United States
Department of
Agriculture

Forest
Service

Miscellaneous
Publication No. 1495

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Executive Summary

Several timber companies in the United States have expressed an interest in importing unprocessed larch logs from Siberia and the Soviet Far East. A variety of exotic forest pests, including insects, nematodes, and fungi, can be transported on or in logs. Many of these organisms can survive in transit and have a high potential to colonize suitable hosts near ports of entry. Experience has proven that exotic pests can become established in new habitats, sometimes producing devastating effects (see Chapter 3 for six case histories of major exotic pests and their effects). This risk assessment estimates the probability of introduction and establishment of insect and disease organisms imported on logs from Siberia and the Soviet Far East and estimates the potential effects these exotic pests may have on the forest resources and associated ecosystems of the Pacific Northwest and contiguous regions.

A team approach was used for this risk assessment, which involved prominent forest scientists from universities in the disciplines of entomology, pathology, economics, and ecology, as well as regulatory professionals from State and Federal agencies in the United States and Canada. In this way, the most current, reliable, and comprehensive information was obtained to assess the potential risks associated with introduced pests.

A conceptual framework was developed to structure the assessment of risk elements (see Appendix E). Within this framework are two components essential to assessing risk. The first is determining the probability that exotic pests will be established. This is made up of the following elements:

- Pest with host-the probability of pest organisms being on, with, or in the logs at the time of importation
- Entry potential-the probability of pests surviving in transit and the probability of pests being detected at the port of entry under present quarantine procedures
- Colonization potential-the probability of pests coming in contact with an adequate food source, the probability of pests encountering appreciable environmental resistance, and the probability of Pests reproducing in the new environment
- Spread potential-the probability of pests spreading beyond the colonized area and the range of probable spread

The second component assesses the consequences of establishment. This consists of the following elements:

- Economic damage potential-the economic impact of pest establishment, including the cost of living with the pest
- Environmental damage potential-the environmental impact of pest establishment

For this risk assessment, time and data were insufficient to evaluate the risks posed by every organism (175 pests have been identified on larch in the Soviet Union) (see Appendix H); instead, representative species were selected based on their perceived risk potential and the availability of sufficient biological information. The team selected 36 organisms on which to focus this assessment. The organisms selected were grouped into three categories: those that could hitchhike on logs, those associated with the bark and innerbark, and those found in the wood. This approach facilitated the evaluation of mitigation measures being considered by a separate team.

Detailed evaluations of the potential establishment and colonization (Chapter 4, Organisms Posing Risk), economic impacts (Chapter 5, Economic Effects Evaluation), and ecological impacts (Chapter 6, Ecological Effects Evaluation) were conducted on six species-Asian gypsy moth, nun moth, spruce bark beetle, pine wood nematode, larch canker, and annosus root disease.

This assessment clearly demonstrates that the risk of significant impacts to North American forests is great. The possible economic impacts range from a low of $24.9 million (best case scenario) because of introduced larch canker to a high of $58 billion (worst case scenario) because of introduced defoliators (see table 7-l). The economic analysis of each potentially introduced pest was calculated independently. Therefore, it is impossible to estimate the cumulative effects that might result from the simultaneous introduction of other pests considered in this analysis.

The economic analyses performed in this risk assessment estimate only the potential financial impacts to commercial timber stands in the Western United States. No attempt was made to quantify nontimber-related impacts (for example, recreation, wildlife, watershed, soil erosion, and so on) or sociopolitical impacts associated with introduced pests. However, some of these impacts are described in Chapter 6 and as part of individual pest risk assessments (Appendix I).

Most of the pests emphasized in this report have the potential to infest extensive areas of one or more forest types in the West. The ecological effects resulting from extensive tree death would be profound in the short run; long-term impacts would depend on how quickly and completely the system recovered. Possible ecological effects include tree species conversion, deforestation, wildlife habitat destruction, degradation of riparian communities, increased fire hazard, and loss of biodiversity. The discussions of the ecological composition, fragility, and value of western forests are not intended to be all inclusive. Rather, they underscore that this vast resource has numerous biological components that might be affected.

This risk assessment focused on larch logs imported from Siberia and the Soviet Far East, but parallels can be drawn with other coniferous logs. Many of the organisms assessed have broad host ranges and could be imported on other genera of logs.

In July 1991, members of the Pest Risk Assessment Team and the Management Practices Team made a site visit to the U.S.S.R. The team met with Soviet scientists and foresters and viewed forest pests, forest harvesting practices, and log handling procedures in Siberia and the Soviet Far East. The team's findings (Appendix L) consistently support the risk assessments developed for pests that might be imported on logs from the Soviet Far East and Siberia.

In conclusion, importing unprocessed logs from Siberia and the Soviet Far East to North America can have serious economic and ecological consequences because of the introduction of exotic forest pests. Measures must be implemented to mitigate the risk of pest introduction and establishment.

Chapter 1
Introduction

Statement of Purpose

This risk assessment estimates the probability of potential impacts that the introduction and establishment of insect and disease organisms from Siberia and the Soviet Far East may have on the forest resources and associated ecosystems of the Pacific Northwest and contiguous regions.

The purpose of this risk assessment is to:

- identify exotic organisms that have the potential of becoming pests that may move with unprocessed logs from Siberia and the Soviet Far East;

- assess the potential of colonization of groups or individual pests during the process of importing, processing, and utilizing logs; and

- assess the relative potential impacts of the identified organisms that may become established.

Background

The U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHlS) is the government agency charged with regulating international commerce into the United States to prevent the introduction of exotic pests and diseases via imported nursery stock, seeds, fruits and vegetables, or forest products. APHIS also works to detect and, when feasible, eradicate exotic pests once they have been introduced.

When a request is made to import any animal or plant commodity, APHlS analyzes the potential risk. Information is collected and assessed on pests that may be hazardous. This information is then sent to APHlS policymakers, who decide whether to permit importation of a commodity that may have adverse pest impacts in the United States. Mitigation procedures may be required to allow safe passage. Risk assessments have routinely been used to apply scientific knowledge to the development and documentation of public policy formation.

At this time, the United States has no specific timber import regulations, and no permits are required. The small volume of low-risk timber that has been imported is detained at ports of entry for inspection. Importers are required to use mitigation measures to eliminate identified risks before the timber is allowed into the country. However, U.S. timber companies are now proposing to import such large quantities of potentially high-risk Soviet timber that it is necessary to identify potential pest risks to determine whether Federal regulations are required and, if so, what the provisions of such regulations should be.

Two small test shipments of Soviet logs were imported into the United States from the Soviet Far East. They arrived at Eureka, CA, in mid-1990 and were processed under a protocol developed jointly by the California Department of Food and Agriculture (CDFA) and APHIS. CDFA and APHIS investigated the shipments for plant pest species and discovered two exotic pests on sample pine log shipments. Before this, insect pests had been identified on Soviet logs imported into Sweden, China, Japan, and Korea (see Appendix A). These interceptions included various species of bark beetles, ambrosia beetles, and wood ***borers.*** The scientific community and the Forest Service (see Appendix B) have expressed concern about the pest risk. This prompted USDA to temporarily ban additional log imports from the Soviet Union until completion of a pest risk assessment. Certain segments of the U.S. timber industry have petitioned USDA and members of Congress to allow more trial shipments of Siberian logs. USDA has decided to defer consideration of new shipments until a scientific assessment can evaluate the pest risk to U.S. forest resources and determine whether the risk can be mitigated.

In the case of timber imports from the Soviet Union, APHlS determined that the nature, complexity, and scope of the potential risk required additional assistance to complete a comprehensive analysis. As a result, APHIS asked the Forest Service to identify and develop the information necessary to effect a decision (see Appendix B). In response, the Forest Service formed a Pest Risk Assessment Team to scientifically assess the risks posed by exotic pests and determine the probable significance of their introduction. An APHlS Management Practices

Team has assessed mitigation measures for the pests of concern identified by this assessment. This effort is aimed at determining whether any feasible alternatives are available or whether the import prohibition should continue.

Proposed Importation

The dramatic economic and political reforms occurring in the Soviet Union have created new opportunities for U.S. firms interested in increased East-West trade. The Soviet forest products industry is certain to play an important role in the future growth and development of the Soviet Union's international trade.

Because of the growing economic, environmental, and political pressures confronting U.S. timber companies, the forests of the Soviet Union appear to be an attractive alternative source of raw materials. However, as trade opportunities with the Soviet forest products industry increase, the United States must examine the risks involved. The threat of exotic pests being introduced into North America by way of forest products imported from the Soviet Union is an important problem that the U.S. Government, the public, and U.S. timber companies must resolve before importation becomes a viable option.

U.S. and other foreign timber companies interested in importing roundwood from the Soviet Union are looking at accessible timber resources in the southern areas of the Soviet Far East. Future development will likely concentrate in this region because logging operations and the requisite transportation infrastructure already exist for harvesting and transporting the logs. The regions most likely to provide logs for export to the United States will be Primorskiy (Maritime) Kray, Khabarovskiy Kray, Amurskaya Oblast, southern parts of Yakutskaya A.S.S.R., Chitinskaya Oblast, Buryatskaya A.S.S.R., lrkutskaya Oblast, and the southern regions of Krasnoyarskiy Kray (see figure l-l).

The Soviet Union exports timber products from 54 different coastal ports. Special port facilities are required for loading and shipping timber and related products. The principal transshipment points in the Soviet Far East equipped for loading timber include the ports of Nakhodka, Vostochniy, Sovietskaya Gavan, Vanino, and Vladivostock.

Estimations of the amount of timber that could be imported into the United States range from 150 to 425 million board feet per year (see Appendix C). The imported logs could include up to four softwoods-larch, pine, spruce, and fir. If the species mix imported into Japan is any indication of possible U.S. imports, the United States can expect a species mix ranging from 100 percent larch to 52 percent fir and spruce, 34 percent larch, and 14 percent pine. Ultimately, the timber mix will be determined by the overall processing quality, the price of the wood, and the Soviets' prior contractual commitments.

Larch is the most common tree species found in East Siberia and the Far East regions. Current proposals to APHIS identify larch as the genus for immediate importation. For these reasons, larch is assumed to be the largest component of future importations into the United States and was selected as the primary host genus in this pest risk assessment process. An overview of Soviet forest resources and profiles of larch, pine, spruce, and fir timber species that may be imported are provided in Appendix D.

Preliminary discussions with industry officials indicate that logs from Siberia and the Far East will probably enter the United States at ports in the Puget Sound region of Washington State; Vancouver, WA; Portland, OR; and the Humboldt Bay area of California for processing. The larch logs are intended to be manufactured into veneer; all other species are to be processed into lumber. After processing, this lumber could be reexported to markets in the Pacific Rim or used to supply domestic needs.

Resources at Risk

The forests of the Pacific Northwest are part of a broad band of vegetation that extends around the Northern Hemisphere in the mid- to upper latitudes. These forests have enormous economic, aesthetic, recreational, wildlife habitat, and watershed value, not only to the region but also far beyond its borders. The Coast Ranges and the west slopes of the Cascade Range are home to some of the highest quality stands of large sawtimber in the world. The east slopes of the Cascades and the lower slopes and benches of the interior mountains are covered by open pine forests and juniper. White fir and Douglas-fir associations and mixed conifer (pine, fir, cedar, Douglas-fir, and larch) forests are found on the interior mountains above the pine zone and on north slopes. Grasslands and

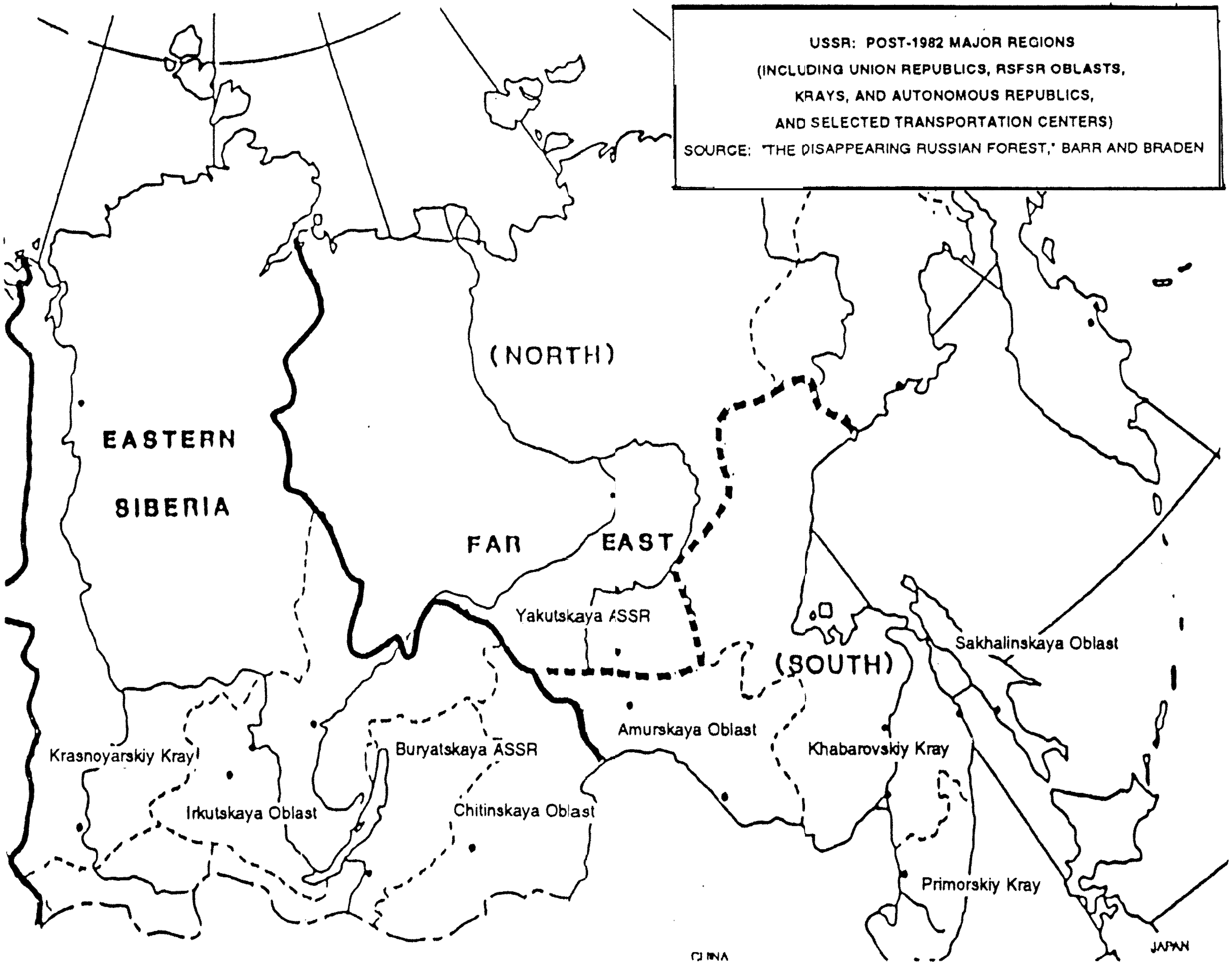

Figure 1-1. Map of Eastern Siberia and the Soviet Far East

desert shrubs extend into the forest in the basins, uplands, and plains areas. Timber resources of Alaska and the Eastern United States may be at risk from pests imported from the Soviet Union; however, these regions are not included in the risk assessment for the following reasons: (1) industry proposals are to import logs to the west coast ports in Washington, Oregon, and California; (2) natural barriers inhibit the spread of pests to the Eastern United States and Alaska, respectively; and (3) spread time to these areas is very long, and discounting reduces the present net value of economic losses virtually to zero.

Even a brief survey of some of the region's principal conifer species suggests the special value and unique diversity of the Pacific Northwest forest system. One conifer, the Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), is the world's third tallest tree, with exceptional individuals reaching 330 feet in height and 16 feet in diameter. This tree grows in the Western United States, where it is a valuable timber commodity and the dominant tree species in ecologically disparate forests from northern California to British Columbia and east to the Rocky Mountains.

Other species of the region have the following characteristics (Norse, 1990):

- In the Pacific Northwest, the shade-tolerant western redcedar is often found in mixed conifer stands and, in particularly moist areas, will occasionally form pure stands. The western redcedar (*Thuja plicata* Donn ex D. Don) grows up to 200 feet in height and 20 feet in diameter.

- Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is probably the most abundant conifer species from coastal Oregon to southeast Alaska. Reaching a height of up to 215 feet with a diameter of 10 feet, this moisture-loving species often lives many years in the understory before becoming a canopy tree.

- The Sitka spruce (*Picea sitchensis* (Bong) Carr.) is the largest spruce species, reaching a height of up to 300 feet with a diameter of 17 feet. It is found in the coastal forest from northern California to southeast Alaska.

- The sugar pine (*Pinus lambertiana* Dougl.), which grows in the drier forests of the California Sierra Mountains and into southern Oregon, is the largest pine in several respects. It reaches a height of 250 feet and a diameter of 18 feet, which makes it the largest of the pines, and it has the longest cones, with some as long as 23 inches.

- Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) is found in a widespread area, from Oregon's Willamette Valley to northwest California, on the west side of the Cascades, throughout the Sierra Nevada, and in eastern British Columbia, Washington, Oregon, and California. This tree can attain a height of more than 230 feet and a diameter of 8 feet.

- The western white pine (*Pinus monticola* Dougl. ex D. Don) is another large member of the genus *Pinus,* with some individuals attaining almost 240 feet with a diameter of 7 feet. This tree is common to inland British Columbia, northeast Washington, throughout the Cascade Range in Oregon and Washington, northern Idaho, and western Montana.

- The noble fir (*Abies procera* Rehd.) is the world's largest fir, reaching a height of 260 feet and a diameter of 9 feet. Its habitat is the higher elevations of the Washington and Oregon Cascades Range.

- Pacific silver fir (*Abies amabilis* Dougl. ex Forbes) reaches a height of 245 feet and a diameter of 8 feet. While scattered pockets are found in northwest California, it is more common in the Cascades and Washington's Olympic Mountains and north into British Columbia and southeast Alaska. It grows in high-elevation sites and even in areas that accumulate deep snow.

- Relatively dry lowland ecosystems are the habitat of the grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl), which ranges from Vancouver Island to northwest California. This species can reach a height of 250 feet and a diameter of 5 feet.

- The white fir (*Abies condor* (Gord. & Clend.) Lindl. ex Hildebr.) extends north from the Sierras of California into southwest Oregon. It can grow as tall as 230 feet and have a h-foot diameter.

- Incense cedars (*Libocedrus decurrens* (Torr.) Florin) can grow as tall as 225 feet with a 12-foot diameter: These trees inhabit dry sites in southern Oregon and northern California, stretching from the Cascade Range, the Siskiyou

Mountains, and Klamath Mountains south to the Sierra Nevada Range.

The Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr) Parl.) is confined to a small region along the southwest Oregon and northwest California coast. It reaches a maximum height of 240 feet and can be 11 feet in diameter. The Port-Orford-cedar is one of the most valuable tree species in the world, and standing timber is often worth several thousand dollars per thousand board feet.

Western larch (*Larix occidentalis* Nutt.) is the largest of the world's larches, often attaining heights of 180 feet and diameters of up to 90 inches. It is an important commercial tree and plays a significant part in the functioning of forest ecosystems in the intermountain region of the United States. Larch is a deciduous conifer and a subclimax species maintained by periodic fire. There are almost 2 million acres of commercial forest land populated with larch (more than 50 percent larch) in the West.

Coast redwood (Sequoia *sempervirens* (D. Don) Endl.) attains diameters in excess of 192 inches. It is the tallest tree in the world, reaching heights of over 300 feet. It has a limited distribution in northwest California and southwest Oregon.

Biological Considerations

Virtually all genera of trees, conifer and hardwood alike, are found in both the Old and New World (Farjon, 1984; Liu, 1971; Suslov, 1961; Tseplyayev, 1965). Many groups of insects, both pest and beneficial, occur in both regions (Linsley, 1958, 1961; Scudder, 1979; Downes and Kavanaugh, 1988; Lafontaine and Wood, 1988). The same may be said for groups of disease organisms. However, the similarities between the Eastern Soviet Union and the Pacific Northwest are largely at the family and generic level; most species are restricted to one area or the other.

Some of the most serious forest insect pests and Pathogens of North American forests are believed to have originated in the Far East. Some examples include the gypsy moth, chestnut blight, Dutch elm disease, white pine blister rust, and Port-Orford-cedar root rot. Other pests that have been introduced from the Far East include the Japanese beetle and the blue alfalfa aphid (from Japan), the Asian tiger mosquito, dogwood anthracnose, and larch canker (introduced into the Northeastern United States). Pests have been directly introduced into the Pacific Northwest, some through ship ballast and others on ornamental plant material.

Many of these introduced pest organisms have had enormous environmental and economic effects. For example, the introduction and establishment of the gypsy moth and the fungi that cause white pine blister rust, chestnut blight, Dutch elm disease, beech bark disease, and larch canker (in the Northeast) have changed the structure and species composition of North American forests forever.

A review of virtually any taxonomic study, fauna1 or floral, dealing with Siberian biota discloses group after group with representatives found on both sides of the North Pacific (Downes and Kavanaugh, 1988; Krivolutskaya, 1983; Linsley, 1958, 1961; Ler, 1988). For example, the long-horn beetles, bark beetles, scale insects, aphids, true bugs, moths, and sawflies clearly show the close similarity between the two areas-a similarity that 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.

In addition to similar pest genera found on both sides of the Bering Strait, some tree species are closely related to each other even though they are placed in different genera. Pests found on one tree species may be able to shift to another closely related species. One example would involve larch, which is closely related to Douglas-fir. Insects and disease organisms found on one might become established on the other, especially in new geographical areas where natural constraints might be missing. There is a spruce budworm found on spruce and fir in Europe and Asia that might be a potential pest to larch in North America.

The trees of the Soviet Far East and the Pacific Northwest have associated fauna and flora, including insects and disease organisms. These associations have developed over millions of years in natural environments. When trees (and other plants as well) from one region are exposed to insects or diseases from another region, the evolved defenses of the tree may not be effective against the new organisms. The results may be expressed as a severe outbreak (for example, the gypsy moth and Dutch elm disease) (Elton, 1958). Even the introduction of a slightly different genetic strain of an organism might result in a recombination more dangerous than the existing form.

Trees from North America have been planted in other parts of the world, especially in Europe where some elements of the Siberian fauna occur (Lines, 1987). There are welldocumented host shifts of native European insects and diseases onto the North American tree species planted in Europe (Bevan, 1987; Leather, Stoakley, and Evans, 1987). Larch canker has attacked Douglas-fir planted in Norway. The winter moth has moved from oak onto Sitka spruce; the great spruce bark beetle, the European spruce sawfly, and the green spruce aphid have moved to Sitka spruce as well. The pine beauty moth has moved from Scots pine to lodgepole pine as has the pine looper and the larch budmoth. The large larch bark beetle has attacked Douglas-fir during the maturation feeding phase (Bevan, 1987).

In summary, the great similarity between the climate, forests, disease organisms, and insects of Siberia and the Pacific Northwest poses an enormous risk of introducing pest organisms with great potential economic impacts.

Chapter 2
The Risk Assessment Approach

Conceptual Framework

To examine any complex problem, it is often useful to develop a conceptual framework. This pest risk assessment consists of two closely related parts and is the framework in which the problems of pest introduction and establishment are analyzed. The first part of the assessment estimates the probability of specific pests being introduced and established in the biota of the United States. In addition, this section identifies specific pests so that recommendations can be made for mitigation. The second part uses economic and ecological models to analyze the potential consequences of the establishment of a specific pest or group of pests identified in the first section. The probability of pest introduction and the subsequent economic or ecological effects are difficult to predict because subjective conclusions are used to assess the risks of a specific pest or group of pests. Nevertheless, the objective of this risk assessment is to use the best available knowledge, information, and data to identify the pests that pose the most significant risks and to assess the potential effects of these pests should they become established.

