and salmonid fish would also decline (USDA Forest Service 1991b).

New Zealand Importations

In contrast to the size of the Siberian Risk Assessment Team, a risk assessment team for logs imported from New Zealand consisted of only five scientists, assisted by 11 experts from New Zealand. In a fashion similar to the Siberian assessment, this report gave detailed attention to only a few of the potential introductions: two diseases and five insect species. The total economic losses associated with introduction of the seven pests evaluated are estimated to fall between $52 and $364 million, exclusive of the costs of suppression, job loss, watershed damage, recreation, or ecological damage (USDA Forest Service 1992).

Lattin (personal communication) has severely criticized the assessment as being too shallow and hurried. He notes that the report ignored several European pests now established in New Zealand. The assessment team originally failed to consult the major source on insects found on Monterey pine (*Pinus radiata*). Although this publication is included in the list of references, inspection of the report's text shows that the relevant information was not incorporated. Below are short summaries of the potential damage that two introduced pests from New Zealand could perpetrate on western forests.

Woodwasp-Amylostereum complex

The woodwasp *Sirex noctilio* and associated fungus *Amylostereum areolatum* can cause tree mortality. The wasp is native to Eurasia and North Africa, but it has become established in New Zealand, Australia, and southern South America. *Sirex noctilio* females fly (100-mile range) to locate physiologically stressed trees to deposit their eggs. The wasp primarily infests pine species, but has been recorded as infesting fir and spruce. During oviposition, the *Amylostereum* fungus with a toxic mucus are injected into the tree (USDA Forest Service 1992). In Australia and South America, this complex causes significant tree mortality. New Zealand controls the pest by biological control agents and improved stand management (USDA Forest Service 1992).

While the assessment ranks the risk of shipping infested *Pinus radiata* logs as low, there is a possibility of larval survival deep within the logs. If importation were to occur, the assessment considers that *S. noctilio* would probably become established and spread throughout the western United States. The authors estimate the economical costs resulting from establishment of the *S. noctilio-A. areolatum* complex at between $24 and $131 million in timber revenues alone (USDA Forest Service 1992).

Leptographium truncatum

The pathogen *Leptographium truncatum* is found on two North American endemic species, Monterey pine and eastern white pine, in New Zealand. The pathogen is considered by some to be the same as *L. lundbergii*, which attacks eastern white and loblolly (*Pinus taeda*) pines (USDA Forest Service 1992). The vector(s) for the fungi are not known with certainty, but bark beetles are suspected (USDA Forest Service 1992).

No effective method of controlling this fungus in logs is available. The assessment team considers that debarking would reduce the risk of transporting vectors from New Zealand, but North American beetles may be able to carry the fungus. Suitable tree hosts are found near the Pacific ports where imports are proposed (USDA Forest Service 1992) (as well as near Gulf Coast ports). Increased tree mortality in commercial forests, ornamental plantings, and Christmas tree plantations would be possible, with the greatest impact on native stands of Monterey pine (USDA Forest Service 1992).

Two pests already present in North America might be reintroduced from New Zealand. Diplodia shoot blight (*Diplodia pinea = Sphaeropsis sapinea*) and the previously discussed *Melampsora* poplar rust are pests in New Zealand forests. Importation of New Zealand logs without proper quarantine protocols presents the possibility of introducing more virulent strains or spreading infestation of these two pathogens to new areas.

New Zealand has had the reputation of applying stringent pest-exclusion programs for several decades. Since adoption of The Forests Act in 1949, the owner has had to pay the cost of inspections, searches, seizures, required treatment or destruction, etc. when importing raw wood. Experts considered that such precautions had helped limit establishment of new wood and bark boring insects to an average of one per year, despite increasing trade. They admitted, however, that “no method is available to estimate accurately how effective quarantine has been in preventing the establishment of forest pests” and that”[t]he effectiveness of New Zealand’s quarantine procedures against fungal and other pathogens is difficult to evaluate because interceptions cannot be related to establishment” (Anonymous 1982).

Governmental surveys, carried out in the late 1970's and 1980s, focused particular concern on importing raw wood via "full container load" shipping containers. Nearly 50 percent of containers at the Port of Auckland during 6 months in 1978 had incorrect information on manifests as to wood content and 14 percent had no code. Forestry officials feared shippers had been deliberately miscoding the contents to avoid quarantine delay (Foley 1980). In consequence, a committee recommended more stringent controls on cargo shipments. The committee also recommended that the Ministry of Agriculture "automatically hold for inspection all foresters entering New Zealand, and should require formalised cleaning of boots, drycleaning of clothing worn in forests, etc." It further recommended inspecting and cleaning all camping gear used in foreign forests (Anonymous 1982).

New, stronger regulations were recently adopted. The Forest Produce Import and Export Regulations of 1989 require prior notice to the quarantine officer of estimated time of arrival of any vessel importing forest produce, and provision of a full manifest (including any pallets). Forest produce is defined to include timber and dunnage; dunnage does not include packing cases or pallets. If a quarantine inspector suspects infestation, he or she may require quarantine and treatment according to an appropriate prescription. The importer pays for the costs of inspection excluding dunnage inspection such as transport to a quarantine facility, treatment, etc.

Chilean Importations

A third risk assessment was conducted to address potential introductions of exotic pests on wood importations from Chile of Monterey pine and two indigenous hardwoods, coigue (*Nothofagus dombeyi*) and tepa (*Laurelia philippiana*). A six-member team assisted by both U.S. and Chilean experts conducted individual assessments of arthropods and diseases that have a probability of being introduced into this country. This report was released in September 1993 (USDA Forest Service 1993). The team examined the risk of introduction for ten insects and four types of diseases associated with Monterey pine. Risks associated with six major arthropods on coigue and two diseases common to both coigue and tepa were assessed by the team. Only "limited consideration" was given to other harmful pests, *e.g.*, nematodes, that "conceivably" could be associated with logs from Chile (USDA Forest Service 1993). No overall estimate of costs associated with these possible introductions was made.

After considering both risk of introduction and probable impacts in the spheres of economics, ecology, and public perception, the team ranked the risk from only one of the insects pests found on Monterey pine as "high." A bark beetle, *Hylurgus ligniperda*, could be a vector for the fungus *Leoptographium* spp., which causes black satin root disease (USDA Forest Service 1993). A group of pathogens, classified variously as *Ophiostoma* or *Ceratocystis* spp., were ranked as "moderate to high" risks overall. Risk of introduction was considered "high." Economic and ecological damage were considered to be significant, however, only if Chilean strains of the fungi proved to cause vascular wilt (USDA Forest Service 1993). "Moderate" risks were assigned to ten species or groups associated with *Pinus radiata*, six found on coigue (USDA Forest Service 1993).

Comparison of the Assessments

A comparison of the Siberian, New Zealand, and Chilean risk assessments raises a number of troubling questions. The authors of the Chilean assessment note two disturbing tendencies not adequately addressed in the Siberian and New Zealand assessments. The first is the prevalence of bark-inhabiting insects on de-barked logs (USDA Forest Service 1993). We suggest that these reports confirm doubts about the effectiveness of de-barking as a phytosanitary measure. Second, the Chilean assessment refers to the apparent frequency with which pests are transported in dunnage or crates (USDA Forest Service 1993). These data indicate the need to incorporate such material into phytosanitary controls on wood imports. Mitigation procedures for dunnage associated with imports from Siberia and New Zealand were not discussed in their respective risk assessments.

Another inconsistency among the reports is the level of risk assigned to a particular pest or pest complex. The risk can vary considerably without an apparent explanation. As an example, the New Zealand assessment assigned a high risk to the woodwasp and its associated fungus (USDA Forest Service 1992). In contrast, the *Sirex*/*Amylostereum* complex is only briefly mentioned in the Siberian assessment (under a different generic name for the wasp, *Paururus*), and no risk is assigned (USDA Forest Service 1991b). In addition, several reviewers of the draft assessments expressed concern over the level of risk assigned to possible reintroductions of pests already present in North America. Their comments focus on the possibility that an introduction of a different genetic strain or variety would increase damage to current hosts species and/or expand the host range.