Understanding the problem of pest introduction and establishment is critical in assessing the scope and magnitude of any potential risk and its impact. The probability of pest introduction is determined by several related factors-the likelihood of a pest traveling with and surviving on a shipment from the place of origin, colonizing suitable hosts at the point of entry, and subsequently spreading to adjacent territories. Appendix E provides a complete discussion of the pest risk assessment methodology.

The Risk Assessment Process

The growth of international trade substantially increases the likelihood of a pest introduction. This likelihood places increased demands on existing plant pest exclusion procedures and their ability to detect and prevent the introduction of pests at ports of entry. The probability of introduction and establishment of exotic pests depends, in large part, on the quantity of timber imported and the efficacy of mitigation measures.

A number of difficulties must be overcome while assessing the damage that could be caused by introduced pests. One of the primary difficulties is determining which organisms to examine. It is quite possible that an insect or disease organism that is of little or no consequence in Siberia and the Soviet Far East, or an undiscovered organism, may be disastrous once it is introduced to North America. The uncertainty of predicting which organisms may be introduced and the lack of data dictate that the focus of the risk assessment be directed to representative species selected from hundreds of potential pests. While the assessment concentrates on potential forest pests, it is clear that the threat also extends to ornamental and native tree species found in urban settings, as well as to tree farms, and perhaps even to threatened and endangered animal species because of potential habitat loss.

Pest Risk Assessment Core Team

To complete this Siberian and Soviet Far Eastern Pest Risk Assessment, the Forest Service chose a team of scientists. The Core Team members (see list of contributors preceding Chapter 1) were responsible for compiling and assessing pertinent data in their specialties. The Core Team assembled an advisory group of scientists and specialists to help them on this project (see list of contributors). This advisory group was made up of scientists and specialists from universities, Federal laboratories, State and Federal regulatory agencies, and Canada. The Forest Service contracted with LABAT-ANDERSON Incorporated to assist the Core Team in assembling the advisory group, facilitating two workshops, writing and producing the risk assessment document, and creating a data base to organize the information gathered during the project.

Once the advisory group was assembled, two project workshops were conducted. The first workshop, held on March 12 and 13, 1991, determined the organisms that posed a risk and assessed the overall risk of larch importation from the Soviet Union. This first workshop was attended by entomologists and pathologists (see Appendix F). The second workshop, held on April 16 and 17, 1991, determined the economic effects of a possible introduction of pests from the Soviet Union. This workshop was attended by entomologists, pathologists, and economists (see Appendix G).

This pest risk assessment was prepared for the selected pests (Chapter 4 and Appendix 1) and was delivered to the Animal and Plant Health Inspection Service (APHIS) Management Practices Team (MM).

The MPT is preparing an associated document that investigates and evaluates the efficacy of potential mitigation measures for the pests identified in this risk assessment.

Chapter 3
Case Histories of Pest Introduction

Introduction

The following six case histories are examples of the consequences of introducing exotic pests-either insects or pathogens-into a new environment. Five of the six pests described were introduced to North America: the gypsy moth, chestnut blight, Dutch elm disease, Port-Orford-cedar root rot, and white pine blister rust. Moreover, all but the gypsy moth were unknown as pests in their native habitats. The sixth case describes the pine wilt disease, which resulted from the introduction to Japan of a North American species, the pinewood nematode. That five of the six pest introductions occurred in North America is not an anomaly, because North America has been the recipient of numerous insect and disease pests of agricultural crops, as well as forest trees. Two of the case history pests, the Dutch elm disease fungus and the pinewood nematode, are particularly relevant to this risk assessment because both were transported on logs.

Gypsy Moth

History of Introduction
Of European origin, the gypsy moth (*Lymantria dispar* (L.)) was introduced into eastern North America in the 1870's by a French entomologist seeking a silk moth that could survive in North America. Several of the moths escaped, and though local authorities were notified, nothing was done. Free from its natural enemies, the gypsy moth dispersed rapidly, and by 1910 it had spread without assistance to three New England States. The insect now occurs in more than 200,000 square miles of northeast forest, and spot infestations have arisen in California; the Carolinas; Colorado; Idaho; Kentucky; Michigan; Oregon; Utah; Washington; Wisconsin; and British Columbia and Ontario, Canada.

Range and Importance of Host
Larvae of the gypsy moth can feed on more than 500 species of trees, shrubs, and vines found in the Eastern United States. The insect prefers oak species, but additional hosts include apple, aspen, basswood, beech, grey and river birch, hawthorn, sweetgum, and willow. Other species are less preferred, but during outbreaks gypsy moths feed on almost all vegetation, including conifers.

Although the gypsy moth feeds on a number of economically important hardwood species, it is the breadth of species fed upon that is of greatest concern. During outbreaks, gypsy moth larvae will defoliate all hardwood and shrub species in their path, and at'the advancing front gypsy moth populations are in an almost permanent outbreak phase.

The polyphagous nature of the gypsy moth is also of concern, especially if it is reintroduced into the Western States. Gypsy moths introduced into Oregon quickly converted from feeding on the sparse populations of hardwood to Douglas-fir before being eradicated. If the gypsy moth becomes established in the Western States, it could become a much greater problem than native pests.

Life Cycle and Biology
The gypsy moth causes its damage in the larval or caterpillar stage of its development by feeding on the foliage of susceptible vegetation. One generation of gypsy moths appears each year, and hatching occurs from April to late May, depending on the area and temperature, though it usually coincides with budbreak of most hardwood trees. The tiny larvae, or caterpillars, may remain in the egg for several days, but when conditions are favorable, they climb to the top of trees or other tall objects. They do not feed, but suspend themselves from silken threads and are dispersed by the wind. The larvae may go through several dispersals before finding a suitable host. Once they begin to feed, the larvae pass through several stages, or instars, in which they shed their skin. Males usually pass through five instars and females, through six. At the fourth stage, the larvae develop the characteristic markings of five pairs of blue spots followed by six pairs of red spots.

At low to moderate population densities, the larvae rest during the day in bark crevices, or they may descend to the ground if no suitable hiding places are available. During outbreaks or on heavily infested trees, the larvae feed day and night. On completely defoliated trees, the larvae may move short distances into adjacent woodlands in search of food.

Depending on location, the larval stage lasts about 7 weeks. Once feeding has been completed, the larvae find sheltered places to pupate. The pupal stage lasts about 2 weeks.· Male moths, which are dark brown and good fliers, emerge before the white, flightless females. The females crawl to suitable sites to lay their eggs and release a sex attractant to lure male moths for mating. After mating, the females deposit their eggs in tan- or buff-colored masses that may contain a few hundred to nearly one thousand eggs.

Gypsy moth outbreaks are cyclic: Insect populations build up to epidemic levels and then collapse. The population collapse'is caused by a gypsy moth virus that develops and spreads best when populations reach very high levels. Outbreaks may last 5 to 7 years and occur over hundreds of thousands of acres. (At the advancing front of the infestation, the gypsy moth population is almost continually at an outbreak level.)

Insect Spread

Natural dispersal occurs when the newly hatched larvae suspend themselves from their silken threads, allowing the wind to move them to potential hosts. In nonmountainous terrain the larvae may be deposited within one-half mile of their source; however, in mountainous terrain the larvae may be dispersed up to 3 miles. Larvae are spread artificially when egg masses are deposited on vehicles or on articles in vehicles and are transported to uninfested areas.

Economic and Ecological Impact

The gypsy moth is the most destructive insect that attacks hardwood forest and shade trees in the United States. Even vigorous trees defoliated by gypsy moths are seriously weakened, and defoliation over 2 consecutive years can kill a tree. In humans, allergic reactions to body hairs of the caterpillars are common and well documented. In urban areas, gypsy moth larvae, their droppings, and egg masses present additional nuisance factors. Urban trees have a much greater value than those grown for timber, and the loss of a tree results not only in removal and replacement costs but also in the loss of aesthetic and property values. In 1973, the value of trees lost to the gypsy moth was estimated at $375 per tree.

Defoliation by the gypsy moth can also severely affect parks and recreational areas. With heavy infestations, larvae crawl over picnic tables, cabins, roads, and trees, leaving their droppings and creating a nuisance and possible health hazard to humans. Defoliated trees are unattractive, and in the Northeast, tourism has suffered sharp declines in areas where outbreaks have occurred.

Because forests are used for many types of activities, the value loss caused by the gypsy moth is more difficult to predict than for urban areas. Value loss to Northeast forests, assessed in 1978, ranged from $0 to $468 per acre, depending on use, and averaged $1'4. Over the 10 years for which records have been available (1978-88), gypsy moth defoliation ranged from a low of 643,600 acres in 1978 to a high of 7 2,872,725 acres in 1981.

Management

Because gypsy moth outbreaks are long (often lasting from 5 to 7 years) and attack a large number of tree species, public pressure for control measures is often intense. Possible control measures for the gypsy moth include chemical insecticides; the release of sterile life stages; mass trapping using a pheromone sex attractant; and biological controls, such as the release of parasites or predators or the use of the biological insecticide Bacillus *thuringiensis* (Bt). With recent public concern over safety and the impact on nontarget insects, chemical insecticides, such as acephate and carbaryl, have lost favor as control techniques. The release of sterile life stages, such as sterile male release, has been used successfully to eliminate isolated low-level infestations, but it has had little effect on larger populations. Mass trappings using pheromones and the use of parasites and predators are likewise effective only when gypsy moth populations are very low. The use of biological insecticides, such as Bt, is favored to protect recreational areas and high-value timber species.

Chestnut Blight

History of Introduction

Chestnut blight, one of the most infamous plant diseases in North America, illustrates the devastating impact of an introduced plant pathogen. The disease was first discovered killing trees in New York City's Bronx Zoological Park in 1904. Two years later, the fungus causing the disease was identified. Five years after the blight's discovery, infected chestnuts were found 30 miles from New York, and pockets of the disease appeared in Pennsylvania, Virginia, Maryland, Connecticut, and Rhode Island. Spread was exceedingly rapid. Within 50 years the disease had spread to the extremes of the natural range of the American chestnut, with the loss of approximately 8 million trees.

Efforts to control the blight were begun soon after its discovery. In New York City, control measures included pruning affected branches and applying bordeaux mixture, but neither method was effective. In Washington, DC, all infected trees within disease centers were cut and burned, but also to little avail. In Pennsylvania, control efforts were abandoned after only 2 years. The quick proliferation of the blight and the enormous toll it took sparked prodigious research. Even by 1974, 399 articles had been published on various aspects of the epidemic.

Chestnut blight was the most destructive plant disease ever recorded. The legacy the blight fungus left was the near total decimation of the American chestnut from its natural range. Today, sprouts from the root systems of blighted trees are all that remain of this once important species.

Range and Importance of Host

The American chestnut (*Castanea dentata* (Marsh.) Borkh.) was once the most abundant hardwood in the eastern deciduous forest. Its natural range encompassed more than 200 million acres. In the southern part of its range, the tree grew to 120 feet in height and 5 feet in diameter. The chestnut had a faster growth rate than its associated hardwood species, and normal growth was 500 board feet per acre per year, with individuals on good sites adding 1 inch in diameter per year.

The American chestnut had more uses than any other tree in the eastern forest: It was important as a timber, nut, and shade tree. The wood was extremely resistant to decay because of the tannins in the bark and wood. It was used for construction, furniture, tannins for leather, fences, boxes, barrel staves, railroad ties, telegraph poles, mine timbers, and musical instruments. The delicious nuts were also an important source of food for wildlife, domestic livestock, and humans.

Disease **Organism**

The chestnut blight fungus (*Cryphonectria parasitica* (Murr.) Barr (= *Endothia parasifica, Diaporthe parasitica*)) is an ascomycete (subclass Pyrenomycetes) belonging to the family Diaporthaceae. The fungus is now distributed throughout the Northern Hemisphere, but it is believed to be of Asian origin. The asexual, single-celled conidia are produced within pycnidial stromata on the bark of diseased trees. The sexual ascospores are two-celled, each with one to four nuclei, and are produced in perithecia within the same stromata as the pycnidia. Both spore types are produced in abundance on diseased trees, and both are capable of causing infection on healthy trees.

Life Cycle and Biology

Cankers can occur anywhere on the branches or trunk, but the fungus requires some type of wound to gain entrance. Once established, mycelial fans produced by the fungus rapidly colonize the bark tissue, encircling and girdling the branch or trunk and killing the cambium. After the sapwood at the site of a girdling lesion ceases to conduct water, the leaves and shoots above the canker wilt and die. Typical cankers on young, smooth-barked stems appear yellowish to reddish brown in contrast to the green-brown bark. On larger stems with thick corky bark, cankers are usually inconspicuous unless the bark begins to swell or crack.

Under moist conditions, orange-brown stromata of the fungus erupt through the surface of infected bark, releasing millions of conidia embedded in a water-soluble, gelatinous matrix. These spores are adapted for spread by rain and perhaps by insects, birds, and small animals. Perithecia, producing ascospores, also form throughout the growing season in the same stromata that give rise to the conidia. These spores are released after rains and are adapted for spread by wind. New infections occur when ascospores or conidia germinate in fresh wounds that penetrate to living bark.

Disease Spread

The rate of spread of the main disease center south of New York has been estimated at 10 to 23 miles per year. The discrepancy in estimates results from spot infections occurring up to 150 miles from the leading edge of the principal center. There are two mechanisms of spread by the fungus. in one, the ascospores are forcibly ejected from the perithecia and may be carried long distances by the wind. In the other, conidia or asexual, spores of the fungus are extruded in a gelatinous matrix that is ideally suited to dissemination by insects, birds, and mammals. These spores can also be splashed by rain and dispersed. The most important insect carriers are probably the wound makers, such as the chestnut-bark borer (*Strophonia nitens*) and the chestnut-bast miner (*Ectoedema phleophaga*). Conidia of the fungus have also been recovered from several species of birds, including woodpeckers and the wound-inducing sapsucker. The north to south migration of birds in the fall may explain the southwest spread of the blight against the prevailing winds.

Economic and Ecological Impact

The American chestnut was once the most economically important hardwood species of the eastern forests. The time that has elapsed since the destruction of the blight makes it difficult to estimate the total impact of the disease. In 1912, the value of the standing chestnut timber in Pennsylvania, West Virginia, and North Carolina alone was estimated at $82.5 million. The value of the nut crop and shade trees in Pennsylvania alone was estimated at another $15 million. In Pennsylvania, $275,000 was spent between 1912 and 1914 in a vain attempt to stop the disease.

Chestnut blight resulted in wholesale species conversions, primarily to oaks, on sites where chestnut was predominant. On the better sites it was replaced by red and white oaks, while on the steeper hillsides these species gave way to pin oak and chestnut oak. However, along many of the ridgetops in the Appalachian Mountains the chestnut has not been replaced, leading to increased soil erosion.

Disappearance of the American chestnut has also led to a serious loss of biodiversity in the hardwood forests of Eastern North America. Oak species, which have predominantly replaced the chestnut, are now under severe attack from gypsy moths in the Northeast and from oak wilt and oak decline in the region between the Mississippi River and the Appalachian Mountains.

Management

Over the past 50 years, experimental attempts have been made to restore the American chestnut using fungicides, biological controls, and breeding for blight resistance. Fungicides have shown some promise for controlling the blight on individual trees of high value, but annual applications are required. Biological control of virulent strains of the fungus by avirulent strains has been shown feasible in Europe. In the United States, however, the greater spread and diversitv of the virulent strains mitigates against the widespread introduction of hypovirulent strains. At this time, breeding for blight resistance is being done, but no clones of American chestnuts have sufficient blight resistance to be useful for outplanting. Attempts to produce suitable hybrids between the American chestnut and Asian species have yielded trees with the poor appletree-like form of the Asian parents.

Dutch Elm Disease

History of Introduction

Dutch elm disease, caused by the fungus *Ophiostoma ulmi (Cerutocysfis ulmi)*, was first described by Schwarz in the Netherlands in 7920. The. fungus was introduced to North America, together with one of the insects responsible for its spread, the smaller European elm bark beetle, *Scolytus multistriatus* (Marsh.), on unpeeled veneer logs, with the earliest cases of the disease on this continent reported in Ohio in 1930. In 1933, a Federal quarantine inspector at the port of Baltimore intercepted elm logs from France carrying the Dutch elm fungus together with the main bark beetle vector of the fungus in Europe. Subsequent inspections revealed the fungus in elm logs intercepted in New York, Norfolk, and New Orleans. The most serious disease centers arose around New York City and Quebec in 1933. In New York City, spread of the disease was attributed to the presence of a breeding population of the introduced smaller European elm bark beetle and an abundance of the native (North American) elm bark beetle *Hylurgopinus rufipes* (Eighh.). A second major disease center occurred in the late 1930's in Ohio and Indiana. Attempts at eradicating the disease, especially in the New York City area, were abandoned at the onset of the Second World War. By 1968, the disease was present throughout the eastern half of the continent and into Colorado and Idaho, beyond the range of native elms. New, more aggressive strains of the Dutch elm disease fungus have been developed in North America and reintroduced into Europe where they cause increased mortality.

Range and Importance of Host

The American elm (*Ulmus americana* L.) is native to all States east of the Great Plains. Interspersed in this region are five other native elm species---slippery elm (*U. rubra* Muhl.), rock elm *(U. thomasii* Sarg.), winged elm (*U. alata* Michx.), red elm (*U. serotina* Sarg.), and cedar elm *(U. crassifolia* Nutt.). Elms usually grow in mixed stands with other hardwoods and in 1938 accounted for an estimated 76 billion board feet of merchantable timber. Elm wood has been used for veneer, furniture, shipbuilding, flooring, sporting goods, boxes, and crates.

The value of America's elms as ornamentals and shade trees surpasses that of all forest elms. Elms are especially adaptable to the urban environment. They are able to endure physical damage, such as repeated pruning for overhead utility lines, and are tolerant of soil compaction. The beauty of elms and their utility as shade trees have contributed to their popularity. As a result, they have been planted extensively on streets, roadsides, and homesites across the United States.

Disease Organism

The Dutch elm disease fungus is an ascomycete (subclass Pyrenomycetes) belonging to the family Ophiostomataceae. Its synnematal imperfect stage was named *Pesotum ulmi* (Schwarz) (Crane & Schoknecht, 1973). The perfect stage has had a number of names, the most recent being *Ophiostoma ulmi* (Buis.) Nannfeldt and the better known *Ceratocystis ulmi* (Buis.) C. Moreau. The fungus has four commonly observed spore types: (1) Sporothrix stage with conidia; (2) synnematal (*Pesotum*) stage, also with conidia; (3) "yeast-like" stage; and (4) perithecial (sexual) stage, producing ascospores. Spores produced by the two conidial stages and the perithecial stages are embedded in sticky mucilaginous drops. The yeast-like stage is thought to be involved in the spread of the fungus within a tree's vascular system.

Life Cycle and Biology

Ophiostoma ulmi is an example of a vector-borne plant disease and a highly specialized vascular-wilt organism. The fungus causes the disease, but insects are necessary to vector the fungus to healthy elms. In North America, two insects (Scolytidae) are responsible for spread of the disease: the smaller European elm bark beetle (*Scolytus multistriatus*) and the native elm beetle (*Hylurgopinus rufipes*).

The fungus is a primary colonizer of the inner bark of dying elms. The beetles lay their eggs in the inner bark of diseased or stressed trees. After the eggs hatch, the emerging larvae feed on the phloem by making tunnels through the bark. If the fungus is present in the tree, the fungus produces mycelium and sticky *Pesotum*-type spores in the beetle tunnels and pupal chambers. When the adult beetles emerge, they carry thousands of spores on and in their bodies. Dispersing beetles fly to healthy elms where they feed or to declining elms where they breed. On healthy elms, the beetles feed on or burrow into the bark of twig crotches where the spores are deposited into the wounded tissues of the tree. The fungus grows rapidly in the injured bark and wood. When it reaches the large xylem vessels of the springwood, it produces *Sporothrix*-type spores, which are carried in the sap stream. The extent of crown symptoms is directly related to the extent of vascular invasion. General invasion of the tissue begins at the dieback phase of the disease, with considerable blockage of the sapwood by gums and tyloses produced by the tree to resist the fungal invasion. Infection induces browning of the water-conducting vessels. Infected twigs and branches soon wilt and die.

Spring infections result in the invasion of the long vessels of the springwood through which spores can be rapidly spread to all parts of the tree. If the vascular invasion becomes general, the tree may die within a few weeks. In summer infections, vascular invasion is limited to the short vessels of the summerwood, resulting in localized infections; tree death occurs the following year.

Disease Spread

Once the fungus has become established, spread to nearby healthy elms can occur without the insect vector by internal movement of the fungus through root grafts. Either the insect vector or human activities can cause long-distance spread of the fungus. The spread rate of the disease across Connecticut was 4.5 miles per year, equal to the flight of two generations of the smaller European bark beetle. Elm bark beetles commonly attack green elm logs cut for lumber or fuel. Cut elm logs colonized by contaminated beetles commonly serve as reservoirs of the fungus, including logs of the **elm** species that are not highly susceptible to the disease itself. Subsequent commercial transport of the logs has allowed both the Dutch elm disease fungus and bark beetles to spread over long distances, even across oceans.

Dutch elm disease is particularly damaging because the insects can introduce 0. *ulmi* into trees- that were not killed by Dutch elm disease during their breeding colonization. Thus, the insects produced in any elm, regardless of the cause of death, will usually carry the fungus. This secondary colonization ensures that most elm material will produce contaminated beetles.

Economic and Ecological Impact

The primary impact of Dutch elm disease has been in the urban environment, rather than in forests. Because of their aesthetic appeal and their hardiness, by 1930 an estimated 77 million elms had been planted in densely populated areas across the United States. By 1977, an estimated 60 percent of urban elms in the United States had been lost to the disease.

The calculations of monetary loss and the costs of control are only rough estimates. More than $11 million was spent over a 5-year period in the 1930's by Federal and State agencies to eradicate the disease. Costs of removal and replacement vary between $100 and $425 per tree, with an average cost of $215. However, when aesthetic and other values are factored in, the cost rises to $430 per tree.

Management

Control programs enacted by urban governments in affected areas have ranged from complete neglect to an all-out assault on the disease. The primary control method has been sanitation, which eliminates the breeding material of bark beetle vectors. Experience has shown that, despite costs, the control efforts are preferable to no action: communities that did nothing eventually incurred costs two to three times greater than those that implemented control programs.

Historic and other highly valued trees may be saved if injected with a systemic fungicide. Effective treatment from 1981 to 1984 cost a minimum of $40 to $100 per tree.

Port-Orford-Cedar **Root Rot**

History of Introduction

Port-Orford-cedar root rot was first reported causing mortality of Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) nursery stock around Seattle, WA, in 1923. The causal fungus was isolated and described in 1942 from declining cedar ornamentals in the Willamette Valley, and the disease appeared in the native range of Port-Orford-cedar in 1952. It subsequently spread throughout much of the area occupied by the host in southwestern Oregon and northern California. The origin of the pathogen is unknown, but based on the resistance exhibited by Asiatic *Chamaecyparis* spp., it is believed to be an Asian species. An alternative theory is that the fungus originated in North America, but outside the relatively small area where the host is native.

Range and Importance of Host

Port-Orford-cedar has a very limited natural range. It is confined to a 40-mile-wide strip along the Pacific Coast from Coos Bay, OR, south to the Mad River near Arcata, CA. It occurs in a number of plant community types, but its natural distribution appears to be limited by its need for substantial amounts of moisture. It prefers sites with year-round water seepage and generally occurs in mixed stands with other species.