The lack of knowledge of foreign tree species' biology and interactions with pests in their native environment was emphasized in the Chilean assessment. In several passages, the authors complained that the paucity of information on most indigenous pests of the hardwood species hampered the assessment of their impact in North America. Without this information, assessments could underestimate potential pests and associated damage to North American forest.

Chapter 3: The Need for a Comprehensive Pest Prevention and Management Program

The current and future demands on forest resources for multiple uses make it essential that a comprehensive national program on integrated pest management be developed and funded. The program should be designed to address exotic pests presently within the country and to prevent or minimize the introduction of new pests from abroad. The framework for a national integrated pest management program already exists under the authorizing statutes for both APHIS and the Forest Service: the Federal Plant Pest Act (7 U.S.C. §§ 150aa - 150jj); the Organic Act (7 U.S.C. §§ 147a - 147e); the Forest and Rangeland Renewable Resources Research Act (16 U.S.C. § 1642); and the Cooperative Forest Assistant Act (16 U.S.C. §§ 2101, 2101, 2104). (For brief summaries of these statutes' provisions, see Appendix A.)

Prevention of Exotic Pest Introduction

For many years, it has been recognized that the most efficient method to eliminate exotic pest infestation is to prevent the organism from entering the country (*cf*. Boyce 1961). The responsible agency is APHIS. APHIS has traditionally concentrated, however, on the prevention of new agronomic and horticultural crop-related pests. As discussed in the Introduction, there are no general plant health (phytosanitary) regulations that specifically govern timber imports. APHIS has relied upon a visual inspection of logs at U.S. ports to detect insects and pathogens. This inspection policy is now antiquated with the advent of large-scale timber importations from other countries. The Siberian Risk Assessment analysis clearly illustrates that visual inspection is insufficient for adequate protection against introduction of foreign pests.

Regulatory controls intended to prevent the introduction or spread of exotic pest species are not completely effective. An additional measure of protections could be a quarantine. Unfortunately, APHIS is not adequately financed or staffed to manage the large quarantine program that would be needed for raw wood products. Another approach is to organize a defense strategy prior to introduction (Boyce 1961). We believe that a much more aggressive prevention program is needed to increase protection for North American forests. APHIS should not wait until the foreign organism has been introduced to begin an emergency eradication or control campaign. Instead, virulent pests in foreign countries that have a potential to attack North American trees should be studied to obtain information to prevent or delay introduction to this continent. Potential pests can be evaluated by planting North American species in infested areas of foreign countries to measure susceptibility. Alternately, pests can be imported into a USDA-approved quarantine facility and evaluated under controlled conditions.

While APHIS has not yet adopted a comprehensive policy, as above, it is willing to increase the effectiveness of its pest exclusion efforts through new regulations. In September 1992, APHIS announced an intent to propose general regulations that would govern "unprocessed wood" products that could transport nonindigenous or not previously introduced pests (see 57 *Federal Register*, No. 184, pp. 43628-43631). The agency sought input on mitigation measures for different "unmanufactured wood products" exported from different countries. APHIS also invited suggestions as to whether the agency should have considerable flexibility in the future to

revise import requirements, or whether it should be required to seek public comment before adopting any future revisions.
Twenty-eight wood importers and trade associations responded to the APHIS notice. Many of the importers and trade associations recognized the risk of pest introduction, but all argued that any regulation must be a reasonable response to “real” rather than “imaginary” risks, economically feasible, and in compliance with free-trade principles. The association of Northwest Independent Forest Manufacturers argued that such high-value wood products as Siberian larch should be imported under less stringent regulations as part of balancing risk against benefit.

Many companies and associations supported adoption of a “universal” rule, but then argued that their particular import, *e.g.*, wood chips from Canada or Mexico, should be subject to less restrictive regulation or exempted completely. Several asserted that tropical woods posed no threat as pests would be killed by winter freezes. However, some firms plan to import chips from pine and other species from plantations in the tropics to Gulf Coast or California ports which are near native pine forests and plantations where freezing temperatures are relatively infrequent.

The assertion that importation of logs from neighboring countries belonging to species native to the United States should cause less concern was expanded by the American Forest Council to included Monterey pine plantations in distant countries. Arguing that Monterey pine plantations “may not be subject to the same insects and pests as exotic [tree] species[,]” the Council concluded that Monterey pine imports should be subject to less stringent phytosanitary regulation than imports of species not native to North America. The American Forest Council has failed to recognize that importations of North America tree species grown in another country should be *more* stringently regulated than nonnative species. A greater probability of successful infestation exists when the imported host species is native to the area of introduction.

Recommendations Re: Raw Wood Imports
The authors of this paper firmly believe that quarantine procedures should be developed for all categories of raw wood imports, including logs and wood chips. However, we are not sufficiently expert to determine the most effective quarantine measures to ensure exclusion of forest pests. The reports by the three risk assessment teams and the Siberian mitigation advisory team are good examples of the interdisciplinary cooperative effort needed to analyze a specific importation situation with a potential to cause pest problems, and then to develop reasonable protocols to insure against the introduction of exotic pests. We suggest that APHIS, in cooperation with other governmental agencies and the private sector, define the different categories of raw wood products and correspondingly develop new inspection procedures and quarantine protocols for each individual category.

New APHIS regulations regarding raw wood importation should be uniformly applied to imported materials regardless of the country of origin, with the possible exception of Canada. It is conceivable that infested raw wood materials could be shipped to a country and infest that country’s forests, and that the newly infested forests could be in turn harvested and the infested materials shipped to the United States. Indeed, many of the pests now of concern on New Zealand logs are exotic to that island nation. Alternately, any country exempted from phytosanitary restrictions has the potential to become a “laundry” for raw wood materials entering the United States indirectly or under false pretenses as in some New Zealand importations. As indicated, the exemption of Canada from new APHIS regulations could be a possibility. Canadian importation regulations are stringent and our forests are contiguous, complicating efforts to prevent cross-border infection. (However, regional quarantines applying to infested species in either or both countries are appropriate.)

After considering expert advice, APHIS should draft a set of procedures and, in compliance with standard regulatory procedures, publish it for public review. All interested parties should be given an opportunity to submit comments on specific provisions as well as general issues and any conflicts among viewpoints should be resolved in the public forum.

Stringent regulation of raw wood imports may not be sufficient. At least seven pests of native tree species discussed in this paper were introduced on nursery stock, and two other pests were dispersed within North America on such material. APHIS has existing authority in this area and may need to review regulations regarding importation of all woody plants.

Management of Current Exotic Pests

Under the broad wording of the Federal Plant Pest Act and Organic Act, APHIS has the primary responsibility to ensure that imported plant and animal species do not contain pests “which can directly or indirectly injure or cause disease or damage in any plants or parts thereof” and to detect, eradicate, control, or retard the spread of plant pests. Within the United States, however, APHIS has largely ceded this authority for forest pests to the Forest Service. APHIS lacks adequate funds to participate in eradication or control measures of all exotic pests. The agency currently spends about $2.25 million on tree pests, 70 percent of it to prevent establishment of the Asian gypsy moth (McGovern, personal communication).

The Forest Service may conduct research and experiments to obtain, analyze, develop, demonstrate, and disseminate scientific information about protecting and managing forests for a multitude of purposes, under the auspices of the Forest and Rangeland Renewable Resources Research Act. Forest protection specifically includes addressing insect and disease problems. A second statute, the Cooperative Forestry Assistance Act, authorizes the Forest Service to protect from insects and diseases trees and wood products in use on National Forests or, in cooperation with others, on other lands in the United States. Such assistance may include surveys and determination and organization of control methods. The Forest Service is further authorized to provide assistance to state foresters to develop and distribute genetically improved tree seeds and to improve management techniques aimed at increasing production of a variety of forest products, including wildlife habitat and water.

Funding for management of exotic pest infestations is unfortunately crisis-oriented. Seventeen years ago, a National Academy of Sciences (1975) report found that, “In the area of pest control research, priorities have often been set under political pressures for immediate answers, with too much regard for short-term problems and too little consideration for broader management objectives. Part of this problem arises from portions of the Forest Pest Control Act of 1947 that...tend[s] to promote an ‘action’ attitude that may inhibit solutions other than short-term, direct chemical control” (National Academy of Sciences 1975). Butternut canker and dogwood anthracnose are good examples of diseases that were allowed to decimate tree populations with little attention, until recently, to controlling these pests or breeding resistant tree varieties. Total expenditures by agencies of the USDA to combat exotic pests of trees in fiscal year 1993 approached $19 million. The vast preponderance was spent by the Forest Service: $11.8 million by the Forest Pest Management program (Lorimer, personal communication), $1.23 million by Forest Insect and Disease Research (Smith, personal communication), and $1.45 million by the Timber Program tree improvement program (Miller, personal communication).