The domestic market for Port-Orford-cedar lumber is limited. Though formerly considered valuable for interior paneling, Venetian blind slats, and battery separators, its primary use in the United States today is for arrow shafts. However, the overseas market for Port-Orford-cedar is substantial.. The wood is especially prized for construction in Japan, where it is used as a substitute for hinoki cypress and has religious significance. Between 1950 and 3980, more than 2.2 million cubic meters of Port-Orford-cedar were exported from the United States. From 1980 to 1989, an additional 307,000 cubic meters were exported. Port-Orford-cedar export logs are priced at about five times the price of prime Douglas-fir.

Disease **Organism**

Phytophthora lateralis Tucker & Milbrath, the fungus that causes Port-Orford-cedar root rot, is an oomycete belonging to the family Phythiaceae in the order Peronosporales. The name *Pkytopktkoru* means plant destroyer. Members of the genus *Phytophthora* are mostly pathogenic and produce stout, colorless, freely branching hyphae that grow inter- and intracellularly in host plant tissues. They produce two kinds of infective spores: zoospores and oospores. *Pkytopktkoru lateralis* also produces a chlamydospore resting stage. All spore types require free water for germination.

Life Cycle and Biology

Phytophthora lateralis is highly adapted for spread in water and soil and is also capable of surviving for considerable periods of time even when conditions are unfavorable for spread and infection. Zoospores produced in sporangia are flagellate and very motile in surface or soil water. Zoospores are attracted by root exudates and will follow an increasing gradient of chemical concentration until they contact host root tissue, germinate, penetrate the root, and initiate infection. Zoospore production is favored by mild, moist conditions and is optimal at temperatures between 10 and 20 °C. When unfavorable warm, dry conditions prevail, *Phytophthora lateralis* forms thick-walled resistant chlamydospores. These resting spores are incapable of direct movement themselves, but their structure provides protection during passive movement in mud, soil, or infected roots. When environmental conditions become favorable again, chlamydospores germinate, forming zoospore-containing sporangia. Oospores (the spore stage produced by sexual union) also act as resting spores and may be transported in infected root tissues.

After infection, mycelia of *Phytophthora lateralis* grow in the host cambium until the entire root system is colonized and the tree dies. This may require up to 4 years in large trees, while small trees may be killed in a few weeks. The fungus lives vegetatively in the host as long as the tree survives.

Disease Spread

Long-distance dispersal of *Phytophthora lateralis* occurs through transport of infected roots and foliage and through earth movement during construction, road maintenance and use, logging, and animal movement. Local spread involving zoospores occurs mainly downhill, below roads and trails in water drainage. Spread from tree to tree can also occur by mycelial growth across root grafts.

Economic and Ecological Impact

Although difficult to assess precisely, losses caused by Port-Orford-cedar root rot have been enormous. *Phytophthora lateralis* has virtually destroyed the once-thriving Port-Orford-cedar nursery industry and has killed ornamental Port-Orfordcedars throughout the Northwest, resulting in considerable property value loss and substantial replacement costs.

In their native range, mortality losses in old-growth Port-Orford-cedars are believed to have peaked at about 10 million board feet per year in the early 1970's, subsequently dropping to about 5 million board feet annually. It is estimated that 60 percent of the trees in young-growth stands have been killed by the disease. Despite some concern that the species itself is endangered, Port-Orford-cedar is an extremely Prolific seeder, and many stands, by virtue of their location, have a high probability of escaping infection. Nonetheless, the disease has greatly hurt the commercial Prospects for Port-Orford-cedar and has also made necessary new and costly control efforts.

Management

The only effective method to manage Port-Orford-cedar root rot involves excluding the disease from areas it has not yet reached. Such a strategy requires careful planning and strict enforcement. Exclusion necessitates road closures, timing access during dry weather, washing equipment, and establishing cedar stands on well-drained ridgetops above roads, among other measures. Screening and breeding programs to promote resistance to the disease may prove effective, but no such results have yet been produced.

White Pine Blister Rust

History **of Introduction**

Cronartium ribicola J.C. Fisch, the cause of white pine blister rust, is believed to be a Eurasian fungus. It was first described on eastern white pine in the Baltic region in 1854, and it was introduced into both Eastern and Western North America on diseased white pine planting stock from Europe around the turn of the century. In the East, white pine blister rust was first discovered near Geneva, New York, in 1906, although it was probably present some years earlier. In the West, introduction resulted from one shipment of infected eastern white pine seedlings shipped to Vancouver, British Columbia, from France in 1910. The disease has since spread virtually throughout the range of its host in the United States and Canada. Despite earlier hopes that unfavorable climatic conditions would prevent its spread to the Southwest, the disease has progressed steadily southward through California and has recently been discovered in New Mexico.

Range and Importance of Host

White pine blister rust is a disease of five-needle pines, including bristlecone (*Pinus aristata* Engelm.), limber (*P. flexilis* James), whitebark (*P. albicuulis* Engelm.), western white (*P. monticola* D. Dougl. ex D. Don), southwestern white (*P. strobiformis* Engelm.), eastern white (*P. sfrobus* L.), and sugar pine (*P. lambertiana* Dougl.). Alternate hosts are currants and gooseberries of the genus *Ribes*. Eastern white pine, western white pine, and sugar pine, in particular, are extremely valuable timber species, known for high-quality wood and excellent growth characteristics. Before the introduction of blister rust, these species often dominated forest stands over significant areas within their respective ranges.

For example, it is estimated that western white pine comprised 80 to 90 percent of the stocking in many old-growth stands in Idaho and Montana before they were ravaged by blister rust.

Disease Organism

Cronartium ribicola is a macrocyclic, heteroecious rust fungus belonging to the order Uredinales in the class Teliomycetes, subdivision Basidiomycotina. The fungus has a complex life cycle involving five spore types and requiring both pine and *Ribes* hosts for its successful completion.

Life Cycle and Biology

Basidiospores of C. *ribicola* infect pine hosts during summer and fall. Infection takes place through needles of any age. The relatively delicate, short-lived basidiospores are wind dispersed, generally over distances of no more than 100 yards. For successful spore germination and infection of pine needles to occur, temperatures must not exceed 68 °F with 100 percent relative humidity for a period of 48 hours. After germination and successful penetration, a sparse mycelium develops and grows from the needle into the bark of the stem. Twelve to eighteen months later, a slightly swollen, cankered area first becomes visible. Two to three years after initial infection, pycnia and pycniospores are produced on the cankers. They are noninfective and have a sexual function. One to two years later in the spring, aecia with aeciospores are produced in the same location on the cankers. The relatively tough aeciospores are disseminated by the wind over considerable distances and infect *Ribes* leaves. Infection of the *Ribes* host is also favored by moist conditions. Two weeks after initial infection, uredinia are produced on *Ribes* leaves. Urediniospores produced from the uredinia reinfect *Ribes* throughout the summer, causing build-up of inoculum. In late summer to early fall, hairlike telial columns emerge from the old uredinial pustules. Teliospores germinate in place on these columns and produce basidiospores, starting the process *over again*. The entire life cycle requires 3 to 6 years for completion.

White pine blister rust rankers develop into resinous lesions, eventually girdling the host at the point of infection. This results in branch and top mortality. The fungus continues to grow through branches and into the main stem, where it ultimately girdles the main stem and kills the tree. Infected trees are also predisposed to bark beetle infestation.

Disease Spread

The initial spread of white pine blister rust in North American forests was phenomenally rapid. In 10 to 20 years the disease had spread through most of the host ranges. The rapid spread in the United States has been the result of the combination of numerous highly susceptible hosts, the close proximity of primary and alternate hosts, favorable environmental conditions, and the fact that C. *ribicola* spores are windborne. Aeciospores, in particular, are effectively transported very **long** distances, sometimes up to 300 miles. Spread is episodic, and is much more dramatic during years with moist summers and falls. The disease is often not as severe in dry microsites as in moist ones.

Economic and Ecological Impact

Losses caused by white pine blister rust have been exceptionally great. It is believed that 80 to 95 percent of the western white pine, sugar pine, and eastern white pine have been killed or damaged in affected stands. In the West, 99 percent of the host type in Idaho and Montana, 96 percent of the host type in Oregon and Washington, and 80 percent of the host type in California have been affected. This represents forest stands on a combined area of about 9 million acres. Loss has occurred in the form of reduced value in salvaged mortality, unsalvaged mortality in mature stands, loss of site potential because of the killing of immature trees, and value loss through top killing. The virtual elimination of western white pine from stands in Idaho and western Montana, where it was formerly a dominant species, has also had severe ecological consequences. Douglas-fir and grand fir have largely replaced white pine in these stands, but because of the susceptibility of these two species to native root diseases and defoliating insects, the stands have since been in a chronic state of poor health and reduced productivity. Grizzly bears, a threatened and endangered species, depend on the nuts of white bark pine. White pine blister rust has recently spread to white bark pine and will greatly reduce this important food source for bears. The recent introduction of white pine blister rust into New Mexico threatens the biodivrrsity of southwestern mixed conifer forests.

Management

The principal control for white pine blister rust involves planting pines with various levels of resistance to C. *ribicola*. Programs to identify and screen apparently resistant pines or to breed trees for greater resistance are expensive but promising. However, there is concern that mutation of the pathogen could negate the results of these programs. Earlier control efforts aimed at eradicating *Ribes* or killing cankers on infected trees with antibiotic chemicals were unsuccessful. However, these efforts were extremely costly: as of 1959, a little more than $100 million had been spent on the largely ineffective *Ribes* eradication program. Pruning the lower branches of young white pines to prevent stem infections and alter the microclimate in plantations is occasionally useful.

Pine Wilt Disease

History of Introduction

Like Dutch elm disease, pine wilt disease is a highly specialized vector-borne plant disease, which is caused by the pine wood nematode (*Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle) and carried by cerambycid beetles.

In Japan, the first record of symptoms similar to those induced by the pine wood nematode dates from 1905 in Nagasaki, Kyushu. Although the cause of death could not be determined, the affected trees were cut and burned. Other outbreaks were recorded on Honshu in 1921, where the disease spread rapidly throughout coastal areas, and 30 miles north of Nagasaki in 1925. Efforts to control the epidemic by cutting and burning were begun in many areas but were abandoned during the Second World War.

For many years, abnormally high populations of pine bark beetles were believed to cause the wilt. But it was eventually established that the pine wood nematode in association with an insect vector, the pine sawyer (*Monochamus alternatus* (Hope)), was the real cause of the disease (Steiner and Buhrer, 1971). The pine sawyer is native to Japan, but recent research has demonstrated that the nematode originated in North America. Thus, pine wilt disease is an example of an introduced pathogen adapting to, and being transported by, a native vector.

The nematode was probably introduced to Japan in pine logs from the west coast of North America. The scattered nature of the infections throughout Kyushu and Honshu suggests that the movement of nematode-infected logs played a major role in spreading the disease.

The first report of pine wilt disease in North America was in 1979, when the disease was diagnosed on an Austrian pine (P. *nigra* L.) growing in Missouri. All subsequent reports of the disease have been on exotic pine species. Pine wilt disease has also been reported in China and Taiwan.

Range and Importance of Host

The two pine species that predominate throughout the islands of Japan are both extremely susceptible to the wilt caused by the pine wood nematode: Japanese red pine (*Pinus densiflora* **Seib et Zucc.**), that nation's most important timber species, and Japanese black pine (P. *thunbergii* Parl.), which is important as a shade tree and as a decorative tree. A third pine species, the Luchu pine (P. *luchuensis*), is found on Okinawa and is also susceptible.

Disease Organism

The pine wood nematode is a member of the superfamily Aphlenchoidae; is native to North America; and has been introduced to Japan, Taiwan, and China. The nematode is microscopic, 800 μm long and 22 μm in diameter. Each female lays about 80 eggs, which after hatching pass through four stages of larval development on the way to adulthood. Depending on temperature, the pine wood nematode can develop rapidly, completing its life cycle in 12 days at 60 °F or in just 4 days at 80 °F.

The nematode has two development stages, designated as propagative and dispersive. The propagative phase occurs while the host is still living and for a period after the host dies. During this time, the four larval stages are functionally similar to one another and immediately precede the adult stage. After the host dies they feed on fungi that invade the dead or dying tree. In the late stages of infection, development switches to the dispersive stage in which the third- and fourth-stage larvae are distinctive. The third-stage larvae are adapted to withstand starvation, the fourth, drying. The third-stage larvae migrate to the pupal chambers of insect vectors and molt to fourth-stage larvae. The fourth-stage larvae, called dauerlarvae, are especially adapted to survive in the respiratory systems of certain cerambycid beetles. They enter the bodies of new adult beetles just before the beetles emerge from the bark and are introduced into feeding wounds created by the beetles as the latter feed on the branches of healthy pines. Nematodes are also introduced into dying trees by the cerambycids during egg laying.

Life Cycle and Biology

The life cycle of the pine wood nematode is intimately interconnected with that of certain cerambycid beetles. In Japanese forests, *Monochamus alternatus* vectors the nematodes to healthy hosts. Female beetles searching for suitable hosts in which to lay their eggs are attracted to pines killed by the nematodes. The beetle eggs hatch in the late summer, and the first two instars of the insect feed under the bark before the third penetrates to the wood. Larvae molt into a fourth instar that overwinters. The following spring, the beetle larvae excavate small chambers in which they pupate. At the same time, third-stage nematode larvae migrate to the pupal chambers of insect vectors and molt to fourth-stage dauerlarvae.

As the adult beetle emerges, the dauerlarvae enter the beetles' respiratory system. The emerging beetles carry an average of 15,000 to 20,000 dauerlarvae. The beetles then fly to healthy trees and feed by stripping the bark to the cambium, during which the dauerlarvae **emerge** from the beetle and enter the plant through the wounds. Once inside the tree, the dauerlarvae undergo a final molt to adult nematodes, which can then reproduce. In the plant the nematodes migrate to the resin canals, feeding on and killing the epithelial cells.

Within 10 days of inoculation, the destruction of the resin cells leads to the cessation of resin flow. After 30 days, foliage transpiration has ceased and is followed by the sudden wilting and loss of foliage color. As the trees die, they become attractive to adult beetle females searching for stressed and dying hosts in which to lay their eggs. The next spring another brood of beetles emerges carrying thousands of nematodes, and the cycle is repeated.

In North America, pine wilt disease has been demonstrated only in exotic or stressed trees. Survival and establishment of nematodes in feeding wounds is apparently limited. However, the nematodes are almost ubiquitous in dying or recently dead trees. Nematodes are apparently transmitted very efficiently during oviposition and fully colonize trees or **logs.** The result is that cerambycids emerging from dying or recently dead trees usually carry pine wood nematodes.

Disease Spread

Pine wilt disease is similar to Dutch elm disease in that an insect is required to vector the pathogen to healthy hosts. In Japan, *Monochamus alternatus* **is** the principal vector of the nematode from infected to healthy hosts, but seven other species of cerambycid beetles can carry the nematode. Spread of the disease has been estimated at about 20 miles per year solely because of beetle movement. However, the movement of infected logs by man has greatly increased the proliferation of the epidemic.

In North America, four species of cerambycid beetles are capable of acting as vectors for the nematode, but the number of nematodes reported per beetle is lower than in Japan.

Economic and Ecological Impact

On the islands of Kyushu and Honshu, losses to pine wilt disease during the 1930's increased from 30,000 cubic meters to 200,000 cubic meters. By 1979, 2.4 million cubic meters of standing timber were destroyed, and by 1983 it was estimated that 25 percent of all Japanese pine forests had been infested.

In North America, native pine species are resistant to the pine wood nematode, and only exotic pine species have fallen prey. However, the mere presence of the parasite in a number of native pine species has prompted Scandinavian countries to embargo all wood products except squared lumber from U.S. Southern States, at an annual loss of $20 million to the U.S. forest products industry. AJI even greater loss is faced by British Columbia, where the discovery of the pine wood nematode in less than 1 percent of the trees sampled has caused the European Community to curtail its imports of green lumber, worth $600 million annually, after January 1, 1992.

The ecological impact of pine wilt disease can only be surmised here. The loss of one-quarter of the Japanese pine forests is comparable in scale to the loss in the United States of the American chestnut from chestnut blight. Reports that the nematode can adapt to the colder regimes found in Northern Japan and at high elevations suggest that soil erosion and flooding may become widespread, especially at higher elevations.

Management

Two methods are used for controlling pine wilt disease: spraying insecticides for eradicating the insect vectors and felling and burning diseased trees to eliminate the breeding habitat of the nematode and the beetle vector. Although destroying infested trees is preferable from an environmental viewpoint, a wider area can be treated by insecticides. However, both techniques are only moderately effective and are practical only in relatively limited areas. Costs of sanitation felling and burning are unavailable. In 1981 alone, $30 million was spent on insecticide aerial applications.

Chapter 4 Organisms Posing Risk

Introduction

A tremendous number of pest species have the potential to be introduced from the Eastern Soviet Union to Western North America (Appendix H). However, with this risk assessment, time and data were insufficient to allow an evaluation of the risks posed by every organism. Instead, representative species were selected for evaluation from each major pest group. These representative species were selected based on their perceived high potential risk and the availability of data. For example, rather than trying to investigate every bark beetle that could be introduced by way of logs imported from the Soviet Far East, several *Ips* beetles were selected as representatives. Conclusions about the likelihood of introduction, potential damage, and possible mitigation measures in these representative cases should apply to other species or even to unknown species of bark beetle.

The selected organisms of concern can be grouped into three categories: those that could hitchhike on logs, those associated with the bark and inner bark, and those found in the wood. Tables 4-l through 4-3 summarize the Siberian forest pests of concern identified by the Core Team and its advisory groups. The tables list probabilities of transport, establishment, and colonization from each pest, along with the estimated potential loss resulting from introduction into North America.

Risk evaluations of 36 pest organisms of concern were completed by the Core Team and advisory groups. This chapter presents the risk evaluations for the possible introduction and spread of the six pest organisms that will receive detailed economic analyses in Chapter 5 and detailed ecological analyses in Chapter 6: Asian gypsy moth (*Lymantria dispar*), nun moth (*L. monacha*), pine wood nematode (*Bursaphelenchus mucronatus*), larch canker (*Lachnellula willkommii*), spruce bark beetle (*Ips typographus*), and annosus root rot (*Heterobasidion annosum*). *(See* Appendix I for the other pest species profiles).

Asian Gypsy Moth and Nun Moth

Scientific Name of Pest—*Lymantria dispar* L. and *L. monacha* L.
Scientific Name of Host(s)—*Larix* spp. and numerous other conifer and hardwood species
Specialty Team-Entomology
Assessor-William Wallner

Summary of Natural History and Basic Biology of the Pest

Lymantriu dispar (Asian gypsy *moth)* and *L. monacha* (nun moth) belong to the order Lepidoptera and family Lymantriidae. *Lymantria dispar* and *L. monacha* are very similar in their habits, development, and host utilization. As major defoliators of numerous trees, shrubs and herbaceous plants, both species have consistently been considered major pests across the Soviet Union, Europe, and Asia. The gypsy moth is present in the United States; however, to date, neither the nun moth nor the Asian gypsy moth has been found in the United States. The Asian gypsy moth's behavior differs significantly from that of the gypsy moth of North America, thus warranting extensive efforts to exclude it from North America. The North American gypsy moth originated from Western Europe, and the strain lacks the capacity of directed flight by winged females. The Asian gypsy moth, on the other hand, is an active flyer, often attracted to lights, and capable of flying up to 40 kilometers.

The capacity to colonize new environments has been consistently demonstrated by the gypsy moth in North America, where it continues to spread and establish populations in the Eastern and Western United States and Canada. Cyclical outbreaks of gypsy moths in the United States have been extensive; more than 12 million acres were defoliated in 1981, and sporadic yearly defoliation continues.

Yearly monitoring, suppression, and eradication efforts cost the United States and Canada several

Table 4-1. Siberian Forest Pests of Concern on Bark (Hitchhikers)

Pest	Probability of Host Association	Transport Potential	Transport Survival	Establishment Potential	Colonization Potential	Potential Loss
Insects:						
Asian gypsy moth (*Lymantria dispar*)	M	H	H	H	H	H
Nun moth (*Lymantria monacha*)	M	H	H	H	H	H+
Root/stump insects (Scolytidae, Curculionidae: *Hylastes, Hylurgus, Hylobius, Hylurgops*)	M/H	H	H	M/H	M/H	H
Scale insects (*Physokermes, Aspidiotus, Lepidosaphes, Nuculaspis, Matsucoccus*)	H	H	H	M	M/H	?
Flatbugs (*Aradus cinnamomeus*)	H	H	H	H	H	H
Aphids (*Cinara* spp.)	H	H	H	H	H	M
Wooly adelgids (*Adelges* spp.)	H	H	H	H	H	H
Siberian silk moth (*Dendrolimus sibericus*)	M	H	H	M	M	H
Pathogens:						
Melampsora rust (*Melampsora* spp.)	L/H	L/H	L/H	L/H	H	M/H
Larch needle cast (*Meria laricis*)	L/H	L/H	L/H	L/H	L/H	L/H
Conifer shoot blight (*Sirococcus strobilinus*)	L/H	L/H	L/H	L/H	H	L/M

Note: H = HIGH, M = MODERATE, L = LOW.

Table 42, Siberian Forest Pests of Concern in Bark and Inner Bark

Pest	Probability of Host Association	Transport Potential	Transport Survival	Establishment Potential	Colonizati Potenti
Insects:					
Engraver beetles (*Ips duplicatus*, *I. sexdentatus*, *I. subelongatus*)	H	H	M	M/H	H
Ips typographus	L	H	H	L	H
Dendroctonus micans	M/H	H	H	H	H
Weevils (*Pissodes* spp.)	M	H	H	L	H

Note: H = HIGH, M = MODERATE, L = LOW

Table 4-3. Siberian Forest Pests of Concern in Wood

Pest	Probability of Host Association	Transport Potential	Transport Survival	Establishment Potential	Colonization Potential	Potential Loss
Insects:						
Monochamus urussovi	H	H	H	H	H	H+
Xylotrechus altaicus	H	H	H	M	H	H-
Siricidae (*Paururus*, *Xeris*, *Sirex*)	H	H	H	M	M	H
Pathogens:						
Larch canker (*Lachnellula willkommii*)	H	H	H	M/H	H	H
Annosus root disease (*Heterobasidion annosum*)	H	H	H	H	H	L/H
Staining/vascular diseases (*Ophiostoma* spp., *Leptographium* spp.)	H	H	H	H	H	M/H
Wood nematodes (*Bursaphelenchus kolymensis*, *B. mucronatus*)	H	H	H	H	H	H
Red ring rot (*Phellinus pini*)	H	H	H	L	L	L/M

Note: H = HIGH, M = MODERATE, L = LOW.

millions of dollars every year. Defoliation by gypsy moths can severely weaken trees and, in most cases, results in reduced tree growth, aesthetic depreciation, and elimination of preferred tree species from forest composition. Both the gypsy moth and nun moth are univoltine, passing the winter as egg masses on the bark or limbs of trees or on other objects such as rocks or fallen branches, or in the litter. The egg stage lasts approximately 9 months, providing an extended period for eggs to be inadvertently transported by man's activities. Egg masses of both species may contain 600 to 1,000 eggs.

The biotic potential of numbers of progeny introduced with one egg mass and the capacity to attack numerous host plants clearly contribute to the potential for such pests to be highly contagious. Spread and establishment can occur either from first instar larvae being carried by wind currents or from female moths flying to suitable host trees.

In Siberia and the Soviet Far East, both of these species are present at varying densities every year, thereby increasing the probability of inadvertent transport. The nun moth is a principal pest of spruce, larch, and fir, and is considered to be one of the most damaging and dangerous pests in the Soviet Union. The gypsy moth currently present in the United States has more than 250 known hosts but prefers oak. The Asian gypsy moth has a similar broad host range, but prefers larch, alder, and willow.

Specific Information Relating to Risk Elements

Probability of Pest Establishment

Pest With Host at Origin—Both species prefer larch as a host and lay their egg masses on the bark of stems and branches. This ensures that there will be a high probability of presence on larch. Probability would increase when either insect is in an outbreak mode, but their common occurrence across the Soviet Union presents a risk even when populations are not high.

Entry Potential—Egg masses are preferentially deposited in bark crevices and fissures and because of their color may be very difficult to detect visually. Masses are very tolerant of extremes in temperature and moisture and are securely attached to the bark; these qualities promote high survival and transport capabilities.

Colonization Potential—As strongly polyphagous insects possessing the capacity to infest more than 250 different plant species and a proven capability to colonize new, diverse habitats, Asian gypsy moth and nun moth must be regarded as serious threats. Thus, if inadvertently introduced into coniferous, mixed conifer/hardwood, or hardwood regions, the capacity for colonization is great.

Spread Potentid—Asian gypsy moths and nun moths disperse as first instar larvae carried by air currents: Though longdistance dispersal (several kilometers) is uncommon, short-distance dispersal (several hundred meters) is well documented. The capacity for prolonged and extensive flight by females of both species imparts a dangerous quality not present in existing Lymantriid moths in North America.

Consequences of Establishment

Economic Damage Potential—The establishment of the North American strain has caused significant economic losses and protection costs. Because the Asian gypsy moth and nun moth possess extremely broad host ranges and because acceptable host material is found in most regions of North America, these defoliators constitute a threat to forests, urban plantings, and agriculture. The behavioral traits of these Lymantriids would necessitate developing and adopting new management strategies and techniques if they were introduced.

Environmental Damage Potential—Defoliation by the gypsy moth in the Eastern United States has changed the composition of the forests. This change in the character of eastern forests portends comparable major shifts in the Pacific Northwest if these species become established.

Perceived Damage (Social and Political Influenced—Past experiences with the gypsy moth in North America have elicited substantial public pressure to deal with the problem. Not only does defoliation impose high costs to protect trees, but at high densities dispersing larvae cause serious allergic responses in humans because of the urticating hairs. The nun moth causes similar impacts. Millions of dollars have been spent annually on the gypsy moth problem. Moreover, control measures may have negative environmental consequences. All these problems would be expected to magnify significantly should the Asian gypsy moth or nun moth become established in the United States.

Estimated Risk
Because of the survivability, transportability, and difficulty of egg mass detection, the probability of detection would be low. The cost and effort necessary to adequately detect entries on logs is very high. Dead trees, pallets, and even the hulls and rigging of ships are known to harbor egg masses. Interception of Asian gypsy moth egg masses on Soviet ships is documented. .

Additional Remarks
The introduction of either the Asian gypsy moth or the nun moth would seriously complicate and compromise ongoing gypsy moth eradication and suppression efforts.. Females capable of strong directed flight would permit extensive recolonization for which current chemical and biological control procedures are extremely inadequate.

Pine Wood Nematodes

Scientific Name of Pest—*Bursaphelenchus mucronatus*, B. *kolymensis*, and other xylem-inhabiting nematodes
Scientific Name of Host(s)—*Abies* spp., *Larix* spp., *Pinus* spp., and other conifers
Specialty Tram----Pathologists
Assessor--Dale R. Bergdahl

Summary of Natural History and Basic Biology of the Pest
Species of nematodes from the genus *Bursaphelenchus* are known to inhabit both the wood and bark tissues, including the roots of many species of conifers. These nematodes are not known to naturally inhabit the soil. The life cycles of *Bursaphelenchus* species are very similar to the cycle of *Bursaphelenchus xylophilus* (pine wood nematode) (see Chapter 3). These nematodes are associated with a large number of species of coleopterous insects and are believed to be primarily vectored by Cerambycidae.

A large number of wood-staining fungi (*Ceratocystis, Leptographium, Verticicladiella,* and so forth) are also associated with and vectored by many species of Coleoptera. Some of these fungi are pathogenic to trees, and some also serve as a food source for *Bursaphelenchus* in the wood and bark tissues of their respective coniferous hosts.

In general, these nematodes are introduced into either healthy, stressed, or dying trees, as well as into freshly cut trees or logs maintained in storage areas while awaiting shipment or processing. These nematodes can affect a large number of relatively vigorous trees (under some circumstances), but they usually prefer a predisposed or dead host substrate. These nematodes have a tremendous capacity to reproduce, especially in dead or dying trees or in wood products, such as roundwood logs or wood chips. Their rate of reproduction is increased greatly by warm temperatures, but they can also be found in areas with a wide temperature range.

Under laboratory conditions B. *xylophilus* and B. *mucronatus* can interbreed and therefore have the potential to form interspecific hybrids. However, the ecological or pathogenic potential of these interspecific hybrids remains unknown. In addition, different pathotypes have been described for B. *xylophilus* and variation of this kind also should be expected for *B. mucronatus.*

Bursaphelenchus xylophilus is the only species of *Bursaphelenchus* that has been associated with considerable tree mortality, especially as an introduced pest. Seedling inoculation tests suggest that B. *mucronatus* may also be capable of killing some tree species, though it appears to be much less virulent.

Specific Information Relating to Risk Elements
of Pest Establishment

Pest With Host at *Origin*—Highly probable. Species of *Bursaphelenchus* are commonly found in all types of dead timber and harvested logs, especially those infested with Cerambycidae. Some of these Cerambycidae (*Monochamus* sp.) complete their maturation feeding on living trees and then oviposit in dying or dead trees or in recently cut logs. If cut logs remain in a forest environment for any length of time during the summer months prior to processing, they will likely be attacked by these Cerambycidae and also will become contaminated with *Bursaphelenchus* spp. *B. mucronatus* and B. *kolymensis* have been reported in Siberia. *B. mucronatus* and associated cerambycids were found in test shipments of imported logs described in Chapter 1.

Entry Potential—Very high. Species of Cerambycidae (*Monochamus* spp.) will easily survive transit to

North America, assuming bark is left on the logs. If the bark has been removed prior to shipment the insects' survival rate may be reduced, especially if the logs were debarked soon after harvesting. *Burasphelenchus* spp. will survive transit to North America in wood or bark tissues. Nematodes will even survive mill processing of wood into lumber or other mill products. However, the nematode will be eliminated by kiln heating/drying when kiln temperatures exceed about 60 °C.

Species of Cerambycidae can be detected at ports of entry by looking for oviposition sites or larval feeding galleries. *Bursaphelenchus* spp. can be detected at ports of entry only by using nematode extraction procedures designed for sampling wood products. These standard extraction methods are time consuming, cumbersome, and not very efficient.

Colonization Potential-Very high. The conifers near U.S. ports of entry are very susceptible to attack by the Cerambycidae. If these exotic insects emerge from nematode-infested logs, the probability of nematode transmission to our native conifers will be extremely high. Once the nematode has been successfully transmitted, native Cerambycidae will continue the vector relationship without any additional involvement by the exotic vector. Any recently dead or dying trees or any logs scattered in the yard or left in piles around the general area of the port of entry could potentially serve as a breeding site for both the nematode and its exotic or native vectors.

There does not appear to be any appreciable environmental resistance to either *Bursaphelenchus* spp. or their insect vectors. The only exception would be that during the winter months the vectors and nematodes are dormant.

Certain environmental stress factors have been reported to enhance the success of *B. xylophilus. These* factors include predisposition of trees as a result of infection by other pathogens, high temperatures, Prolonged drought, and insect attack. Also, trees growing outside of their native ranges are believed to be more susceptible to *B. xylopkilus.* Other species of *Bursaphelenchus* may also be favored by similar factors of environmental stress.

If the exotic *Bursaphelenchus* spp. enter this new North American environment, they could propagate without any known obstacles. The host species are quite similar and some extend across the entire northern boreal region of North America. Also, significant coniferous forests extend along the Pacific Coast and throughout the Rocky Mountain regions of North America. In addition, the meteorological and climatological parameters should not offer any resistance to colonization by the exotic species of *Bursaphelenchus* because native species of this nematode (and their vectors) commonly occur throughout the geographic regions and host ranges just described.

Spread Potential—Very high. Species of *Bursaphelenckus* are commonly found on a wide range of coniferous hosts, though B. *xylophilus* appears to be more pathogenic on some hosts than others. Host specificity for other species of *Bursaphelenchus* is unknown but is likely to exist. However, when these nematodes are feeding on fungi in wood they appear to feed on a large number of different fungal species. Whatever level of host/pathogen specificity that exists should not hinder spread because the species of *Bursaphelenchus* are capable of propagating on a large variety of substrates. These nematodes also have a relatively large number of vector species that may have particular host preference, and this factor should serve to enhance probable spread. See the earlier section on colonization potential for additional discussion of the potential for spread as related to host and geographic range and to environmental factors.

Consequences of Establishment

Economic Damage Potential-ln North America, *B. xylopkilus* is not considered a serious pest of U.S. native conifers. However, some exotic pines (P. *sylvestris, P. nigra,* and *P. thunbergii*) have experienced considerable mortality in certain areas. This mortality has occurred when these tree species have experienced environmental stress such as prolonged drought and associated high temperatures. To date, our native conifers have not experienced this kind of mortality, but they do become infested with the nematode once attacked by some Cerambycidae.

In Japan, the pine wood nematode is considered the most serious pest of native conifers in both forests and landscape settings, especially in the warmer coastal areas. The economic and aesthetic impacts associated with this exotic pest have been very substantial, especially in landscape settings. Forested areas also have been decimated.

In Japan, the overall cost of pest management has been very high, and management options are consequently limited to management of the insect vector. The vector management program requires strict sanitation procedures for *diseased* trees and the application of chemical insecticides to prevent vector feeding on healthy trees. This pest management program has reduced the nematode problem in some areas, but in general it has not been an overall success.

If exotic species or strains of *Bursaphelenchus* spp. were introduced into North America, the outcome of such an introduction would constitute a serious threat to western conifer resources. The nematode experience in Japan, along with experiences in the United States with other pathogens and insect pests, demonstrates the need for concern about the introduction of exotic pests, such as *Bursaphelenchus* spp.

The overall economic impact of exotic pathogenic strains of *Bursaphelenchus* spp. on the forests of North America would be devastating. Also, new strains of the pathogen would most likely emerge due to both the interspecific and intraspecific breeding behavior of this group of nematodes. The potential development of new nematode strains in association with native, established insect vectors is another reason for concern.

Environmental Damage Potential—The experience with *B. xylophilus* in both the Japanese forest and landscape ecosystem clearly demonstrates potential for significant environmental impacts. Many old-growth trees have been destroyed, thus significantly changing ecological succession. Also, environmental damage could result from the application of pesticides for vector control or during the implementation of sanitation procedures. These sanitation procedures require tree removal, and substantial mechanical damage to the site could result.

Perceived Damaged/Social and Political Influences— If new species or strains of *Bursaphelenchus* are introduced to or are developed in North America, our forest industries would face new restrictions (embargoes) on coniferous wood products by importing countries. A number of European countries have placed embargoes on the importation of coniferous wood from countries known to have *B. xylophilus*. These restrictions have reduced U.S. and Canadian timber exports, negatively affecting our forest industries and the working communities they serve. In the long run, these restrictions also will have an impact on our forest management practices. Effects on landscape plantings could make this a local political issue. In addition, effects on Christmas tree growers and nurseries could also be significant and carry additional political implications.

Estimated Risk
The estimated risk for the pine wood nematode is high in all categories.

Larch Canker

Scientific Name of Pest—*Lachnellula willkommii* (Hart.) Dennis (cause of larch canker)
Scientific Name of Host(s)-Affects members of the genus *Larix*: *L. eurolepsis*, *L. laricina*, *L. decidua*, *L. sibiricn*, and *L. occidentalis* Nutt. are rated as highly susceptible, whereas *L. gmelinii* and *L. kaempferi* are less so; closely related species of *Lachnellula* affect *Abies* spp., *Pinus* spp., and probably other species of conifers. *L. willkommii* has been reported on *Pseudotsuga menziesii* planted in Norway.
Specialty Team—Pathology
Assessors-Katharine Parks and Donald J. Goheen

Summary of Natural **History and Basic Biology of the Pest**
Lachnellula willkommii is a Discomycete in the order Helotiales, family Hyaloscyphaceae. It forms apothecia in the centers of young cankers and around the edges of old cankers. Throughout the year these discharge ascospores into the air when moistened by rain. Spores are wind dispersed. Precise sites of new infections are not known but are suspected to be dead branchlets and dwarf shoots. Frost injury may aggravate damage by *L. willkommii*. 1 t is believed that most new infections occur in autumn. The fungus is a good saprophyte and survives for a considerable time in dead wood and bark. The pathogen is alien to North America. *Lachnellula willkommii* is favored by oceanic climates. Its most extensive damage is associated with cool conditions, high humidity, frequent fog formation, and moist soils.

Effect of Pest on Host—*Lachnellula willkommii* causes perennial cankers, usually centered on dead dwarf shoots, twigs on branches, or small-diameter (up to 10 cm) main stems. Cankers are misshapen, swollen, and resin impregnated. Stems are often girdled, resulting in the death of the branch or tree.

Specific Information **Relating to Risk Elements**

Probability of Pest Establishment

Pest With Host at Origin—*Lachnellula willkommii* is widely distributed on larch in Siberia and the Soviet Far East.

Entry Potential—There is a high probability of entry. The fungus survives well as a saprophyte on dead branchlets and in the bark and wood of cankers. It can survive in wood protected from surface disinfection and bark removal. *Lachnellula willkommii* has been introduced at least twice into the Eastern United States and Canada.

Colonization Potential—Presumed to be moderate to high. Climatic conditions should be particularly favorable for the fungus in Washington, Oregon, and northern California. Western larch is a highly susceptible host. Fortunately, however, the natural range of western larch is east of the Cascade Mountains, so wild trees should not be directly exposed to inoculum from imported logs unless such logs are transported from the coast to east-side mills. Ornamental larch are grown on the west side and could be infected and serve as bridges to natural stands of western larch. Colonization of eastern larch has been very widespread following introduction into the Eastern United States and Canada. If the fungus could infect *Pseudotsuga menziesii,* colonization potential would be extremely high.

Spread Potential—Once established, potential to spread should be high. Favorable climate, a highly susceptible host, and fairly extensive, contiguous stands, often containing substantial components of young trees, should be ideal for this fungus. Wind-borne spores allow rapid and extensive spread of *L. willkommii.* An introduction of the pathogen in 1980 has resulted in the establishment of the disease throughout much of Maine and New Brunswick and into Nova Scotia.

Consequences of Establishment

Economic Damage Potential-Economic losses would be considerable if the pathogen is established in western larch stands. Based on experiences in the Eastern United States and Canada, 50 to 100 percent of larch in plantations and young managed stands are infect* and damaged by *L. willkommii* when the fungus is Present.

Environmental Damage Potential—Western larch is an extremely important seral tree species in many plant communities in Oregon, Washington, Idaho, and Montana. If populations were seriously affected by larch canker or if foresters discriminated against larch because of real or perceived management problems associated with the disease, successional tree species, including true fir and Douglas-fir, would probably be favored in management on east-side sites (especially high-elevation sites where pines would not do well). These tree species are much more susceptible to damage by native insect and disease pests than western larch.

Perceived Damage (Social and Political Influences)—There is the possibility of severe damage to omamental larch plantings. Aesthetic effects in natural stands could be substantial but are difficult to assess.

Estimated Risk

The estimated risk for the larch canker is high.

Additional Remarks

To mitigate this pest, a procedure would have to be developed that **could kill** the fungus at some depth in the wood of cankered stems. Treating the bark only is not sufficient.

Spruce Bark Beetle

Scientific Name of Pest-Jps *typographus* L. (spruce bark beetle)
Scientific Name of Host(s)—*Picea* spp., *Pinus* spp., and *Larix* spp.
Specialty Team-Entomology
Assessor-Alan A. Berryman

Summary of Natural History and Basic Biology of the Pest

Ips typographus belongs to the order Coleoptera, family Scolytidae. It breeds in cut logs, windfallen trees, and, during epidemics, standing spruce trees and occasionally other species of conifer (for example, pines and larches). The beetle is found in all areas where spruce grows on the Eurasian continent. Adult beetles bore through the bark of the tree and construct "tuning-fork" shaped galleries in the phloem-cambium layers of the host. During attacks, they inoculate the tissues of the tree with several species of fungi, some of which are extremely pathogenic. In Norway, the most pathogenic species is *Ophiostoma polonica;* living spruce can be killed by mass inoculation of this fungus alone.

During initial attack on a susceptible host, beetles release powerful chemical pheromones that draw other beetles to the attacked tree. This aggregated attack enables the beetles to mass inoculate the tree with pathogenic fungi, which then kill the tree by invading its conducting tissues.

Female beetles lay their eggs in tunnels constructed in the inner bark of dead or dying trees. Larvae hatching from these eggs feed on the phloem and eventually pupate at the end of their mines. All the life stages are located in the inner bark layer (phloem-cambium region) of the tree. Finally, the brood adults bore out of the dead tree and either overwinter or fly to new host material.

Spruce beetles normally complete a single generation each year in the cooler parts of their range but may complete two or even three generations in warmer areas. Adults usually overwinter in the forest litter and duff, but about 10 percent of the brood can be found overwintering within trees.

Spruce beetles most often infest downed trees (for example, logs and windfalls), and in this endemic state do little damage to the forest. On occasion, however, their populations can grow following large windstorms or droughts, and they can then attack and do considerable damage to forested ecosystems. For example, spruce beetle epidemics in Norway in the 1850's and 1970's were preceded by windstorms and accompanied by severe droughts, while the outbreaks in Germany after World War II started in neglected forests damaged by warfare.

Specific **Information Relating to Risk Elements**
Probability of Pest Establishment

Pest *With* Host *at Origin-The* probability of association with raw logs depends on the species of tree. Spruce is the preferred host, followed by pine and then larch. The probability of host association is high for spruce, moderate for pine, and low for larch.

Entry Potential—Given host association, the probability of entry on raw logs is very high because brood larvae and adults can be found under the bark of the host almost all year round; i.e., eggs or larvae can be found in logs all year, but most abundantly in spring and summer. Adults will usually be found in logs in fall and winter but in rather low numbers, because most emerge from logs and overwinter in the litter and duff on the forest floor.

Colonization Potent&--If beetles are introduced into an area containing spruce logs or windfalls, the probability of colonization and establishment would be high. Highest risk would be around ports of entry in Washington, Oregon, northern California, and Alaska where Sitka spruce forests grow along the coasts.

Spread Potential-Spruce beetles are strong fliers and, once established, would be expected to spread rapidly into adjacent spruce forests. For example, native American bark beetles have been found frozen on the glaciers of Mt. Rainier, which demonstrates that they can disperse over the Cascade Range. The rate of spread of bark beetle outbreaks is quite variable. In general, beetles will fly as far as necessary to find suitable hosts. Mass attacks on many trees 30 miles away from a source of beetles have been observed. The rate of spread of spruce beetles is estimated to be from 1 to 30 miles per year, with a mean of approximately 10 miles per year. If established in the spruce forests of Western North America, the beetle would probably spread throughout the Pacific Northwest, eventually, north into Alaska and east to the Atlantic in the contiguous boreal spruce forests.

Consequences of Establishment

Economic Damage Potential—The introduction of *Ips typographus* into the spruce forests of North America could have disastrous consequences. The outbreak in Norway during the 1970's killed 5 million cubic meters of spruce. In addition, the spruce beetle carries one of the most pathogenic conifer fungi known, *Ophiostoma polonica*. If this fungus becomes established in North America, it could also be picked up and transmitted by native *Dendroctonus* spruce beetles. This could be as disastrous to North American spruce as the Dutch elm disease was to elms.

Environmental Damage Potential—Infestation by *I. typographus* could cause replacement of Sitka spruce by western hemlock and hardwoods in coastal areas and replacement of Engelmann spruce by true firs, mountain hemlock, and lodgepole pine at high elevations.

Perceived Damage (Social and Political Influences)—British Columbia has extensive and very valuable Sitka spruce forests. Destruction of these forests by insects or diseases introduced by U.S. interests could have severe political consequences. The possibility of lawsuits by injured parties, including U.S. forest landowners and foreign governments, should be considered. Several spruce species are extensively planted as ornamentals. Damage to homeowners' trees could have considerable political ramifications.

Estimated Risk

Because of economic, social, and political damage potential of the introduction of *Ips typographus* and its associated fungi, particularly *Ophiostoma polonica,* into North America, the estimated risk must be considered extremely high in raw (unpeeled) spruce logs, high in unpeeled pine logs, and moderate in unpeeled larch logs.

Annosus Root Disease

Scientific Name of Pest—*Heterobasidion annosum* (Fr.) Bref. (=*Fomes annosus)* cause of annosus root disease.
Scientific Name of Host(s)-This fungus 'has been reported on virtually all conifers and many hardwoods in the Northern Hemisphere. Different strains of the fungus exist that are specific to certain hosts or host groups.
Specialty Team-Pathology
Assessors-Donald J. Goheen and William J. Otrosina

Summary **of Natural History and Basic Biology of the Pest**

Heterobnsidion annosum belongs to the division Eumycota, subdivision Basidiomycotina, class Hymenomycetes, order Aphyllophorales, and family Polyporaceae. Basidiocarps (conks) of *H. annosum* develop in hollow stumps, root crotches, hollows in logs, on the outsides of trees or stumps near ground level, or on the undersides of windthrown trees. Basidiospores are released throughout the year (fewer during particularly cold or warm periods) and are dispersed over long distances (100 miles or more) by the wind. Spores that land on freshly cut stump surfaces or fresh wounds germinate, and the fungus colonizes the tree or stump (Rishbeth, 1951; Yde-Andersen, 1962; Cobb and Barber, 1968). Subsequently, the pathogen can grow via root contacts into surrounding hosts, creating gradually expanding disease foci (Hadfield et al., 1986; Sinclair et al., 1987; Otrosina and Cobb, 1989). In addition to basidiospores, *H. annosum* has an asexual conidial spore state, designated as *Spiniger meineckellus.* Asexual spores can also initiate infections (Kuhlman and Hendrix, 1964; Kuhlman, 1969; James et al., 1980). Asexual spores are readily produced on damp, decayed wood and may be dispersed by water and perhaps insects (Hunt and Cobb, 1982). Wind dispersal by this spore stage is not believed to be nearly as effective as that of basidiospores, but there is evidence that it does occur (Shaw and Florance, 1979; Florance and Shaw, 1988).

Heterobasidion annosurn is a heterothallic fungus. Individual basidiospores of the fungus, upon germination, give rise to homokaryotic mycelia (multinucleate cells with haploid nuclei). Homokaryotic mycelia are self-sterile and do not differentiate to form a basidiocarp. Mating must take place between two sexually compatible homokaryotic mycelia to form a dikaryon (which has cells with n+n nuclear condition) prior to mitotic division and formation of a sexual fruiting body. There are several subpopulations of morphologically identical but genetically different strains within the species *H. annosum* (Chase, 1989). These strains cannot be distinguished on the basis of appearance, but they are intersterile and will not form dikaryons with each other. They also differ markedly in pathogenicity and host range. In Europe, "P," "S," and "F" strains have been identified that are quite specific to pines, spruce, and true firs, respectively (Korhonen, 1978; Korhonen et al., 1988). In North America, a "P" strain that affects pines and an "S" strain that affects mainly true firs and hemlocks have been identified (Chase, 1989; Chase et al., 1989). European and North American strains differ. Identities of *H. annosum* strains from Siberia and the Soviet Far East are not known. They may differ from all strains that have been studied to date.

Effect of Pest on Host-Heferobasidion annosum affects host trees in two ways, either by causing outright mortality or by causing progressive butt and stem decay. Generally, among North American hosts infected by native strains of *H. annosurn,* pines are killed fairly rapidly, while hemlocks develop butt rot and true firs exhibit both kinds of damage (Sinclair et al., 1987; Hadfield et al., 1986; Schmitt, 1989). The literature suggests that the strain or strains of *H. annosum* that occur in Siberia and the Soviet Far East cause Jnortality of *Abies, Picea, Pinus,* and *Larix* spp., with the latter being somewhat less severely damaged than the other three (Davidenko and Nevzorov, 1978; Korotkov, 1978). *Heterobasidion annosum* also causes butt rot in *Picea* spp. (Fjodorov and Poleschuk, 1978) and old-growth *Larix* spp. (Rozhkov, 1966).