Two other agencies of USDA also contributed to the effort. Expenditures by APHIS vary considerably from year to year because it responds to introductions when they are detected. Thus, in fiscal year 1992, APHIS spent $20 million on efforts to eradicate the Asian gypsy moth. In fiscal year 1993, APHIS allocated only $2.25 million for preventing the dissemination of introduced exotic tree pests into the country. This figure does not include APHIS' port inspection program effort devoted to wood imports (a small proportion compared to inspections of fruits, vegetables, live plants, etc.) or administrative costs (including APHIS' cost associated with preparing either the country-specific risk assessments or the more general regulations to govern imports of "unprocessed wood" products) (McGovern, personal communication). Finally, the Agricultural Research Service is spending $350,000 on research on dogwood anthracnose and $1.9 million on gypsy moth research (Faust).

Over two-thirds of all USDA tree pest control funds ($13 million from the Forest Service's Forest Pest Management program and Agriculture Research Service) are devoted to efforts to suppress or eradicate the European gypsy moth. An additional $1.8 million is being spent, largely by APHIS, to monitor Asian gypsy moth populations in Siberia and ships entering our ports to prevent a re-introduction of this insect. In sum, over three-quarters of all USDA tree pest control funds were gypsy moth-related.

Pest control in the white pine group received a total of over $2 million dollars in Forest Service funds. The bulk of this amount funds a western white pine blister rust breeding program. Several introduced pests or pathogens received funding at levels between $600,000 and $700,000. These included the European pine shoot beetle, which was discovered in the Lake States in 1992; and dogwood anthracnose. Dutch elm disease control efforts received $544,000. The only other pest control program receiving more than $100,000 was the hemlock woolly adelgid. Other trees threatened by exotic pests, fungi, or disease pathogens - Port-Orford-Cedar, butternut, beech, and chestnut - were funded at levels of from $52,000 down to $14,000.

Recommendations Re: A Comprehensive Program

We see no need to create new institutions to implement a truly comprehensive pest prevention and management program for America's forests. The various tasks should be conducted by existing institutions under existing legal authorities. However, these agencies must act out of a new appreciation for forest *ecosystems*, not just concern for timber production. Cooperation and coordination among the various agencies must improve. Finally, funding for APHIS, the Forest Service, and cooperating state agencies will have to be increased substantially.

We envision that APHIS will retain its emphasis on exclusion; expand quarantines to prevent spread of incipient infestations; where possible, eradicate incipient infestations; continue funding some research; and conduct research on pests and control measures in countries from which raw

wood products and nursery stock would be imported.
The Forest Service would continue to lead research and application of control measures in the United States. The work should be in active collaboration with state forestry divisions and universities. Other interest groups, which are affected by the decline of America's forests or contribute to the threat by importing items which could carry pest organisms, should contribute knowledge, funds, public education efforts, and other resources to improving our understanding of and efforts to contain exotic pests of trees. These interest groups would include the forest industry, nursery industry, recreation industry, ecologists and wildlife management and conservation organizations. Wider involvement of the conservation movement would augment efforts by citizen organizations such as the American Chestnut Foundation.

In testing and adopting control methods, all parties must recognize the environmental impacts of those methods. It is important to emphasize that environmental and financial costs are associated with *both* courses of action - applying pest control measures and allowing the exotic pest to damage tree species and their associated ecosystems. A difficult, careful balancing of these countervailing environmental costs is inherent in adopting our recommendations.

As we noted earlier, funds must be considerably increased over current levels. As the continuing damage to native forests by exotic pests and new dangers posed by potential importation of raw wood products prompted this paper, it is tempting to conclude that expanded pest management programs should be funded by timber and paper industries' revenue. Yet if forests are to be truly managed as ecosystems, *i.e.*, for multiple use, the burden of costs must be shared by all users, including timber producers and consumers, conservationists, recreationists, and preservationists. Because the identification, testing, and application of mitigation and control measures for introduced pests require years of dedicated effort, it is essential that funds also be stable, to prevent interruptions of long-term projects.

We support the Forest Service's recent initiative to create an emergency fund of up to $3 million to enable rapid start-up of research on newly introduced pests which threaten native forests. In just the past two years, the Asian gypsy moth, European pine beetle, *Melampsora* fungus, and European spruce beetle have been discovered at our ports or in our forests. A prompt response is necessary to minimize damage from the pest, but, since the occurrence and size of such introductions cannot be anticipated years in advance, the amount of funding needed cannot be determined during the normal, lengthy, budget-development process.

Another Forest Service initiative, the National Center of Forest Health Management, is an encouraging step toward comprehensive pest management. The Center's goals are: 1) "with partners, promote and facilitate development and use of technologies to sustain or enhance forest health," and 2) "advance understanding of forest health and effects of forest health technologies on forest ecosystem and management goals." Three work areas will be focused upon: 1) biorational methods, 2) biological control, and 3) nontarget effects.

A comprehensive pest prevention and management program for America's forests will be expensive, but it is an investment well worth making. At stake are financial outlays by the Forest Service and APHIS, lost fiber production, and the ecological health of some of the most treasured elements of our natural heritage.

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Appendix A

Summary of Statutes (Laws and Treaties) Governing Introductions of Alien Species Which May Attack Native Tree Species

International Plant Protection Convention (IPPC) (195)
[Article 14 of the Constitution of the Food and Agriculture Organization of the United Nations] establishes international system under which inspections and quarantines are implemented to prevent dissemination of pests affecting plant resources.

Federal Plant Pest Act (1957) [7 U.S.C.§§ 150aa-150jj]
prohibits knowing importation or interstate transportation (except with a permit issued by the Secretary of Agriculture) of any plant "pest"; "pest" is defined as any living stage of invertebrates, bacteria, fungi, parasitic plants, viruses, infectious substances, etc., "which can directly or indirectly injure or cause disease or damage in *any* plants or parts thereof, or any processed, manufactured, or other products of plants" [emphasis added].

Organic Act (1944) [7 U.S.C. §§ 151-164a, 167]
authorizes the Secretary of Agriculture, alone or in cooperation with the states or local jurisdictions, farmers' associations, governments of Western Hemisphere countries, and international organizations, to detect, eradicate, control, or retard the spread of plant "pests." (See definition of "pest" under the Federal Plant Pest Act, above.)

Plant Quarantine Act (1912) [7 U.S.C. §§ 151-164a, 167]
authorized the Secretary of Agriculture to regulate imports or interstate shipments of nursery stock or other plants and plant parts and propagules when necessary to prevent introduction of injurious plant diseases and inspect pests.

Agricultural Quarantine Enforcement Act (1989)
prohibits the shipping of any plant, fruit, vegetable or other matter quarantined by the Department of Agriculture via first-class mail; search warrants required to open packages.

Forest & Rangeland Renewable Resources Research Act (1978) [16 U.S.C. § 1642]
authorized the Secretary of Agriculture to conduct research and experiments to obtain, analyze, develop, demonstrate, and disseminate scientific information about protecting vegetation, forest, and rangeland resources from insects, diseases, noxious plants, animals, air pollutants, and other agents.

§ 1642 (b) requires the Secretary to maintain a current comprehensive survey of the "present prospective conditions of an requirements for renewable resources of the forests and rangelands...and means needed to balance the demand for and supply of these renewable resources, benefits, and uses in meeting the needs of the people of the United States..."

Cooperative Forestry Assistance Act (1978) [16 U.S.C. §§ 2101, 2102, 2104]

§ 2101 (a) recognized that "efforts to prevent and control...insects and diseases often require coordinated action by both Federal and non-Federal land managers..."
§ 2102 (b) authorizes the Secretary of Agriculture to provide assistance to state foresters to develop and distribute genetically improved tree seeds sand to improve management techniques aimed increasing production of a variety of forest products, including wildlife habitat and water.