Specific Information Relating to Risk Elements
Probability of Pest Establishment

Pest With Host at Origin—*Heterobasidion annosum* is reported to be widely distributed on *Larix, Picea, Abies,* and *Pinus* spp. in Siberia and the Soviet Far East (Rozhkov, 1966; Negrutsky, 1975). It is also reported to be one of the most damaging tree diseases of the Soviet Union. According to Negrutsky, "On the territory of the U.S.S.R., *H. annosum* is one of the most dangerous and widespread pathogens which, at the same time, is encountered in the forests of the Baltic Republics-in Estonia, Latvia, Lithuania, and in the forests of Byelorussia, the Ukraine, in the central region of the R.S.F.S.R., the Urals, Siberia, Kazakhstan, and it may be characterized by the concept of epiphytation."

Entry Potential—Entry potential for *H. annosum* is very high. Infected logs would be difficult to detect and discriminate against at logging or shipping sites. Incipient decay of H. *annosum,* in particular, is difficult to distinguish, but even conks on infected trees could be missed because of their cryptic appearance and inconspicuous nature. *Heterobasidion annosum* is an excellent saprophyte that can survive for 10 to 60 years in old stumps (Sinclair et al., 1987). Survival periods in logs would be shorter but still substantial, especially if logs were shipped and stored in moist, cool environments. Survival times of the fungus in large logs would be greatest. To effectively deal with H. *annosum,* a mitigation treatment would have to kill fungal mycelia in the center of logs. If untreated H. *annosum*-colonized logs are delivered to ports in northern California, Oregon, and Washington, the likelihood of spore production would be high. It is possible that conks already present on or in logs before shipment or that develop on logs subsequently during storage would produce basidiospores. A much more likely scenario, however, is that the *Spiniger* form of the fungus would develop on logs or wood and bark scraps and release asexual spores.

Colonization Potential—Colonization potential would be high. Suitable hosts and sites for initial infections (stumps, wounded trees) are common in the vicinities of the proposed ports of entry. Though the various strains of *H. annosum* exhibit host specificity, it is usually at the level of genera rather than species, and some strains affect several genera. Given the similarity of conifer genera in the Eastern Soviet Union and Western United States, it is almost certain that *H. unnosum* strains that are capable of infecting *Larix, Pinus, Abies,* and *Picea* spp. in Siberia and the Soviet Far East could infect members of the same genera in the Western United States. It is also possible that an introduced strain could affect other hosts here. For example, seedling inoculation tests suggest that *Pseudotsuga menziesii* is very susceptible to a strain of *H. annosum* from pine in Scandinavia, according to a personal communication with E. M. Hansen.

Spread Potential—If established, the potential for H. *unnosum* to spread is high. Basidiospores from sexual fruiting bodies are wind dispersed, giving the fungus an extremely dangerous ability to spread far and rapidly. Asexual spore spread would probably cover much shorter distances, but there is the 'possibility of insect-vectored spread and some wind dispersal with this spore stage as well. Spread from tree to tree via mycelial growth across roots occurs at a rate of 1 to 2 feet per year.

Consequences of Esfablishtnent

Economic Damage Potential—The amount and type of economic damage associated with *H. unnosum* from the Eastern Soviet Union would largely depend on whether the strain or strains of the fungus introduced were the same as native North American strains. If the same, there would probably be little or no increase in amount of H. *annosum*-caused tree mortality or decay. If a different strain were introduced, however, increased damage would be very likely and would take one of two forms: (1) increased killing or decay in a host genus or species that is already affected by *H. unnosum* in the Western United States; or (2) mortality or decay in a host not previously damaged by *H. unnosum.* Relative to this second scenario, the possibility of introducing a strain of the fungus that would be damaging to *Pseudotsuga menziesii* or *Larix occidentalis* in the Pacific Northwest would be of special concern.

Obviously, a comparison of the strains of *H. unnosum* from the Eastern Soviet Union and the Western United States is key to a definitive assessment of risk associated with importing infected logs. To date, there has been no effort to do this. In the absence of this research information, there is reason for caution because forest pathologists who have studied the genetics of H. *annosum* in other parts of the world believe that there is a high probability that strain differences exist, and the little existing literature indicates that the pathogen acts more aggressively in the Soviet Union than in the United States. The research necessary to answer this critical question should be done before unprocessed logs are allowed entry into the United States.

The magnitude of wood losses caused by native strains of *H. annosum* in the Western United States varies. Loss due to decay in young *Tsuga heterophylla* stands has been measured at approximately 1 to 3 percent of the volume (Goheen et al., 1980; Littke and Browning, 1989); however, in stands over 180 years old it may be as high as 25 to 50 percent (Buckland et al., 1949; Foster et al., 1954). Loss due to mortality in *Pinus ponderosa* stands ranges from 3 to 20 percent of the basal area on especially dry sites (Goheen and Goheen, 1989). Losses reported in managed *Abies concolor* stands ranges from 0.5 to 27 percent of the trees (Goheen and Goheen, 1989). Associated basal area losses were from 0 to 50 percent. In the Pacific Coast States, H. *annosum* is rarely found on *Pseudotsuga menziesii* and *Larix occidentalis* and causes virtually no damage to these species. This could change with the introduction of new strains of the fungus. When considering economic implications of annosus root disease, it should be noted that chemical control (stump infection prevention) is possible. Cost of stump treatment is about $0.75/stump. Effectiveness of control is believed to be about 95 percent.

There is some question about the future environmental suitability of chemical stump treatment.

Environmental Damage Potential-Because the tree killing strains of *H. annosum* tend to cause mortality of one or several closely related genera or species and because killing tends to occur in radially expanding infection centers, the pathogen could be responsible for tree species shifts. The type or magnitude of any such shift cannot be predicted without additional information on specific fungus strains and hosts that might be involved.

Perceived Damage (Social and Political Influences)—Depending on the strain of the fungus introduced, H. *annosum* could have significant impacts on omamental plantings, nurseries, and Christmas tree plantations.

Estimated Risk

The estimated risk for annosus root disease is high.

Chapter 5
Economic Effects Evaluation

Introduction

Oregon, Washington, and northern California are major exporters of timber, agricultural, and fish products. The regional economy is diversifying to some extent; however, these natural resources will continue to be a significant part of the area's employment and commerce.

Forest products remain the core of the Pacific Northwest regional economy, and directly account for 44 percent of Oregon's income and 28 percent of Washington's. Forest products of the inland West play a lesser, yet significant role in their regional economies. Conifers constitute California's major timber resource. From 1977 to 1981, the State's commercial forests yielded an average of 3.5 billion board feet of timber with a value of almost $621 million. Softwood log exports from Washington, Oregon, northern California, and Alaska totaled 3370,444 thousand board feet in 1989. The average value for those logs varied from $443.71 per thousand board feet in Washington to $632.71 per thousand board feet in Oregon. If the introduction of exotic pests causes an international embargo on logs from the Western United States, the economy of these States will be severely affected.

These forest lands, both public and private, are among the most productive in the world. About 76 percent of the forested land in the Pacific Northwest has a timber productivity of at least 20 cubic feet per acre per year. Approximately 85 percent of this acre age is currently available for regulated timber management and represents approximately 65 percent of the total national forest land in the Pacific Northwest region.

Lands west of the Cascades constitute the Douglas-fir subregion, while the lands to the east are part of the ponderosa pine subregion. The two subregions differ markedly in their timber production. The Douglas-fir subregion is the more productive, with 43 percent of the Douglas-fir subregion yielding more than 120 cubic feet per acre per year, while only 7 percent of the ponderosa pine subregion is in this class. Yet even with its lower productivity, the ponderosa pine subregion is still valuable timber producing land, vital to the local economy.

This chapter presents the economic evaluations of infestations of defoliator insects, pine wood nematodes, larch canker, spruce bark beetles and annosus root rot developed by separate teams during the second workshop. The following analyses estimate the potential economic costs to the commercial timber resources of the Western United States from. each pest and disease group evaluated in Chapter 4. The following factors should be considered:

(1) Each pest group was analyzed independently, and the economic costs were developed in isolation from other potential economic costs caused by other introduced pests. The sum total of economic costs of individual pest groups may not produce a valid estimate of the total costs from introduction of all the pest groups considered because:

(a) Many of the'host trees may be simultaneously attacked by several other introduced pests and it would be impossible to estimate what proportion of host type mortality is attributed to a particular pest. Similarly, it would be impossible to allocate growth loss estimates to each group of pests. In this context, summing up the economic costs of each group may overestimate the total economic costs from a simultaneous introduction of pests since a tree only dies once.

(b) Simultaneous attack on host types may also increase mortality rates and growth losses through the synergistic effect of multiple attacks. In this context, summing up the economic costs of each pest group may underestimate the total economic costs from a simultaneous introduction of all or some of the pests considered in this analysis.

(2) There are various assumptions made for each group of pests analyzed. To determine the assumptions, one should refer to each separate pest group analysis. Each economic analysis may use different, yet acceptable, economic methodologies to segregate problems through the use of the team approach. The use of different methodologies makes summation of

economic impacts from individual pest groups a problem.

(3) The separate analysis of pest groups is considered a useful approach for the Animal and Plant Health Inspection Service (APHIS) management practices assessment, particularly when a given mitigation measure is effective for only one or a few groups of pests. The residual effect of the unmitigated pest(s) may be more clearly illustrated when viewed according to independent behavior. This approach may also allow the placement of values on benefits gained for each mitigation measure under consideration.

(4) Analysis of each pest group considered unreserved forests (all ownerships, both public and private) in the Western United States at risk. Potential additions to forest reserves that are being considered for withdrawal or modified management to provide habitat for threatened species were considered in this analysis. If significant reserves are eventually withdrawn, this may significantly decrease the cost figures given below.

(5) It is recognized that control costs for eradication of infestations would be an expected occurrence for epidemics of introduced pests. However, these costs were not considered in the analyses because of: (a) uncertainty about efficacious treatments for introduced pests, (b) uncertainty of optimal funding levels thus affecting efficacy of control efforts, and (c) uncertainty of public acceptance of pesticide use.

Defoliator Insects

Summary

The following ranges display a best case and worst case scenario for damage caused by the introduction of defoliators. Worst case damages are $58.41 billion, assuming a net growth loss of 25 percent per decade. Best case damages are $35.05 billion, assuming a 15-percent net loss in growth per decade.

Economic Analysis

The market effects of defoliators were estimated in a supply and demand context for three regions-the Pacific Northwest, Pacific Southwest, and the Rockies-using derived demand and stumpage supply functions from the 1989 Resources Planning Act (RPA) Timber Assessment (Haynes, 1990). The Alaskan region was investigated early in the study, but was omitted from the published results because of the extreme time frame required for defoliators to spread to Alaska (more than 90 years).

The method decreases the stumpage supply functions (from the 1989 RPA Timber Assessment, (Haynes, 1990)) by the amount of the change in softwood growing stock inventories from reduced forest growth. This approach was adopted because inventory levels are one of the main determinants of stumpage supply. Mortality is reflected in the stumpage supply functions. Changes in inventories act to shift stumpage supply functions in the long& term, while price changes help establish supply levels in the near term. These changes in inventories were computed using a growth drain identity, and the supply functions were shifted by the ratio of base inventory (that is, without defoliators) to the modified inventory.

Among the assumptions employed in this analysis of the economic impacts of defoliators were the following factors:

(1) Basic loss data as given in Appendix J (Data Table for Calculations of Potential Impacts). It is assumed to result in a 15-percent net loss in growth per decade.

(2) Spread rate is assumed to be 20 kilometers/year. Spread rates for each region are assumed (moving from west to east) as follows:

Year	Percent of Spread		
	PNW	PSW	Rockies
1990	0	0	0
2000	45	53	0
2010	91	100	0
2020	I 00	100	44
2030	100	100	100
2040	100	100	loo

(3) Harvest fractions by timber type (information derived from tables 15 and 29 in Waddell et al., 1989).

Area	Percent of Harvest				
	Douglas-Fir	Fir/Spruce	Hemlock	Larch	Other Softwood
PNW	48.1	13.0	19.3	1.8	17.8
PSW	27.4	27.4	0.2	0.0	45.0
Rockies	22.9	28.8	1.0	4.9	42.3

(4) Average reduction in net growth (computed from assumptions 1 and 3):

Year	Percent of Reduction		
	PNW	PSW	Rockies
1990	0.0	0.0	0.0
2000	6.0	6.8	0.0
2010	12.2	12.8	0.0
2020	13.4	12.8	5.9
2030	13.4	12.8	13.5
2040	13.4	12.8	13.5

(5) Effect of growth reductions on softwood growing stock inventories (that is, the ratio of RPA figures to those modified for changes in growth shown above) areas as follows (inventory figures computed using the growth drain identity $I_t = I_{t-1} + G_t - H_t$):

Year	Growth Reductions		
	PNW	PSW	Rockies
1990	1.0	1.0	1.0
2000	0.986	0.988	1.0
2010	0.958	0.967	1.0
2020	0.927.	0.949	0.992
2030	0.896	0.932	0.975
2040	0.865	0.918	0.961

Where I_t = current year inventory, I_{t-1} = previous year inventory, G_t = current year growth, H_t = current year harvest.

Economic Impacts

Economic impacts were compiled by: (1) computing the equilibrium price and quantity by decade and by region, and then (2) recomputing the modified equilibrium price and quantity following a shift in the stumpage supply functions, assumed to be induced by changes in growing stock inventories. Basic economic impacts are slow to develop and depend on the extent to which lower growth reduces inventories and hence timber supplies.

The impacts are the largest in the Pacific Northwest with effects eventually reaching the Rockies (see, for example, the differences in stumpageprices shown in table S-l). The different rates of impact among the three regions reflect both the differences in growth impacts and the rate of spread.

The largest effect is on producers of forest products, who, for example, lose roughly one-half their potential gains in the year 2020. Consumers are much less affected, losing less than 4 percent of their potential gains. The reason for this disparity is the possibility that production in unaffected regions will offset lost production in the West.

This analysis makes no explicit assumption about salvage except to the extent that the demand for some product demands (fuelwood) is often filled by using dead material. In much of the West, fuelwood becomes the only market after tree mortality. Much of the dead material remains in the woods, where it may contribute to non-commodity products. When dead or dying material is salvaged, it is often sold on a per-unit basis at base rates.

This assumption causes stumpage prices to rise, increasing returns to stumpage owners, although this increase is slight in the next decade in the Pacific Coast States. Stumpage price increases in the Rockies are slower to develop because a lower rate of spread is assumed.

All of these analyses assume independence of events among the regions. Taking such direct effects into account would alter the results, as stumpage price increases in one region would shift production to unaffected regions. One further caveat: much of the timber harvest in the West comes from public timberlands where harvest levels are set using harvest scheduling algorithms that would attempt to reduce harvest levels as net growth fell.

The following table summarizes price, quantity, and welfare impacts from reduced growth with the introduction of defoliators and without the introduction of defoliators.

Table 5-1. Price, Quantity, and Welfare Impacts of Reduced Growth Caused by Defoliators, Best Case Scenario

Prices
(1967$/MBF)

	With Defoliators			Without Defoliators		
Year	PNW	PSW	RM	J'NW	PSW	KM
2000	**49.40**	**46.48**	19.21	48.17	45.81	18.84
2010	75.02	63.64	45.76	71.41	61.78	45.42
2020	89.35	82.07	61.92	84.42	79.52	60.07
2030	91.58	85.81	68.62	85.19	82.75	62.63
2040	91.13	85.98	71.58	83.07	82.51	62.48

Quantities
(million cubic feet)

	With Defoliators			Without Defoliators		
Year	I'NW	PSW	KM	PNW	PSW	KM
2000	2,548.65	628.53	835.13	2,557	633	834
2010	2,667.43	625.73	919.82	2,684	636	919
2020	2,707.85	583.50	947.16	2,737	598	950
2030	2,761.26	551.27	941.09	2,799	568	951
2040	2,761.86	511.71	940.51	2,804	530	958

Welfare Impacts-Without Defoliators
(millions 1967 $)

	Consumer Surplus			Producer Surplus		
Year	J'NW	J'SW	KM	PNW	PSW	KM
2000	2,352.65	163.76	740.37	534.42	129.85	76.44
2010	2,645.13	171.54	924.09	773.60	172.17	197.26
2020	2,823.84	156.51	1'019.54	880.57	199.49	267.08
2030	3,045.08	140.33	1,055.66	890.93	191.88	279.43
2040	3,149.28	132.66	1,111.57	921.61	176.20	281.98

With Defoliators
(millions 1967 $)

Year	PNW	PSW	KM	PNW	PSW	KM
2000	2,336.55	161.64	740.38	543.78	130.57	78.01
2010	2,604.39	165.65	924.07	524.57	126.43	83.46
2020	2,760.70	148.99	1,01 2.07	4Y8.85	112.52	84.95
2030	2,959.85	138.47	1,030.80	404.21	103.00	84.25
2040	3,046.27	**123.72**	1,070.38	**485.83**	**94.08**	**84.29**

PNW=Pacific Northwest, PSW=Pacific Southwest, RM=Rocky Mountain Regions of the USDA Forest Service.

Table 5-2. Net Welfare Impacts Resulting From Defoliators in Millions of 1967 Dollars, Best Case

Year	Consumer Surplus			Producer Surplus			Net Welfare Effects	NWE PNV
	PNW	PSW	RM	PNW	PSW	RM		
2000	16.10	2.12	-0.01	-9.36	- 0.72	-1.57	6.56	6.56
2001	18.56	2.50	-0.01	16.48	3.93	9.97	51.43	49.45
2002	21.03	2.87	-0.00	42.32	8.57	21.50	96.29	89.03
2003	23.49	3.25	-0.00	68.16	13.22	33.04	141.16	125.49
2004	25.96	3.63	0.00	94.00	17.86	44.58	186.02	159.01
2005	28.42	4.01	0.01.	119.83	22.51	56.12	230.89	189.77
2006	30.88	4.38	0.01	145.67	27.16	67.65	275.76	217.93
2007	33.35	4.76	0.01	177.13	32.23	80.13	327.61	248.96
2008	35.81	5.14	0.01	197.35	36.45	90.73	365.49	267.06
2009	38.28	5.51	0.02	223.19	41.09	102.26	410.35	288.31
2010	40.74	5.89	0.02	249.03	45.74	113.80	455.22	307.53
2011	42.98	6.05	0.77	262.30	49.86	120.63	482.59	313.48
2012	45.22	6.22	1.51	275.57	53.99	127.47	509.97	318.52
2013	47.46	6.38	2.26	288.84	58.11	134.30	537.34	322.71
2014	49.70	6.54	3.00	302.11	62.23	141.13	564.71	326.11
2015	57.94	6.71	3.75	315.38	66.36	147.96	592.08	328.76
2016	54.18	6.87	4.49	328.64	70.48	154.80	619.46	330.73
2017	56.42	7.03	5.24	341.91	74.60	161.63	646.83	332.07
2018	58.66	7.19	5.98	355.18	78.72	168.46	674.20	332.81
2019	60.90	7.36	6.73	368.45	82.85	175.30	701.58	333.00
2020	63.14	7.52	7.47	384.72	86.97	182.13	728.95	332.68
2021	65.35	7.85	9.21	383.22	87.16	183.44	736.23	323.08
2022	67.56	8.19	10.95	384.72	87.35	184.74	743.51	313.73
2023	69.77	8.52	12.69	386.22	87.54	186.05	750.78	304.61
2024	71.98	8.86	14.43	387.72	87.73	187.35	758.06	295.74
2025	74.19	9.19	16.16	389.22	87.92	188.66	765134	287.09
2026	76.39	9.52	17.90	390.72	88.12	189.96	772.62	278.67
2027	78.60	9.86	19.64	392.22	88.31	191.27	779.90	270.48
2028	80.81	10.19	21.38	393.72	88.50	192.57	787.17	262.50
2029	83.02	10.53	23.12	395.22	88.69	193.88	794.45	254.74
2030	85.23	10.86	24.86	396.72	88.88	195.18	801.73	247.19
2031	87.01	10.67	26.49	400.63	88.20	195.43	X08.43	239.67
2032	88.79	10.48	28.13	404.53	87.53	195.68	815.13	232.36
2033	90.56	10.28	29.76	408.44	86.85	195.93	821.83	225.26
2034	92.34	10.09	31.39	412.34	86.18	196.18	828.53	218.36
2035	94.12	9.90	33.02	416.25	85.50	196.44	835.23	211.66
2036	95.90	9.71	34.66	420.16	84.82	196.69	841.93	205.15

Table 5-2. Net Welfare Impacts Resulting From Defoliators in Millions of 1967 Dollars, Best Case (continued)

Year	Consumer Surplus PNW	Consumer Surplus PSW	Consumer Surplus RM	Producer Surplus PNW	Producer Surplus PSW	Producer Surplus RM	Net Welfare Effects	NWE PNV
2037	97.68	9.52	36.29	424.06	84.15	196.94	848.63	198.83
2038	99.45	9.32	37.92	427.97	83.47	197.19	855.33	192.69
2039	101.23	9.13	39.56	431.87	82.80	197.44	862.03	186.73
2040	103.01	8.94	41.19	435.78	82.12	197.69	868.73	180.95
Total PNV 1967 $								10,144.17
Total PNV 1990 $								35,048.70

Notes:
PNW=Pacific Northwest, PSW=Pacific Southwest, RM=Rocky Mountain Regions of the USDA Forest Service.

The scenario for table 5-2 is the best case scenario analysis of 15 percent growth reduction per decade. The worst case scenario is 25 percent reduction in growth per decade.

Consumer/Producer Surplus (net welfare impacts)-Net consumer and producer surplus impacts were derived from table 5-l by determining the difference between consumer and producer surplus with and without defoliators. Impacts between decades were derived by simple linear interpolation.

NWE = Net welfare effects--Consumer surplus plus producer surplus.

Net welfare effects (PNV)—a discount rate of 4 percent was used. Net welfare effects are then expressed in 1990 dollars by using Producer Price Index multiplier from "Economic Report of the President, 1991."

Pine Wood Nematodes

Summary
The following ranges display a best case/worst case scenario of potential damage caused by the introduction of the pine wood nematode. Worst case damages are $1.67 billion, for an assumed mortality rate of 100. percent. The best case damages are $33.35 million, for an assumed mortality rate of 2 percent.

Economic Analysis
In the following sections, we analyze the cash flow from timber harvest by assuming pathogenic infestation and concomitant salvage operations net of stand conversion costs and cash flows from timber harvest and the residual stand value without infestation. For the sake of simplicity, we analyzed only the 100 percent mortality case. The other scenarios can be scaled down under an assumption of linear and proportional relationships.

Assumptions
(1) Vectors native to the United States will effectively transmit introduced nematodes. Vectors introduced to the United States (*Monochamus*) may be even better vectors but are not necessary for disease development.

(2) The introduced nematode, whether it is *Bursaphelenchus xylophilus, B.* mucronafus, or *B. kolymensis,* will be pathogenic. Although the nematode occurs in many conifer genera, only the pines are damaged. We assume that only one species, ponderosa pine and its close relative Jeffrey pine, are as susceptible as the Japanese pines. However, the possibility that an introduced nematode could affect other genera of conifers or other pines cannot be excluded.

(3) Within 25 years of introduction, the nematode would be established throughout the western conifer region and as far east as the Great Plains.

(4) Based on the Japanese experience, susceptible species could be eliminated in as little as 10 years. Thus, within 35 years of introduction (10 years after it is established throughout the region), all

ponderosa and Jeffrey pine, pole sized and larger, would be killed. Several **other scenarios are possible:**

a. all ponderosa and Jeffrey pines killed;
b. 50 percent of ponderosa and Jeffrey pines killed;
c. 10 percent of ponderosa and Jeffrey pines killed;
d. 2 percent of ponderosa and Jeffrey pines killed.

Mortality and premature harvest are the primary components of examined loss; growth loss and defects are not important or can be minimized with prompt salvage.

Justification for Assumptions

(1) *Monochamus* spp. present in the United States are demonstrated vectors of *Bursaphelenchus xylophilus* and *B. mucronatus,* which are also endemic. There is no reason to expect that they would not be as effective in transferring nematodes of the same or closely related species.

(2) Because these are closely related nematodes—*B. xylophilus* and *B. mucronatus* are capable of mating, and there is a "mucronate" form of *B. xylophilus*-the standard taxonomic classification of the organisms tends to minimize the potential for reproduction and spread.

Although B. *xylophilus* is at most a weak pathogen in the United States, causing minimal losses if any, the nematode presents a more substantial threat in other nations, including some where it is already present. Considering that it already causes serious damage in Japan, and that nematodes imported from Japan will mate with those in the United States, it is reasonable to assume that a similar nematode (or even a different subspecies) introduced from the Soviet Union could become a formidable pathogen in this country.

Although the wilt disease can be initiated in seedlings of many species, in the United States the disease has been reproduced only in larger trees-Scotch pine and slash pine. Tests on seedlings are thus poor indicators of mature plant susceptibility.

(3) In Japan, the nematode spreads about 20 miles per year. Potential spread is more rapid when transport of logs and firewood is a contributing factor. By the time the nematode damage is discovered, movement of logs and firewood will have established infestations well beyond the damaged area.

(4) The nematode **is** a beetle-vectored wilt disease, **similar** to Dutch elm disease. We believe that movement of logs will be a major factor in the spread of the nematode and any introduced vectors. *Monochamus* introduced in imported logs will quickly infest domestic log decks. Thus, it is not just the movement of imported logs that poses a risk for the spread of an introduced nematode.

Economic Impacts

The economic analysis is summarized in tables 5-3 through 5-6. Table 5-3 shows the rate of spread and the rate of mortality over 10 years, both in terms of acres and volume. Note the implicit assumption of constant volume per acre, made in the interest of simplicity. Table S-4 translates the data in table 5-3 into current-year market values and their present-value counterparts. Table 5-5 presents the current value of stand conversion costs after nematode infestation and table 5-6 contains present value analyses without nematode infestation. Table values were computed using the following assumptions:

(1) An exponential rate of spread of the infestation of approximately 2.8 percent per year was assumed, such that the entire ponderosa-Jeffrey pine region is infested in 25 years.

(2) The same spread rate of mortality after a 10-year period of incubation was assumed. Thus, at 100 percent mortality, the entire inventory of this timber type will be gone in 35 years.

(3) The inventory was assumed to be salvaged within 1 year of mortality as it occurs, and that stand conversion to species resistant to the nematodes takes place concurrent with salvage operations.

(4) Total area of this timber type throughout the western conifer region of 26,645,000 acres with a total volume of 192,065,000 MBF was assumed (USDA, 1982).

(5) The normal annual harvest without infestation was assumed to be 4.267 billion board feet, equal to the annual rate of growth of the residual stand. This represents a growth rate of approximately 2.22 percent per year, which is a reasonable

Table 5-3. Volume of Pine Mortality (MBF) Based on Acres of Ponderosa Pine Timberlands Infected by Pathoge
Hypothetical Introduction in Imported Siberian Logs

Year	1+% of Area	% of Area Infected	Total Acres Infected	Annual Acres Infected	Ave
					Current Y Pine Mort 100%
1	1.028113827	0.028113827	749,093	749,093	
2	1.057018041	0.057018041	1,519,246	770,153	
3	1.086734863	0.086734863	2,311,050	791,805	N
4	1.117287138	0.117287138	3,125,116	814,065	N
5	1.148698355	0.148698355	3,962,068	836,952	N
6	1.180992661	0.180992661	4,822,549	860,482	N
7	1.214194884	0.214194884	5,707,223	884,673	N
8	1.248330549	0.248330549	6,616,767	909,545	N
9	1.283425889	0.283425898	7,551,883	935,116	N
10	1.319507911	0.319507911	8,513,288	961,405	N
11	1.356604327	0.356604327	9,501,722	988,434	74
12	1.394743666	0.394743666	10,517,945	1,016,223	77
13	1.433955248	0.433955248	11,562,738	1,044,793	79
14	1.474269217	0.474269217	12,636,903	1,074,166	81
15	1.515716567	0.515716567	13,7412,68	1,104,365	83
16	1.558329159	0.558329159	14,876,680	1,135,413	86
17	1.602139755	0.602139755	16,0440,14	1,167,333	88
18	1.647182035	0.647182035	17,244,165	1,200,152	90
19	1.693490625	0.693490625	18,478,058	1,233,892	93
20	1.741101127	0.741101127	19,746,640	1,268,582	96
21	1.790050142	0.790050142	21,050,886	1,304,247	98
22	1.840375301	0.840375301	22,391,800	1,340,914	1,0
23	1.892115293	0.892115293	23,770,412	1,378,612	1,0
24	1.945309895	0.945309895	25,187,782	1,417,370	1,0

Table 53. Acres of Ponderosa Pine Timberlands Infected by Pathogenic Nematodes After Hypothetical In (continued)

Year	1+% of Area	% of Area Infected	Total Acres Infected	Annual Acres Infected	Curr Pine 1
25	2	1	26,645,000	1,457,218	
26	N.A.	N.A.	N.A.	N.A.	
27	N.A.	N.A.	N.A.	N.A.	
28	N.A.	N.A.	N.A.	N.A.	
29	N.A.	N.A.	N.A.	N.A.	
30	N.A.	N.A.	N.A.	N.A.	
31	N.A.	N.A.	N.A.	N.A.	
32	N.A.	N.A.	N.A.	N.A.	
33	N.A.	N.A.	N.A.	N.A.	
34	N.A.	N.A.	N.A.	N.A.	
35	N.A.	N.A.	N.A.	N.A.	
Totals					

N.A. = Not available.

Table 5-4. Economic Analysis of Pine Wood Nematode Infestation

Year	% Inventory Affected	Total MBF Affected	Annual MBF Affected	Market Val. 1986 Prices (@ $141 MBF)	(Includ Befo
					PV Fact
				---$MILLIONS---	
1	0.028113827	5,399,682	5,399,682	601.6	1.04
2	0.057018041	10,951,170	551,488	601.6	1.0816
3	0.086734863	16,658,731	5,707,561	601.6	1.124864
4	0.117287318	22,526,754	5,868,023	601.6	1.169859
5	0.148498355	28,559,750	6,032,995	601.6	1.216653
6	0.180992661	34,762,356	6,202,606	601.6	1.265319
7	0.214194884	41,139,340	6,376,985	601.6	1.315932
a	0.248330549	47,695,607	6,556,266	601.6	1.368569
9	0.283425898	54,436,195	6,740,588	601.6	1.423312
10	0.319507911	61,366,287	6,930,092	601.6	1.48024
11	0.356604327	68,491,210	7,124,923	761.4	1.53945
12	0.394743666	75,816,442	7,325,232	782.8	1.60103
13	0.433955248	83,347,615	7,531,172	804.8	1.66507
14	0.474269217	91,090,517	7,742,903	827.4	1.73167
15	0.515716567	99,051,102	7,960,585	850.7	1.80094
16	0.558329159	107,235,490	8,184,388	874.6	1.872981
17	0.602139755	115,649,972	8,414,482	899.2	1.94790
18	0.647182035	124,301,017	8,651,045	924.4	2.02581
19	0.693490625	133,195,277	8,894,259	950.4	2.10684
20	0.741101127	142,339,588	9,144,311	977.1	2.1911
21	0.790050142	151,740,980	9,401,393	1,004.6	2.2787
22	0.840375301	16,1,406,682	9,665,702	1,032.9	2.3699

Table 5-4. Economic Analysis of Pine Wood Nematode Infestation (continued)

Year	% Inventory Affected	Total MBF Affected	Annual MBF Affected	Market Val. 1986 Prices (@ $141 MBF)	(Includes Normal Cash Flow Before Mortality Starts) PV Factor	Present Value
				---$MILLIONS---		
23	0.802115293	171,344,124	9,937,442	1061.9	2.464716	430.8
24	0.945309895	181,560,945	10,216,821	1091.7	2.563304	425.9
25	1	192,065,000	10,504,055	1122.4	2.665836	421.0
26	N.A.	SUM=	192,065,000	1154.0	2.772470	416.2
27	N.A.	N.A.	N.A.	1186.4	2.883369	411.5
28	N.A.	N.A.	N.A.	1219.8	2.998703	406.8
29	[illegible]	N.A.	N.A.	1254.1	3.1185[illegible]	402.1
30	N.A.	N.A.	N.A.	1289.3	3.243398	397.5
31	N.A.	N.A.	N.A.	1325.6	3.373133	393.0
32	N.A.	N.A.	N.A.	1362.9	3.508059	388.5
33	N.A.	N.A.	N.A.	1401.2	3.648331	384.1
34	N.A.	N.A.	N.A.	1440.6	3.794316	379.7
35	N.A.	N.A.	N.A.	1481.1	3.946039	375.3
Totals						14,687.9

Table 5-5. Current Value of Stand Conversion Costs After Nematode Infection

Year	Annual Acres Treated	Stand Reestablish Cost @ $200 /Acre	PV Factor	Present Value (Million 5)
1	N.A.	N.A.	1.04	N.A.
2	N.A.	N.A.	1.0816	N.A.
3	N.A.	N.A.	1.124864	N.A.
4	N.A.	N.A.	1.169859	N.A.
5	N.A.	N.A.	1.216653	N.A.
6	N.A.	N.A.	1.265319	N.A.
7	N.A.	N.A.	1.315932	N.A.
8	N.A.	N.A.	1.368569	N.A.
9	N.A.	N.A.	1.423312	N.A.
10	N.A.	N.A.	1.480244	N.A.
11	749,093	149.8	1.539454	97.3
12	770,153	154.0	1.601032	96.2
13	791,805	158.4	1.665074	95.1
14	814,065	162.8	1.731676	94.0
15	836,952	167.4	1.800944	92.9
16	860,482	172.1	1.872981	91.9
17	884,673	176.9	1.947900	90.8
18	909,545	181.9	‘2.025817	89.8
19	935,116	187.0	2.106849	88.8
20	961,405	192.3	2.191123	87.8
21	988,434	197.7	2.278768	86.8
22	1,016,223	203.2	2.369919	85.8
23	1,044,793	209.0	2.464716	84.8
24	1,074,166	214.8	2.563304	83.8
25	1,104,365	220.9	2.665836	82.9
26	1,135,413	227.1	2.772470	81.9

Table 5-5. Current Value of Stand Conversion Costs After Nematode Infection (continued)

Year	Annual Acres Treated	Stand Reestablish Cost @ $200/Acre	PV Factor	Present Value (Million $)
27	1,167,333	233.5	2.883369	81.0
38	1,200,152	240.0	2.998703	80.0
29	1,233,892	246.8	3.118651	79.1
30	1,268,582	253.7	3.243398	78.2
31	1,304,247	260.8	3.373133	77.3
32	1,340,914	268.2	3.508059	76.4
33	1,378,612	275.7	3.648381	75.6
34	1,417,370	283.5	3.794316	74.7
35	1,457,218	291.4	3.96089	73.9
Total	26,645,000			2,126.8

Table 5-6. Present Value of Cash Flow and Residual Stand Value After 35 Years Without Nematode Infection

Year	MBF Pond. Pine	Market Val. [@ $141/MBF] (millions of $)	PV Factor	Present Value (millions of $)	Notes
1	4,267,000	601.6	1.04	578.5	market val
2	4,267,000	601.6	1.0816	556.3	[@ 1986 prices]
3	4,267,000	601.6	1.124864	534.9	equals $141/MBF
4	4,267,000	601.6	1.169859	514.3	
5	4,267,000	601.6	1.216653	494.5	
6	4,267,000	601.6	1.265319	475.5	
7	4,267,000	601.6	1.315932	457.2	Residual val
8	4,267,000	601.6	1.368569	439.6	of stand after 35 yrs
9	4,267,000	601.6	1.423312	422.7	[Pres Val]
10	4,267,000	601.6	1.480244	406.5	3811.7 (millions of $)
11	4,267,000	601.6	1.539454	390.8	
12	4,267,000	601.6	1.601032	375.8	Pres Value
13	4,267,000	601.6	1.665074	361.3	of Cash Flow
14	4,267,000	601.6	1.731676	347.4	11,230.5
15	4,267,000	601.6	1.800944	334.1	
16	4,267,000	601.6	1.872981	321.2	NPV of
17	4,267,000	601.6	1.947900	308.9	Unaffected
18	4,267,000	601.6	2.025817	297.0	Situation
19	4,267,000	601.6	2.106849	285.6	15,041.2 (millions of $)
20	4,267,000	601.6	2.191123	274.6	
21	4,267,000	601.6	2.278768	264.0	
22	4,267,000	601.6	2.369919	253.9	
23	4,267,000	601.6	2.464716	244.1	
24	4,267,000	601.6	2.563304	234.7	

Table 5-6. Present Value of Cash Flow **and** Residual Stand Value After 35 Years Without Nematode Infection (continued)

Year	Annual Timb Harvest MBF Pond. Pine	Market Val. [@ $141 /MBF] (millions of $)	PV Factor	Present Va (millions o
25	4,267,000	601.6	2.665836	225.7
26	4,267,000	601.6	2.772470	217.0
27	4,267,000	601.6	2.883369	208.7
28	4,267,000	601.6	2.998703	200.6
29	4,267,000	601.6	3.118651	192.9
30	4,267,000	601.6	3.243398	185.5
31	4,267,000	601.6	3.373133	170.4
32	4,267,000	601.6	3.508059	171.5
33	4,267,000	601.6	3.648381	164.9
34	4,267,000	601.6	3.794316	158.6
35	4,267,000	601.6	3.946089	152.5
Total				11,221.70

estimate for a normal forest of the ponderosa-Jeffery pine type (USDA, 1982).

(6) An average value of $141 per MBF in 1986 constant dollar prices was assumed to extend into the indefinite future.

A continued harvest at normal rates until mortality begins was also assumed. Thereafter, we assume that dead trees are salvaged within 1 year of mortality without significant defect. We also assume that the increase in the volume of pine-types salvaged is offset by an equal reduction below normal levels of other coniferous types in the mixed forest. This latter assumption is important in simplifying the analysis for two reasons: first, we assume no effect on the average price of stumpage; second, we assume no fall-down below normal levels of coniferous timber harvest after the completion of pine-stand conversion, because levels of inventory of other species will have been built up. The age-class distribution of the total coniferous inventory will have been altered along with the species composition after the passage of 35 years, but the increased inventory of other species should be nearly enough to prevent significant reductions in annual harvest levels.

Table 54 shows that under all of the above assumptions, salvage of ponderosa pine mortality would generate present value of cash flow of about $15.7 billion 1986 dollars. Table 5-5 shows that, assuming that the average cost of stand conversion is $200 per acre more than the cost of stand regeneration under normal conditions, the present value of the salvaged timber would be about $13.6 billion.

Table 5-6 shows that the present net value of the cash flow under the normal condition, subject to the above assumptions, is approximately $11.2 billion. Note that this figure is actually smaller than the figure for the infestation scenario. This is due to the accelerated rate of harvest to salvage dead timber. However, under our assumptions, the value of the residual stand of pine must be added to the present value of the cash flow, which is $3.8 billion, bringing the total to $15.04 billion. Thus, the net economic cost of the assumed infestation is 1.67 billion 1990 dollars for the worst case scenario of 100 percent mortality. The best case scenario, which assumes 2 percent mortality, would be $33.35 million 1990 dollars. Note that these latter figures do not include a downward adjushnent for the value of the new stand established concurrently with the salvage operation. While the new stand will not have reached financial maturity, it would have market value as growing stock.

Larch Canker

Summary

The following ranges display a best case/worst case scenario for damage caused by the introduction of larch canker disease from the Soviet Union. The worst case damages are $240.6 million, assuming high rates of infection and high rehabilitation costs. The best case damages are $24.9 million, assuming low rates of infection and no rehabilitation costs. For background material on larch canker and its effects, see Appendix' K.

Economic Analysis

We limited our analysis to three financial impacts:

(1) Reduced yields in present larch stands;

(2) Premature conversion of larch to other tree species;

(3) Direct rehabilitation costs, consisting of:

- (a) Stumpage value lost in unsalvageable mortality in salvage and sanitation operations;
- (b) Direct costs of further disposal, including piling, burning, or activities in excess of normal silvicultural treatment.

(1) Larch canker disease will spread completely through the larch forest resources in 25 years.

(2) Larch forest types in the seedling/sapling and poletimber size (up to 'f-inches mean diameter) are susceptible. Our final estimate was 793,000 acres at risk.

(3) The average age of the susceptible larch stand is 30 years: For calculation simplicity, we assumed that all stands are exactly 30 years old.

(4) The larch component of other forest types (less than 50 percent larch stock) will be killed by the disease, but the stands will not undergo yield reduction.

Silvicultural Assumptions

(1) Larch stands will be replaced with Douglas-fir that will be grown under a management regime with costs, rotation length, yields, and values identical to the larch regime.

(2) The basic management regime is as follows:

Activity	Age	(Cost)/Revenue
(a) Site Preparation	1	($150)
(b) Planting	1	($100)
(c) Precommercial thinning	20	($100)
(d) Commercial thinning	50	$150 (3 MBF/acre @ $50/MBF)
(e) Final harvest	100	$2,100 (30 MBF/acre @ $70/MBF)

Note: The higher final harvest stumpage value is based on higher quality and lower cost logging. See financial assumptions.

(3) In two-thirds of the infected host acreage, there will be enough residual growing stock in conversion species to finish out the rotation. In the other third, immediate conversion will be necessary.

(4) In infected host acreage, all of the merchantable sawtimber will be sold at current (projected) stumpage prices identical to those of green larch. Furthermore, the volume salvaged is identical to what would have been harvested in planned commercial thinnings. Therefore, the kill of any merchantable volume does not contribute to any value loss.

(5) In stands that are allowed to finish the rotation, yields will be reduced by 1/3 from 30 MBF per acre to 0 MBF per acre at 100 years.

Program *Assumptions*

(1) The larger larch (above 11 inches diameter at breast height (d.b.h.)) in all forest types will be removed.
(2) The only value loss from the rehabilitation program is the unsalvageable mortality, which is 25 percent of the current sawtimber volume of the greater than 11 inch d.b.h. trees.
(3) Rehabilitation costs, net of the logging costs included in the unsalvaged mortality, is $10 per MBF of unsalvageable volume cut in the rehabilitation program.
(4) Stumpage values for larch removed in the rehabilitation program are identical to prices for green uninfected larch.

Financial Analysis Assumptions

(1) Current stumpage prices for green larch are assumed to be $70/MBF. This represents the average stumpage price paid for larch on national forest sales in the Northern and Pacific Northwest Regions for the years 1985 to 1989 (Warren, 1990).
(2) Real discount rate is 4 percent.
(3) Rate of inflation for all costs is 3 percent per year.
(4) Real timber price increase is 1 percent per year.
(5) Present rotations are financially optimal. None of the stands of susceptible size is financially overmature:
(6) The total financial impact from premature conversion and yield reduction is the sum of the stand-level estimates for the assumed acreage infected. We estimated no allowable cut adjustments.
(7) The premature conversion effect is calculated with the formula:

$$\text{Value Change} = PNW^{wo} - PNW^{w}$$

where PNW^{wo} is the discounted present value of the present rotation and all future rotations without larch canker and PNW^{w} is the discounted present value of the present and future rotations with the larch canker.
(8) The form of PNW used in this analysis combines the present value of the remaining rotation with the soil expectation value (SEV) of an infinite series of rotations after the stand is converted. The SEV component is discounted to the present from its starting point, which is 70 years in the future for stands in which the current rotation is allowed to finish.
(9) The annual rehabilitation cost-plus-loss is the total rehabilitation impact divided by 25 years. Since the disease spreads uniformly over the acreage during the period, the impact is the discounted present value of a stream of 25 equal annuity payments, using the 4 percent rate.

(We assumed no real net of inflation increase in stumpage prices in the rehabilitation impacts.)

Economic Methods

(1) Develop three alternative scenarios composed of different levels of infection and extent of rehabilitation.

(2) Estimate the acres of susceptible larch (host) type for each scenario. Larch in this area are completely killed in each scenario. Seedlings, saplings, and poletimber size classes of larch are at risk. Acres that are reserved or deferred are not included.

(3) Estimate the sawtimber volume of nonsusceptible larch that is affected in a direct rehabilitation program for the scenario. Part of this volume is salvageable at current market prices for stumpage; the rest is unsalvageable mortality. The volume that occurs as reserved or deferred timberland is not included.

(4) Estimate a combined yield reduction and conversion impact for the host acreage.

(a) Estimate a per-acre yield reduction impact for infected stands that are assumed to finish the rotation.
(b) Estimate a per-acre stand conversion impact for infected stands that are converted immediately after infection.
(c) From (a) and (b) above, calculate a weighted average per-acre impact based on estimated relative frequencies of the two situations.
(d) Multiply the average loss in (c) above by the number of host acres infected in the scenario, adjusting for unreserved acres.

(5) Estimate the direct rehabilitation cost-plus-loss.

(a) Estimate the value of the merchantable-size larch that are cut during rehabilitation measures, but are not sold, multiplying the stumpage prices by the portion of the standing sawtimber volume. That portion is specified by each scenario.
(b) Estimate the disposal costs not included in (a) above by multiplying some assumed net cost per MBF by the unsalvaged volume.
(c) Add (5 a) and (4 b), and adjust to the unreserved volume.

(6) Add (4 d) and (5 c) for an estimate of the total impact for the estimated duration of the disease epidemic.

(7) Calculate the discounted present value of the impact in (6).

(a) Divide the total impact by the number of years of the epidemic (see the assumptions listed below).
(b) Apply the formula for the present value of an annuity to the annual impacts calculated in (6).

Scenarios

(1) High infection level with no rehabilitation program.
— 100 percent of the susceptible host acreage is affected.

(2) Medium infection level with a medium intensity rehabilitation effort.
— 50 percent of the host acreage is affected.
— 25 percent of the sawtimber volume in nonsusceptible larch is cut.

(3) Light infection level with a high intensity rehabilitation effort.
— 25 percent of the host acreage is affected.
— 50 percent of the volume in nonsusceptible larch is salvaged and sanitation cut.

Economic Impacts

The impact of larch canker disease will be a timber and forestland value loss of $129 million. This figure represents the net present value of a stream of impact over the 25-year spread period. This figure is the average of the three infection and rehabilitation scenario impacts, which range from $99 million to $166 million (table 5-7).

Half of this impact would come from yield reduction and conversion in present stands, and half from rehabilitation costs and unsalvageable rehabilitation mortality.

Under the high infection scenario, 100 percent of the impact would come from yield reduction and stand conversion. By contrast, under the low infection and high rehabilitation scenario, 81 percent of the impact would come from control cost-plus-loss. A worst case scenario would include a high infection level in spite of an intensive control program, producing a value reduction of $99 + $142 = $240 million.

Table 5-7. Financial Loss From Larch Canker on Western Larch Under Three Scenarios, Four Western States

Scenario	Impact component		
	Yield reduction/ Stand conversion	Control cost/ loss	Total impact
	present value in millions of dollars for 25-year period		
7. High infection and control	99.2	0	99.2
2. Medium infection and medium control	49.7	70.6	120.3
3. Low infection and high control	24.9	141.4	166.3
Average Impact	57.9	70.7	128.6

Spruce Bark Beetles

Summary
The following ranges display best case and worse case scenarios for damage caused by the introduction of spruce bark beetles from the Soviet Union. These figures are expressed in 1990 dollars. Worst case damages are $1.5 billion, assuming that the spruce resource in Washington and Oregon is entirely killed in 7 years. Best case damages are $201 million, assuming that 25 percent of the spruce resource in Washington and Oregon is killed in the next 30 years.