§ 2104 authorizes the Secretary to protect from insects and diseases trees and wood products in use on National forests or, in cooperation with others, on other lands in the U.S.; such assistance may include surveys and determination and organizations of control methods. Programs on non-federal lands can be instituted only with the consent of, and with a contribution of resources from the owner. The Secretary may also prescribe other conditions for such cooperative efforts.

Executive Order 11987 (1977)
directs federal agencies to restrict the introduction of exotic species into natural ecosystems under their jurisdiction and to encourage states to do the same; directs the secretaries of Interior and Agriculture to restrict the introduction into any natural system of animals or plants designated as injurious or noxious under the Lacey Act and Federal Noxious Weed Act.

Appendix B: Tree Species Mentioned in This Report

Deciduous	
Allegheny chinkapin	*Castanea pumilla* Mill
American chestnut	*Castanea dentata* (Marsh.) Borkh
American elm	*Ulmus americana* L.
red or slippery elm	*Ulmus rubra* Muechl.
oaks	*Quercus* spp.
sugar maple	*Acer saccharum* Marsh.
butternut or white walnut	*Juglans cinera* L.
black walnut	*Juglans nigra* L.
American beech	*Fagus grandifolia* Ehrh.
European beech	*Fagus sylvatica* L.
Chilean beech or coigue	*Nothofagus dombeyi* (Mirb.) Oerst.
flowering dogwood	*Cornus florida* L.
Pacific dogwood	*Cornus nuttallii* Aud.
Chilean tepa	*Laurelia philippiana* Looser
black cottonwood	*Populus trichocarpa* Torr. & Gray
quaking aspen	*Populus tremuloides* Michx.
Conifers	
pines	*Pinus* spp.
eastern white pine	*Pinus strobus* L.
western white pine	*Pinus monticola* Dougl. ex. D. Don
sugar pine	*Pinus lambertiana* Dougl.
whitebark pine	*Pinus albicaulis* Engelm.
southwestern white pine	*Pinus strobiliformis* Engelm.
limber pine	*Pinus flexilis* James
Rocky Mountain bristlecone pine	*Pinus aristata* Engelm.
loblolly pine	*Pinus taeda* L.
red pine	*Pinus resinosa* Ait.
jack pine	*Pinus banksiana* Lamb.
ponderosa pine	*Pinus ponderosa* Dougl. ex
Jeffrey pine	*Pinus jeffreyi* Grei. & Balf.
lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Monterey pine (radiata pine)	*Pinus radiata* D. Don
Siberian pine	*Pinus siberica* Ledeb.
Scotch pine	*Pinus sylvestris* L.
Siberian Scotch Pine	*Pinus sylvestris mongolica* Litv.
coastal Siberian pine	*Pinus koraiensis* Sieb. et Zucc.
firs	*Abies* spp.
balsam fir	*Abies balsamea* (L.) Mill.
northern bracted balsam fir	*Abies balsamea* (L.) Mill. var. *phanerolepsis* Fern.
Fraser Fir	*Abies fraseri* (Pursh.)

bristlecone fir	*Abies bracteata* D. Don
subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
spruce	*Picea* spp.
red spruce	*Picea rubens* Sarg.
eastern hemlock	*Tsuga canadensis* (L.) Carr.
larch	*Larix* spp.
eastern larch or tamarack	*Larix laricina* (Du Roi) K. Koch
western larch	*Larix occidentalis* Nutt.
Siberian larch	*Larix siberica* Ledeb.
Chinese pseudolarch or golden larch	*Pseudolarix amabilis* (Nelson) Rehder
Port-Orford-Cedar	*Chamaecyparis lawsoniana* (A. Murr.) Parl.