Economic Analysis
Economic effects are analyzed by considering the timber supply effects of catastrophic mortality to the spruce resources in Washington and Oregon. Damages are computed in a comparative static framework; that is, as the difference between a precatastrophe market equilibrium (the base case) and a sequence of "catastrophic" market equilibriums. Change in measures of economic surplus are used to indicate the magnitude of potential economic effects.

Biological Assumptions

(1) The most important pest of concern for evaluating potential bark beetle impacts associated with log imports from Siberia is *Ips typographus* (European spruce bark beetle).

(2) The spruce bark beetle will vector pathogenic fungi such as the highly pathogenic species *Ophiostoma polonica*. Once established, vectors native to the United States, such as *Dendroctonus* spruce beetles, could effectively transmit pathogenic fungi.

(3) The primary hosts of concern in the Western United States are Sitka spruce (*Picea sitchensis)* and Engelmann spruce (*Picea engelmannii*). The analysis is focused on forests in Washington and Oregon.

(4) Increased mortality is the biological endpoint of significance, rather than decreased growth. Mortality occurs at the rate of 100 percent in the infested area.

(5) The rate of spread (r) of spruce beetles is from 1 to 30 miles per year, with a mean of about 10 miles per year. if *Ips typographus* became established in the forests of the Western States, it would likely spread into Canada and Alaska. For our analysis, we parametrically vary the r value.

(6) The host type is homogeneously distributed in all directions from the epicenter (port of entry). Considering that the area of a semi-circle with ϕ radians = $\phi r^2/2$, where r is the radius (that is, the rate of spread) and the relevant number of radians (accounting for the Pacific Ocean) equals π. By "redistributing" the entire spruce resource in Washington and Oregon around the epicenter, we have, in effect, increased the rate of spread above r = 10.

(7) Beyond the current rotation, the soil expectation value of damaged forests remains unchanged. This implies no change in future yield or management costs.

Mortality Computation

The expected volume of timber killed in year t is the area of the year t annulus times the volume per unit area. This can be computed as:

$$K_t = \frac{c_t \pi r^2 s}{2}$$

$$\text{given } c_t = c_{t-1} + 2 \text{ if } t > 1$$
$$c_t = 1 \text{ if } t = 1$$

Where: K_t = the volume of timber killed in year t, r = the rate of beetle spread in miles/year, t = year, c_t = annulus area coefficient in year t, s = timber volume per square mile.

Notice that $\partial K_t/\partial r = 2c_t\pi rd > 0$ and $\partial^2 K_t/\partial r^2 = 2c_t\pi D > 0$. Therefore, the volume of timber killed increases at an increasing rate in response to a parametric increase in r.

Timber volume per square mile(s) is computed using:

(1) The net volume of Sitka spruce growing stock in Oregon and Washington = 1,735 million cubic feet (USFS, 1989).

(2) The number of hemlock-Sitka spruce forest acres in Washington and Oregon = 3,984 thousand acres (USFS, 1989).

(3) One square mile = 640 acres.

(4) Therefore, the volume of Sitka spruce per acre or mi^2 can be computed: (1,735,000,000/3,984,000) **= 435.5** ft^3/acre or **278,715** ft^3/mi^2.

(5) Net volume of Engelmann and other spruce types in Oregon and Washington = 1,193 million cubic feet (USFS, 1989).

(6) Number of fir-spruce forest type acres in Washington and Oregon = 4,088 thousand acres (USFS, 1989).

(7) Therefore, the volume of Engelmann and other spruce per acre or mi^2 can be computed: (1,193,000,000/4,088,000) = 291.8 ft^3/acre or 186,771 ft^3/mi^2.

(8) The total spruce volume per acre or mi^2 is the sum of all spruce types: 727.3 ft^3/acre or **465,472** ft^3/mi^2.

(9) Board foot volumes are computed assuming 1 cubic foot = 5 board feet.

Based on the annual mortality formula and the above timber volume computations, the spruce inventory ***in*** Washington and Oregon is completely destroyed in slightly more than 6 years if r is not equal to 10. If the rate of spread is not equal to 1, approximately 25 percent of the standing inventory of spruce is killed over a 30-year period.

Economic Method

Similar to a method used by Binkley and Dykstra (1987) and Holmes (1991), constant elasticity inverse supply and demand curves are used in our analysis: $S_t(Q) = b_0Q^{b1}$, $D_t(Q) = a_0Q^{a1}$, where b_1 and a_1 are inverse supply and demand elasticities, respectively. Timber supply and demand elasticities were chosen to be broadly representative of estimates reported in the literature. We used a supply elasticity of 0.25 and a demand elasticity of -0.50. The base case parameters b_0 and a_0 are calibrated using data reflecting 1989 market conditions in Washington and Oregon (Warren, 1990).

Two supply impacts are modeled. First, a reduction of spruce inventory shifts lagged supply back, because damaged timber stocks are no longer available for harvest in the future. We use an inventory elasticity of 1 (Adams and Haynes, 1980). Second, we considered the possibility that spruce mortality is salvaged during the year it is killed. Since the opportunity cost of dead timber approaches zero, the salvage supply curve is perfectly inelastic. Market supply is the sum of salvage supply and supply from undamaged forests. Therefore, the consequence of salvage is to increase market equilibrium quantity and reduce equilibrium price. To understand the potential impact of salvage on timber markets, we compute market equilibrium assuming: (1) 100 percent salvage, and (2) 0 percent salvage.

Market impacts are computed over a 30-year period. Since future impacts are discounted to the present, after 30 years market impacts are relatively small.

To add salvage supply to the supply from undamaged forests, invert $S_t(Q)$ and add the volume of timber salvaged Q^d to the volume of undamaged timber Q^u:

$$Q_t^m = Q_t^d + Q_t^u = Q_t^d + \left(\frac{P_t}{b_{0_t}}\right)^{\frac{1}{b_1}}$$

Equilibrium price for various levels of Q^d are found by numerical methods. Of course, equilibrium quantity is found by substituting equilibrium price into either the supply or demand equation.

The impact of a change in inventory on timber supply is computed assuming that price elasticity does not change. Following Binkley and Dykstra (1987), a change in inventory alters the location parameter b_0 in the following fashion

$$b_{0_{t+1}} = \frac{b_{0_t}}{\left(\frac{I_{t+1}}{I}\right)^{b_1}}$$

where $b_{0_{t+1}}$ is the revised location parameter, I_{t+1} is revised inventory, and I is initial (base case) inventory. The next period's timber inventory is computed from current inventory I_t, current mortality K_t, current harvest of undamaged timber Q^u_t, and current growth G_t using the growth-drain relationship:

$$I_{t+1} = I_t - K_t \quad Q_t^u - G_t$$

Economic Impacts
Several results are worthy of note. First, economic losses, to owners of damaged forests are not very sensitive to the salvage assumption. Under the 100 percent salvage scenario, losses to owners of the damaged resource are somewhat smaller (about $1.0 billion). This is due to: (1) under the 100 percent salvage scenario, owners of damaged timber receive a return-thereby'reducing their losses, and (2) under the no salvage option, timber damages are valued as a proportion of inventory from the year of mortality to the year in which they would have been marketed, if the stocks had not been killed. This latter effect imparts a downward (conservative) bias to damage estimates, due to the proportionality impact and the effect of discounting.

Second, timber salvage has the greatest impact on owners of undamaged forests and timber consumers. Under the 100 percent salvage scenario, owners of undamaged forests suffer the greatest economic damages resulting from the decrease in equilibrium price. Producers of undamaged forests move back along their timber supply curves (reduce their harvest level) in response to a decrease in price. Of course, timber consumers benefit from the decrease in timber price and move out along their timber demand curve. Conversely, under the no salvage option, timber consumers suffer the greatest economic loss, due to the overall rise in equilibrium market price. Timber producers with undamaged forests benefit from the price rise and move out along their supply curve (increase their harvest level).

Third, the net loss in economic welfare from catastrophic damage to the spruce resource in Washington and Oregon ranges from a low estimate of $201 million to a high estimate of $1.5 billion.

Annosus Root Disease

Summary
The following ranges display best case and worse case scenarios for damage caused by the introduction of a new strain of annosus root disease from the Soviet Union. The figures are expressed in 1989 dollars. Worst case damages are $331.4 million, assuming a mortality of 2.3 billion board feet (bbf) per year. Best case damages are $81.7 million, assuming a mortality of 0.5 bbf per year.

Economic Analysis
Effects of a new strain of annosus root disease (*Heterobasidion annosum*) are assessed using a comparative statics framework. Supply and demand equations are used to estimate equilibrium price and quantity, and changes in these values that result from effects on the timber resource are computed. This provides a means to calculate the changes in net economic welfare. Two different impacts are analyzed: (1) the effect of changes in inventory resulting from increased mortality, and (2) the effect of increased log defect due to damage. Both of these impacts result in an inward shift in supply. The high and low damage scenarios are presented in table 5-8.

Assumptions

(1) Damage begins at year 20, and continues until the end of the planning horizon used in this analysis (30 years). New growth on damaged sites and discounted values will lessen future impacts.

(2) Losses consist of (a) increased mortality in Douglas-fir and larch ranging from 0.5444 to 2.2864 bbf per year, and, (b) increased defect causing volume reductions of 0.01502 to 0.0603 bbf per year.

(3) Beyond the current rotation, the soil expectation of damaged forests remains unchanged. This implies no change in yield or management costs.

(4) Control efforts are considered too costly over a large area, and we therefore assume no control measures are taken.

(5) None of the annosus mortality is salvaged, which is consistent with the actual practice in much of the Western United States.

Economic Method
Effects of mortality and the defects from annosus on timber markets are examined using the methodology outlined in Binkley and Dykstra (1987) and Holmes (1991) and used in the bark beetle impact

analysis found in this report. We use constant elasticity inverse demand and supply curves (equations 1 and 2), and inventory accounting and adjustment equations using an inventory elasticity of 1 (Adams and Haynes, 1980) (equations 3 and 4).

Table 5-8. Market Equilibrium Price and Quantity Ilarvested Resulting From Annosus Damage

	Low	Alternative	High	Alternative
Year	Price ($/mbf)	Quantity (bbf)	Price ($/mbf)	Quantity (bbf)
0 (base year)	277.17	14.974	277.17	14.974
"				
"				
20	277.19	14.983	277.22	14.982
21	277.55	14.973	278.72	14.942
22	277.90	14.963	280.23	14.901
23	278.26	14.954	281.77	14.861
24	278.62	14.944	283.31	14.820
25	278.98	14.935	284.88	14.779
26	279.34	14.925	286.45	14.739
27	279.70	14.915	288.04	14.698
28	280.06	14.905	289.64	14.616
29	280.42	14.896	291.27	14.616
30	280.80	14.886	292.61	14.575

$$S_t(Q) = b_{0_t} Q_t^{b_1} \tag{1}$$

$$D_t(Q) = a_0 Q_t^{a_1} \tag{2}$$

$$b_{0_{t+1}} = \frac{b_{0_t}}{\left(\frac{I_{t+1}}{I}\right)^{b_1}} \tag{3}$$

$$I_{t+1} = I_t - K_t - Q_t^u - Q_{t+1}^d \tag{4}$$

where Q is quantity, Q^d is quantity of harvest with defect, Q^u is undamaged harvest, K is mortality, a, and b_0 are location parameters, a, and b, are inverse elasticities, I is inventory, and G, is growth. These equations are further explained in the bark beetle analysis section of this chapter. Both mortality (K) and defect (Q”) are accounted for by a decrease in inventory, reflected by a pivotal shift in the supply curve (a change is $b\alpha$). Economic welfare changes are computed for (1) timber consumers (ACS), representing a loss to timber buyers (equation 5), (2) timber producers with undamaged forests (Al’s”) representing a gain (equation 6), and, 3) timber producers with damaged forests (ΔPS^d), representing a loss (equation 7).

$$\Delta CS = \int_{P^*}^{P_t} D(x)dx = \int_{P^*}^{P_t} (P_t/u_0)^{-.5}\, dP \tag{5}$$

$$\text{APS}^u = \int_{P_t}^{P^*} S_t(x)dx = \int_{P_t}^{P^*} (P_t/b_{0_t})^{.25}\, dP \tag{6}$$

$$\Delta PS^d = \int_0^{P^*} [S^*(x) \quad S_t(x)]\; dx = \int_0^{P^*} [(P^*/b_0)^{.25} - (P_t/b_{0_t})^{.25}]\; dP \tag{7}$$

where P^* is the initial equilibrium price, P, is the equilibrium price resulting from annosus impacts, and S^* is the initial supply function.

Economic Impacts

Table 5-8 shows equilibrium price and quantity that result from the high and low alternatives. No impacts were assessed before year 20, and all values are present values, using a discount rate of 4 percent. Table 5-9 and table 5-10 show the discounted welfare impacts of the low and high alternatives, respectively.

Consistent with the theory and with this model’s development, losses in consumer surplus are slightly higher than gains to producers of undamaged forests. Producers with damaged forests lose on the value of mortality as well as through reduced harvest volumes resulting from defect. Total welfare impacts for the 30-year horizon are from -$81.1 million to -$331.4 million. The primary influence on welfare is the change in inventory resulting from mortality.

Table 5-9. Welfare Impacts of Annosus Root Disease (Mortality and Defect): Low Alternative. (Mortality = 0.544 bbf/year, Defect = 0.01502 b&f/year)

Year	ΔPS-damaged ($million)	APS-undamaged ($million)	ΔCS ($million)	ΔNet welfare ($million)
20	-.054	.111	-.111	-.054
21	-1.831	2.562	-2.564	-1.833
22	-3.569	4.767	-4.777	-3.579
23	-5.124	6.845	-6.865	-5.144
24	-6.553	8.752	-8.786	-6.587
25	-7.864	10.543	-10.594	-7.916
26	-9.065	12.136	-12.235	-9.164
27	-10.161	13.586	-13.679	-10.254
28	-11.159	14.904	-15.021	-11.275
29	-12.064	16.097	-16.239	-12.206
30	-12.883	17.247	-17.416	-13.051
Total	-80.326	107.551	-108.286	-81.063

Note: All dollar figures are present values. A denotes change and PS, CS, and NW refer to producer surplus, consumer surplus, and net welfare, respectively.

Table 5-10. Welfare Impacts of Annosus Root Disease (Mortality and Defect): High Alternative. (Mortality = 2.2864 bbf/year, Defect = 0.0601 bbf/year)

Year	APS-damaged ($million)	APS-undamaged ($million)	ACS ($million)	ΔNet welfare ($million)
20	-.198	.321	-.321	-.198
21	-7.559	10.129	-10.171	-7.601
22	-14.357	19.203	- 19.360	-14.514
23	-20.614	27.583	-27.925	-20.956
24	-24.237	35.308	-35.893	-24.822
25	-31.666	42.414	-43.294	-32.547
26	-34.094	48.974	-50.115	-35.235
27	-40.931	54.845	-56.449	-42.536
28	-44.961	60.277	-62.300	-46.984
29	-48.615	65.238	-67.711	-51.087
30	-51.928	69.737	-72.686	-54.876
Total	-319.161	434.030	-446.225	-331.356

Note: All dollar figures are present values. A denotes change and PS, CS, and NW refer to producer surplus, consumer surplus, and net welfare, respectively.

Chapter 6
Ecological Effects Evaluation

The Resource

The forests of the Western United States have their own unique and delicate ecosystems. These systems, in turn, are home to thousands of animals that depend on the forests for their existence. The forests of the Western United States have about 1,000 vertebrate species, including resident and migrant bird species, freshwater and estuarine fish species, mammals, reptiles, and amphibians. However, little basic inventory information is available for many of these species.

Several of these animal species have specific management needs. These include species dependent on specific habitat conditions, such as riparian areas; cavity-nesters; species requiring early, mature, or old-growth forest conditions for optimum habitat; and popular game species.

A mission of the Forest Service is to secure for the Nation the benefits of an enduring wilderness resource by administering and protecting designated wilderness in the National Forest System. National forests and national parks in the West contain millions of acres of designated wilderness. The rate of use differs widely among individual wilderness areas throughout the region. Some areas are used little, while some of the more popular wilderness areas near population centers are beginning to exhibit signs of resource degradation. Approximately 25 percent of all National Forest System recreation use occurs in California, despite the fact that only about 10 percent of the total U.S. population lives in California. Many of California's national forests are concentrated in northern California and in the Sierra Nevada Mountains. Most of the distinctive and natural-appearing forest and mountain scenery that remains in California is located within the 20 million acres of national Forest system lands, the national and State parks, and Bureau of Land Management lands.

Private industrial forest lands are managed principally for timber production rather than wildlife, while Private, nonindustrial lands are more likely to have multiple uses. Nevertheless, privately owned forest and rangelands are important wildlife habitats. About 60 to 80 percent of small game hunting and 20 to 35 percent of big game hunting occur on private land. Lands managed by other Federal agencies (principally the Bureau of Land Management, Department of the Interior) along with State-managed lands, contribute about 20 percent of small game hunting and 20 to 30 percent of big game hunting.

Recreation

The Western United States has a national and international reputation for outstanding mountain, valley, and coastline scenery. The most valuable scenery in the West is on those lands that are not only distinctive in character, but highly visible from scenic travelways, resorts, and recreation areas. Both the demand for scenic quality and the concern over the degradation of scenic resources are increasing and are expected to continue to increase. The policy of the U.S. Department of Agriculture is to advocate the conservation of natural and artificial scenic resources and protect and enhance the visual quality of the landscape. The Forest Service likewise strives to protect and improve the quality of natural beauty. Along with its other goals, the Forest Service is charged with applying these policies to all activities that result in visual alteration of the national forest landscapes. The forest recreation industry is structured around this scenic beauty with billions of dollars of capital investments tied to this resource.

The recreational resources on forest lands in the Western United States provide an enormous range of opportunities because of the mix of climates and landforms and their relative accessibility. Nearly any type of recreational experience, from resort living to rugged backcountry treks, is available. Regardless of the recreational activity, the northwest tourist industry depends heavily on the scenic beauty people associate with the forested landscapes of this area. Recreation use includes camping, hotels, lodges, resorts, motoring, hiking, hunting, fishing, and skiing. The Western United States maintains campgrounds with a capacity to accommodate hundreds of thousands of people at a time. These campgrounds are distributed **throughout the area,** and most are located close to population centers.

Wildlife

The forests of the Western United States provide habitats for a variety of wildlife, including important game species and many threatened or endangered species. Game species in the Western United States include deer, elk, bear, bighorn sheep, cougar, pronghorn, mountain goat, caribou, moose, grouse, rabbit and hare, quail, dove, squirrel, pigeon, turkey, chukar, and a variety of waterfowl. Economically important furbearers include beaver, raccoon, bobcat, and coyote. Threatened and endangered species that are sensitive to habitat changes include Columbian white-tailed deer, peregrine falcon, grizzly bear, northern and Mexican spotted owls, wolverine, tassel-eared squirrel, and accipiter hawks.

Perhaps no old-growth forest animal has received as much media attention as the northern spotted owl. It has been the focus of intense study, debate, and legal battles, and has become the symbol for the effort to save the old-growth forests of the Pacific Northwest. It is believed that the northern spotted owl has fairly selective habitat requirements that are closely tied to stands of old-growth Douglas-fir. The owl may require dense cover for protection from predators and the weather, a specific type of tree for nesting, sufficient food, and a large range for foraging. The owl is found only in southwestern British Columbia, westem Washington and Oregon, and northwestern California, and destruction of stands in these areas may result in the loss of this species.

Important resident game fish, which have high recreational fishery values, include rainbow, eastern brook, brown, Dolly Varden, and cutthroat trout, as well as Kokanee and mountain white fish. Anadromous fish have both sport and commercial value, and are found in virtually all watersheds in the western part of the Pacific Northwest. Most of the spawning and rearing habitat for anadromous fish in the Pacific Northwest is found on the national forests. These salmon are born in the streams that run throughout these forests, migrate to the Pacific Ocean where they feed and grow, then return to the freshwater streams to reproduce. Reaching the mating grounds is often difficult, and once there, the chinook require the proper substrates-plentiful, cool, well-oxygenated fresh water and food. In addition, the forests provide the streams with blowdown logs, which create vital microhabitats for the salmon. The Olympic salamander is a species native to the springs and streams in the forests of the Pacific Northwest. Like most salamanders, it needs cool, moist conditions for survival, and it is extremely sensitive to sedimentation. Thus, disturbances in the forest riparian zone can harm populations of this species for decades.

These discussions on the ecological composition, fragility, and value of western forests are not intended to be all inclusive. Rather, they underscore that this vast forest resource has numerous biological components that might be affected. The following are perceived impacts (both positive and negative) that could occur as a result of the activity of one or more exotic pests acting alone or in combination.

Potential Pest Impacts

Plant-eating insects and pathogens are a normal part of forest ecosystems-at low population levels they play a positive role in cycling nutrients and diversifying habitats. Even the periodic insect outbreaks that have characterized many northern forests in the past were normal cyclic or episodic phenomena that had little long-term impact on forest health, and may have even improved it (Mattson and Addy, 1975). However, when outbreak cycles intensify or population numbers remain chronically high, insects and diseases become destructive forces within ecosystems. This generally happens when some ecological constraint on pest population growth is removed; it is much more common in exotic than in native pests. While it is impossible to say how many exotic pests are imported across national boundaries without becoming established in their new habitat, there are sufficient examples of exotics becoming major pests to conclude that introduction of organisms carries considerable risk. Chestnut blight, Dutch elm disease, white pine blister rust, gypsy moth, balsam wooly adelgid, larch casebearer, larch sawfly, and the European pine shoot moth are a few of the introduced pests that have caused economic and ecological disruption in forests of the United States. As of 1977, 70 foreign insects were established in forests of the Western United States, 4 of which had become major pests (Fumiss and Carolin, 1977).

The risk associated with introduced pests is even greater now than in the past. To understand why this is so, it is necessary to briefly discuss the ecology of pest population dynamics. In natural ecosystems, four factors constrain the ability of insects and pathogens to attain high population levels: (a) the availability of suitable food plants; (b) chemical defenses produced by food plants; (c) climate; and (d) biotic controls, such as parasites, predators, and diseases (DeBach, 1974; Baker and Cook, 1974; Furniss and Carolin, 1977; Perry, 1988; Perry and Maghembe, 1989). These factors do not operate independently but rather work together to limit pests. For example, by dampening the growth of pest populations, natural enemies may reduce the rate at which the pests can adapt to plant chemical defenses. On the other hand, by slowing the growth of individual pest organisms, climatic factors and plant chemical defenses combine to make the pest more vulnerable to natural enemies. Imbalance in ecosystems occurs periodically. For example, the reduction in the array of plant chemical defenses is curtailed when trees become stressed by any factor (Waring and Schlesinger, 1985; Perry and Maghembe, 1989). Drought, for example, is a common trigger of insect outbreaks throughout the world (Mattson and Haack, 1987).

Exotic pests are particularly destructive because they are operating in a new ecological context, one in which one or more of their natural controls is absent: they may have few or no natural enemies, and trees that have effective defenses against the pests with which they have coevolved may have none against an invading pest. To give just one example, two factors contributed to the European pine shoot moth (*Rhyacionia buoliana*) becoming a greater pest in the United States than in its native Europe: trees were more palatable to it in the United States, and in contrast to its native habitat, the moth had no internal parasites in the United States (Miller, 1967). Attempts to control R. *buoliana* by introducing its parasites from Europe failed, perhaps because the parasites did not have suitable alternate hosts in the United States (Miller, 1967). Similarly, of 40 natural enemies of gypsy moth introduced into the United States, only 10 became established, and only 1 of these provided a measure of control (Pimentel, 1986). The point here is that controls over pest populations in their native habitats involve many direct and indirect interactions within the ecosystem, which implies that there are no quick technological fixes. This is not to say that attempts to control exotic pests by introducing their natural enemies are doomed to fail-there have been a *umber of clear successes (Ryan, 1987; Ryan et al., 1987); however, success is far from guaranteed, and even when achieved may take many years (Elton, 1958; Pimentel, 1986). For example, *Entomophaga maimaiga*, a fungal parasite of the gypsy moth that was released in the United States in 1970 did not begin to kill the moth in large numbers until 1989.