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Appendix C: Arthropods Mentioned in This Report

smaller European elm bark beetle	*Scolytus multistriatus* (Marsham)
(native) elm bark beetle	*Hylurgopinus rufipes*
bark beetle introduced in Chile	*Hylurgus ligniperda* (F.)
spruce bark beetle	*Ips typographus* L.
spruce beetle	*Dendroctonus rufipennis* Kirby
European bark beetle	*Tomicus piniperda* (L.)
gypsy moth	*Lymantria dispar* (L.)
nun moth	*Lymantria monacha* L.
larch casebearer	*Colephora laricella* (Huebner)
winter moth	*Operophtera brumata* (L.)
balsam woolly adelgid	*Adelges piceae* (Ratzeburg)
hemlock woolly adelgid	*Adelges tsugae* Annand
pine bark adelgid	*Pineus strobi* (Hartig)
red pine adelgid	*Pineus boerneri* Annand
beech scale	*Cryptococcus fagisuga* Lindinger
elongate hemlock scale	*Fiorinia externa* Ferris
circular hemlock scale	*Nuculspis tsugae* (Marlatt)
European pine sawfly	*Diprion similis* (Hartig)
European pine sawfly	*Neodiprion sertifer* (Geoffroy)
pear thrips	*Taeniothrips inconsequens* (Uzel)
basswood thrips	*Thrips calcaratus* Uzel
woodwasps	*Sirex* spp.; S. *noctilio* F.
chestnut gall wasp	*Dryocosmus kuriphilus* Yasumatsu
European spruce sawfly	*Gilpinia hercyniae* (Hartig)
Asiatic oak weevil	*Cyrtepistomus castaneus*
pine wood nematodes	*Bursaphelenchus muscronatus*
braconid that parasitizes larch casebearer	*Agathis pumila* Latrielle
euplophid	*Chrysocharis laricinellae* (Huebner)
parasite of winter moth	*Cyzenis albicans* Robineau-Desvoidy
parasite of winter moth	*Agrypon flaveolatum* (Gravenhorst)
beetle that attacks beech scale	*Chilocorus stigma* (Say)

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Appendix D: Fungi and Disease Pathogens Mentioned in This Report

chestnut blight	*Cryphonectria parasitica* (Murr.) Barr (=*Endothia parasitica* (Murr.) And. & And.)
Dutch elm disease	*Ophiostoma ulmi* (Buis.) Narruf. (= *Ceratocystis ulmi* Buis.) C. Moreau or = *Ceratostomella ulmi* Buisman)
white pine blister rust	*Cronartium ribicola* J.C. Fisch.
scleroderris canker	*Ascocalyx abietina* (Lagerberg) Schlaepfer. (=*Scleroderris lagerbergii* (Lagerberg) Gremmen) (=*Gremmeniella abietina*)
European larch canker	*Lachnellula* (=Dasyscypha) *willkommii* (R. Hartig) Dennis (=*Dasyscypha willkommii*(R. Hartig) Rehm)
melampsora leaf rust	*Melampsora larici-populina* Klebahn & M. *Medusae* Thuem. F.sp. *Deltoidae*
butternut canker	*Sirococcus clavigignenti-juglandacearum* Nair, Kostichka,& Kuntz
beech bark disease	*Nectria coccinea* (Por.:Fr.) Fr. Var. *faginata* Lohman, A.M. Watson, and Ayers
beech bark disease	*Nectria galligena* Bres. in Strauss.
dogwood anthracnose	*Discula destructiva* Redlin
Port-Orford-Cedar root disease	*Phytophthora lateralis* Tucker & Milbrath
ink disease	*Phytophthora cinnamomi* Rands
Annosus root disease	*Heterobasidion annosum* (Fr.:Fr.) Bref. (=Fomes annosus (Fr.:Fr.) Cooke
on of fungi associate with Siberian spruce beetle	*Ophiostoma polonica*
fungus on Siberian pines, fir, spruce introduced in New Zealand	*Amylostereum areolatum*

fungus on Monterey pine eastern white pine, loblolly pine	*Leptographium truncatum* (L. *Lundbergii*)
diplodia shoot blight	*Sphaeropsis sapinea* (Fr.:Fr.) Dyke & Sutton in Sutton. (=*Diplodia pinea* (Desnaaz.) J. Kickx fil.)
fungus which attacks gypsy moth	*Entomophaga maimaiga* Humber, Shimazu & Soper
"Bt" fungus which attacks gypsy moth	*Bacillus thuringiensis* Berliner
fungus that parasitizes *Nectria*	*Nematogonum ferrugineum* (Pers.) S.J. Hughes

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