North American forests are likely to be particularly vulnerable to the introduction of exotic pests during the coming decades. Factors, such as environmental stress associated with anthropogenic agents, may reduce the ability of trees to defend themselves, and extensive habitat modification and fragmentation have altered various ecosystem and landscape factors that affect pest dynamics.

Environmental Stress

The history of biological invasions clearly shows that exotic pests establish themselves most successfully in ecosystems that have been stressed by mismanagement, overutilization, or some other factor (Elton, 1958; Orians, 1986). Air pollution is a unique stress that affects even pristine ecosystems: outbreaks of bark beetles and the balsam woolly adelgid in the Eastern United States are believed to have been triggered by pollution (Hain, 1987); in the San Bernardino National Forest of California, ponderosa pines stressed by pollution become more susceptible to bark beetles (Taylor, 1973).

Possible effects of climate change on forest health are complex and incompletely understood, but in all likelihood pest problems will be exacerbated in a warmer, drier climate (Oregon Department of Energy, 1990; Perry and Borchers, 1990). Drought stress will reduce the ability of trees to produce defensive chemicals, weakening an important line of defense against pests (Mattson and Haack, 1987). It has been suggested that higher levels of atmospheric CO_2 will allow plants to produce more defensive chemicals, but the experimental evidence is unclear on that point: studies conducted to date show that insects consume from 20 to 80 percent more when fed on plants grown in an elevated CO, atmosphere than when fed on plants grown in ambient CO,; however, they perform relatively poorly on the former (Bazzaz, 1990). Another factor that strongly influences the probability of pest outbreaks is the intrinsic rate of pest population growth, which is likely to increase with warmer average temperatures (Andrewartha and Birch, 1954). At least one of the Siberian pests that might be imported, the pine wood nematode (*Bursaphelenchus xylophilus*), is known to be limited by low temperatures (Rutherford et al., 1990); other factors being equal, the nematode will favor a warmer climate.

In summary, while the issue is complex, the weight of evidence indicates that forests will be more vulnerable to both native and introduced pests in a changing climate. It should be noted that trees stressed by one pest often become more vulnerable to others. For example, balsam fir attacked by the introduced insect, balsam wooly adelgid, became more susceptible to the root pathogen, *Armillaria mellea* (Hudak and Singh, 1970). It is entirely within the realm of possibility that changing climate, increased incidence of established pests, and the introduction of new pests could act in combination and amplify one another.

Habitat Modification

Modified habitats have increased the risk associated with introduced pests because the relative uniformity of managed forest landscapes facilitates the spread of pests and the severity and spread of some tree pathogens has been exacerbated by forest management (Perry, 1988). The habitat for some natural enemies of pests has been reduced by forest fragmentation and the removal in managed forests of certain key structural elements, such as snags, logs, and multi-structured canopies (Wilcove, 1985; Torgersen et al., 1990). Declining numbers of migratory songbirds, important consumers of forest insects, have been well documented in the United States and Canada over the past several years (Wilcove, 1985). Holling (1988) concludes that, while the presence of fewer insect-eating birds alone is unlikely to trigger insect outbreaks, one important line of defense has been clearly weakened, and forests have consequently become more vulnerable to pests.

Moreover, Schowalter's (1989) studies in the Northwest and Southeast show that, in both areas, plantations support quite a different insect fauna than old-growth forests. Canopies of the former are dominated by tree-eating insects (aphids and related sucking insects), while older forest canopies have a much more diverse insect fauna, including many more species of spiders that prey on tree-eating insects. The same results from two different forest types suggests a general phenomenon.

It is unclear what Schowalter's findings imply for the ability of forests to resist newly introduced pests, but other factors being equal, the combination of fewer natural enemies and more preexisting pests suggests that plantations would be more vulnerable to introductions than older forests. If so, that has considerable implications for the rate at which new introductions will spread, since a high proportion of the forested landscape is now occupied by younger forests as a result of logging and subsequent replanting.

Criteria for Assessing Ecological Impacts

While the ecological impacts of potential pest introduction are difficult to assess because of the complexity of forest ecosystems, general concepts can be applied.

Proportion of the Total Susceptible Plant Cover in the System

Ecological impacts from a particular pest are most severe when its host preferences are general, or, if its preference is specific and the host upon which it feeds accounts for most of the primary timber production. Even a highly virulent pest, such as chestnut blight, may have a relatively minor long-term ecological impact if it attacks only one or a few tree species within a species-rich forest, if the tree species that are attacked do not perform some unique function within the ecosystem. However, many western forests differ significantly from the eastern deciduous forests that were attacked by chestnut blight and gypsy moth, in that western forests are often dominated by relatively few (or even one) tree species, hence they are particularly vulnerable to specialized pests.

The Role of the Susceptible Plant Species in the Ecosystem

Hardwoods provide a good example of keystone species in the conifer-dominated West. Riparian hardwoods shade streams, stabilize channels, and provide organic matter to aquatic foodwebs (Cummins, 1980). Nitrogen-fixing plants, such as the various species of alders and ceanothus, are critical to long-term soil fertility. Hardwoods and other flowering plants serve as a vital link in the food chain for some animals, including species of wasps and flies that parasitize defoliating insects.

Adaptability and Aggressiveness of Potential Introduced Pests

The following sections discuss the adaptability and aggressiveness in North American forests of the potential introduced pests profiled in Chapter 4.

Asian Gypsy Moth

The gypsy moth has been relatively specialized in the Eastern United States, attacking hardwoods most readily, and particularly oaks. Spread to conifers has occurred only when they are mixed with hardwood hosts. The California Department of Food and Agriculture (CDFA) (1982) lists 71 plant species native to that State that would be susceptible to gypsy moth defoliation, including Douglas-fir, sequoia, redwood, five species of oaks, nine species of pine, and four species of manzanita. Feeding trials with western plant species indicate that oaks, alders, maples, poplars, and manzanita are highly suitable hosts (Miller and Hanson, 1989; CDFA, 1982). Suitability of Douglas-fir varies widely with temperature, with larval survival peaking at 84 percent at 22 “C, then dropping sharply at both cooler and warmer temperatures (Miller et al., 7991). With regard to virulence, trees in the Eastern United States were able to recover from gypsy moth defoliation so long as they were initially healthy, and providing they were not chronically defoliated. The potential threat to keystone hardwood species is high; the potential for extensive infestation of conifer forests is largely unknown but probably ranges from moderate to high. Based on experience in the Eastern United States, tree kill resulting from attack is likely to range from moderate in healthy forests to high in stressed forests.

Based on its host preferences in Siberia and the Soviet Far East, the nun moth will attack all western conifers except the pines. Hence the potential for extensive infestation is high if this insect is introduced and becomes established. This insect consumes most or all foliage on a tree, which is particularly devastating to conifers; mortality resulting from nun moth attack is likely to be high.

Pine Wood Nematode

Host records suggest that this nematode would readily attack ponderosa and Jeffrey pines. Ponderosa pine is the dominant tree on 27 million acres of forest, second only to Douglas-fir in the Western United States in terms of area on which it is the principal tree (Van Hooser and Keegan, 1988); however, stands at lower elevations in the more southerly portions of the range are most likely to be attacked under current Climatic regimes. The pine wood nematode is extremely virulent in area5 where the average summer temperature exceeds 20 “C, and relatively innocuous where it does not (Rutherford et al., 1990).

Larch Canker

Specific to members of the genus *Larix,* this disease could have a major impact on the 2 million acres of Western U.S. forest with 50 percent or more larch cover.

Annosus Root Disease

If introduced and established, this pathogen has a high potential to infest extensive areas of true fir and dry pine forests. Mortality in infested areas would probably be high.

Spruce Bark Beetle

Though it will occasionally attack pines and larch, this insect’s main hosts are *Picea* spp. It can infest and kill substantial numbers of standing trees during epidemics. If introduced, spruce bark beetle has a high potential to cause extensive mortality in Sitka and Engelmann spruce stands in the Western United States and Canada.

Ecological Impacts of Large-Scale Infestations

Most of the pests emphasized in this report have the potential to infest extensive areas of one or more forest types in the West. It is impossible to state the probability of extensive infestation should one or more exotic pests be introduced, or the feasibility of their control. However, since the risk of spread of these pests is high, large-scale infestations and tree mortality are likely to occur. Ecological effects of extensive tree death would be profound in the short run. Long-term impacts would depend on how quickly and completely the system recovered. Trees provide the energy that fuels ecosystems, and much of the habitat structure required by animals and microbes. Roots and associated microorganisms stabilize soils, thereby protecting watersheds, and canopies affect regional climates by cycling water and absorbing heat. Hence, the more total tree cover is reduced, and the longer it stays reduced, the greater will be the impact on local ecosystems, associated streams and rivers, and entire regions.

Loss of a significant proportion of living trees within stands would trigger complex changes in food supply and habitat. One of the first effects would be a shift in the pathways of energy flow through ecosystems, accompanied by changes in community composition. 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. The latter include a complex community of microbes, invertebrates, and from several score to perhaps several hundred vertebrate species (Harris, 1984). It is uncertain how many species could switch successfully from the living food chain to the detrital one; among those unlikely to make that transition are a number of mycorrhizal fungi, several species of voles, flying squirrels, and spotted owls.

Greater forage production beneath open canopies would provide more summer food for elk and deer; however, older closed-canopy forests are believed to be the most limiting habitats for elk in west-side forests (Raedeke and Lehmkuhl, 1986), and for deer in southeast Alaska (Wallmo and Schoen, 1980). Hence, the net effect on those animals would probably be negative. Other species that would be negatively impacted by loss of the habitat structure provided by old-growth or closed-canopy mature forests include western yew, spotted owl, and accipiter hawks. Species that depend on snags and logs for habitat would benefit in the short run from the pulse of dead wood, but would lose a future source of snags and logs.

With regard to aquatic habitat, the combination of more water moving through the soil and reduced root strength would increase the probability of surface erosion and mass soil movements, which would in turn pulse more sediment to streams (Swanson et al., 1989). Salmonids are particularly sensitive to sediments, which reduce aeration within spawning gravels. One study found that emergence of alevins from eggs declined from greater than 90 percent to less than 5 percent as the percentage of fine sands mixed with spawning gravels increased from 0 to 50 percent (Cedarholm and Salo, 1979).

Regional hydrology would be altered if trees were killed over a wide area. Reduced evapotranspiration and sublimation of snow from tree canopies would cause more of the yearly precipitation in heavy tree kill areas to run into streams (Bosch and Hewlett, 1982), while rainfall in downwind areas could decrease because less water was cycled back to the atmosphere (Andre et al., 1989; Newson and Calder, 1989). Without the modulating effect of upslope forests, stream flows would probably become more variable, with greater peak flows in the spring and lower summer water levels.

The long-term implications of the impacts discussed in this section depend critically on how fast the pest (or pests) spreads, and how quickly the system recovers from attack. A rapidly spreading, virulent pest would almost certainly destroy forests faster than they could recover, and species whose habitat is already limited (such as spotted owls) may be pushed toward extinction. Longer term effects of a more slowly spreading, or less virulent, pest could be relatively minor if new forests were established quickly; even suitable old-growth structure might be recouped in several decades if enough large trees survived to provide the basic structural framework. The establishment of new forests would depend on various factors, principally availability of seed, the degree to which pests attacked establishing seedlings, and other environmental stresses that might limit successful seedling establishment. In some areas of the Eastern United States, regeneration has completely failed due to the combined effects of defoliation by gypsy moth and deer feeding on the seedlings (Gottschalk, 1990).

System recovery from pest attack will depend upon abiotic factors such as climate. While the reality of global climate change is unpredictable, it is instructive to consider its implications relative to potential pest introductions. Successful seedling establishment is likely to become more difficult if the trees occupying a given site become increasingly maladapted to their local climate. Drought already hampers reforestation throughout much of the interior West and from southern Oregon south into California; increasing dryness can only exacerbate that problem. Heavy fuel loads will make young stands particularly vulnerable to wildfire (Franklin et al., 1989; Gottschalk, 1990), and a warmer, drier climate would greatly exacerbate fire danger. It is entirely possible that a combination of unusual stresses could tip forested sites into relatively stable grasslands or chaparral----such threshold changes have occurred, and may even be widespread (Perry et al., 1989). In some situations at least, including high-elevation forests of the Western United States, deforestation triggers physical and biological changes in soils that make reforestation more difficult; soils can actually lose their ability to support trees (Perry et al., 1989).

Potential ecological impacts of introduced pests upon ecosystems vary with the pest, the severity of damage, and the structure and health of the forest resource. An analysis of select pest species effects serves to illustrate the complexity of these interactions.

Asian Gypsy Moth

While the gypsy moth will potentially feed on a wide variety of western trees and shrubs, experience in the Eastern United States suggests that hardwoods will be most heavily affected. Gottschalk (1990) listed the following effects of the gypsy moth infestation in the Eastern United States:

- Higher water temperatures.
- Lower water quality.
- Less hard mast production (acorns); defoliation can result in several consecutive years of complete mast failure.
- More woody debris in streams.
- More snags, dens, and cavity trees.
- More understory vegetation and vertical stratification.
- . Altered microclimate due to loss of canopy cover.
- More patchiness within forests resulting from site-related tree mortality.
- Greater insect availability to consumers.
- Loss of nesting sites.

While most of these effects could be expected in the West as well, several factors argue that there would also be significant differences between Asian gypsy moth in western forests and European gypsy moth in the East. Unlike the European variety, female Asian gypsy moths fly (up to 40 km) and will disperse much more effectively. Furthermore, gypsy moth larvae survive better in dry summers than in moist ones (Leonard, 1974). Hence, other factors being equal, gypsy moth populations may have a higher growth potential in the West, where summers are drier than in the East. Species composition and structure of eastern and western forests differ in ways that are likely to influence gypsy moth behavior and patterns of defoliation. Many eastern forests are dominated by hardwoods with admixed conifers, while the situation is quite the opposite in most western forests-hardwoods are admixed with dominant conifers. That difference has two implications. Lower hardwood density might slow gypsy moth spread in western forests; on the other hand, older larvae will eat some conifer species, hence spread may be little affected by admixed conifers.

Unlike the East, where some hardwood species are relatively resistant, feeding trials indicate that western hardwoods are uniformly palatable to the insect (Miller and Hanson, 1989). In the relatively species-rich hardwood forests of the Eastern United States, gypsy moth infestations caused species composition to shift toward trees that were less susceptible to the insect, but had little or no long-term impact on total stocking (Herrick and Ganser, 1988). in the West, gypsy moths could shift mixed conifer-hardwood forests toward pure conifers, with the loss of certain roles played by hardwoods. Western forests that are dominated by hardwoods, including some keystone communities such as riparian zones, are relatively monotypic, and likely to be much more heavily affected than diverse eastern forests. In the West, defoliation will translate to losses in total tree cover, or to losses in keystone species such as nitrogen-fixing alders. Risk is greatest in riparian forests, and in upland forests with a significant hardwood component.

Riparian forests are frequently dominated by alders, maples, or, in the interior West, poplars; all of which are highly palatable to the gypsy moth (Miller and Hanson, 1989). These communities provide critical habitat for a variety of terrestrial animals, and link with streams in multiple ways. Riparian zones are considered the most critical wildlife habitats in the Blue Mountains of Oregon and Washington: “Of the 378 terrestrial species known to occur in the Blue Mountains, 285 are either directly dependent on riparian zones or utilize them more than other habitats” (Thomas et al., 1979). Riparian zones play the same keystone role in western Oregon and Washington (Oakley et al., 1985), and in the arid interior (McKern, 1976). Removing riparian trees increases productivity of headwater streams since more light stimulates primary production within the stream, but it also raises water temperatures and could destabilize stream banks by increasing the silt load. Both effects would be detrimental to salmonids.

Hardwoods commonly occur intermixed with conifers in upland forests west of the Cascade crest. Alders are common pioneers on disturbed sites, where they play a keystone role as nitrogen-fixers. Maples frequently form a secondary canopy layer in mature Douglas-fir forests. Hardwoods are a particularly important component of the so-called mixed conifer forests that cover extensive upland areas from southern Oregon through California and Arizona, while relatively monotypic oak woodlands frequently occur at lower elevations in the same areas. in California alone, hardwoods occur on 21.3 million acres of forest or Savannah (more than 20 percent of the total land area in the State), including 9 million acres classified as hardwood forest types and 1.8 million acres of Savannah (Bolsinger, 1988).

The effect of gypsy moth defoliation and subsequent tree mortality in mixed-species forests could shift communities toward greater dominance by conifers, with varying long-term ecological effects, depending on the degree to which hardwoods are reduced. In some cases, past management practices have inadvertently shifted forests toward a greater hardwood dominance than probably occurred in the past; some hardwood defoliation would increase biological diversity in these situations by permitting conifers to be reestablished. However, extensive hardwood defoliation throughout the region would diminish tree diversity and affect animals as well. Biologists generally agree that conifer monocultures support fewer animal species than mixed forests (Salwasser and Tappeiner, 1981). As flowering plants within conifer forests, hardwood nectar provides a unique source of food for some animals. Loss of hard mast (acorns) as a result of oak defoliation was a primary concern in the Eastern United States (Gottschalk, 1990) and would also be a factor in the West.

In addition to their role in supplying habitat and food, hardwoods are keystone players in certain processes within mixed conifer forests. Nitrogen fixation is clearly one of these, but even non-nitrogen-fixing species strongly influence soil fertility by accumulating cations and stimulating nutrient cycling (Klemmedson, 1987; Amaranthus et al., 1990; Borchers and Perry, 7990; Freid et al., 1990). Hardwoods are better adapted than many conifers to quickly recover from catastrophic disturbance, and stabilize soils during the critical early stages of system recovery following wildfire or clearcutting (Amaranthus and Perry, 1989; Borchers and Perry, 1990). Considerable anecdotal evidence indicates that some hardwoods are relatively inflammable and protect admixed conifers from fire. The strong regenerative capacity of hardwood species within the mixed conifer type could allow them to recover quite well from one or perhaps several defoliations. However, chronic defoliation would eventually exhaust that capacity.

Oak woodlands are quite monotypic, hence defoliation would translate to lost tree cover rather than shifts in species composition. Valley oak forests in California are already threatened because of various factors that have greatly reduced regeneration success (Bolsinger, 1988), and extensive defoliation would probably convert these forests to annual grasslands. Despite their relatively low tree species diversity, oak forests provide important animal habitat. They are important winter range for deer, and support a surprising diversity of breeding birds (Landres and MacMahon, 1983); extensive loss of oak woodlands would seriously threaten at least one of these, the acorn woodpecker.

Nun Moth

The nun moth has tremendous potential for extensive defoliation of western forests; probable hosts cover 172 million acres in the Western United States (including Alaska), and extensive areas of Canada. Virtually all forests west of the Cascade Crest would be vulnerable, as would high elevation spruce-fir forests throughout the Cascades, Rockies, and Sierras. All boreal conifers, except lodgepole and jack pines, would be vulnerable.

The nun moth is reported to defoliate trees more rapidly and completely than spruce budworm and tussock moth, the two most common native defoliators in spruce-fir forests. Hence, tree mortality would almost certainly be greater in a nun moth infestation than is the case with the native defoliators. Experience with gypsy moth suggests that 60 percent defoliation is a critical level beyond which hardwoods must use vital reserves to refoliate (Herrick 'and Ganser, 1987); however, conifers are more likely to die following complete defoliation than hardwoods (CDFA, 1982). As discussed earlier, the ecological factors that reduce outbreaks of native pests (tree resistance, natural enemies) seldom operate as effectively on exotic pests; hence, barring some unforseen control agent, nun moths would have a significantly greater long-term impact on ecosystems and regions than the native defoliators.

The most probable outcome of nun moth establishment in the United States is complete conversion of vegetation type in susceptible forests. Ecological impacts would depend on the nature of the conversion. If converted to pine, habitats would be altered somewhat, but basic ecological processes such as nutrient and water cycling would probably remain intact. If converted to nonforest vegetation, effects on both habitats and ecosystem processes would be considerable.

Under favorable conditions, high elevation spruce-fir forests in the Rockies would probably be replaced by lodgepole pine, while boreal spruce-fir would be replaced by lodgepole pine, jack pine, aspen, and alder (assuming that the hardwoods are not attacked by gypsy moth). Rocky Mountain forests without a nearby source of colonizing pine would probably convert to shrubs, forbs, and grasses. High elevation true fir forests on the west slopes of the Cascades support no hardwoods, and only rarely pines, so these forests would probably convert to grasses, sedges, and shrubs. This has already happened in many high elevation clearcuts. Pines do not occur in Douglas-fir/western hemlock and Sitka spruce/western hemlock forests, and the hardwood trees within these types are generally restricted to Jnoist sites. Assuming no gypsy moth infestation, alders and maples would tend to replace conifers in the moist Sitka spruce/hemlock types of the west slopes of the coast range. In the Douglas-fir/hemlock type, those species are likely to successfully replace conifers only on north slopes and other moist microsites. Many of the west-side forests now dominated by Douglas-fir could be converted to nonforest.

Potential ecological impacts of this insect correspond to those discussed earlier for a widespread, lethal pest, especially in forest types with few or no resistant tree species. The combined effects of altered habitats and food supply would produce complex responses in animals that are beyond the scope of this report to analyze in any detail. One food chain that would almost certainly collapse in western Oregon and Washington is that based on truffles, which includes several species of mycophagous small mammals that are virtually the sole prey of the spotted owl. It is difficult to see how remaining owls could survive a combined loss of remaining habitat and food supply. On the other hand, insect-eating birds would benefit, at least in the short run. Elk and deer would gain summer food in herbaceous and shrubby undergrowth, but that could outweigh the loss of winter food and thermal cover. Because they remain relatively snow-free, old-growth coniferous forests are critically important winter foraging areas for elk and deer (Wallmo and Schoen, 1980; Witmer et al., 1985). Extensive loss of forest cover in the Western United States and Canada would lead to the destruction of an important source of carbon sequestering.

Pine Wood Nematode

Of the two western pines believed susceptible to this pest, the Jeffrey pine has a relatively narrow distribution and usually occurs in mixed stands, while the ponderosa pine is widely distributed and often occurs in monotypic stands. Therefore, the greatest ecological impacts would be associated with infestation of the latter species.

The pine wood nematode is highly lethal to pines, but only in areas where the mean July temperature exceeds 20 °C (Rutherford et al., 1990). Siberian nematode Strains that operate at lower temperatures are possible. According to climatic data compiled by Neilson et al. (1989), July temperatures in the southern interior West, circa 42 degrees north latitude, average greater than 20 "C. The areas of maximum ponderosa pine development includes southern Oregon, California, Arizona, and New Mexico. The low elevation stands most likely to be attacked are relatively pure ponderosa pine forests that occur in an elevation band immediately above oak woodlands, chaparral, rangelands, or pinyon juniper, depending on locale (Shelford, 1963). In theory, death of the pines would convert the pine stands to whatever type formed their lower boundary. In fact, one or more of the many exotic weeds that have a strong foothold in the West (for example, cheatgrass) are likely to be the first to invade areas' with heavy tree kill. Once established, the weeds would make it more difficult for other plants to invade. Nematodes would affect higher elevation forests in two ways if the climate warms as predicted. First, pines growing at higher elevations would become vulnerable. Second, the loss of ponderosa pine would eliminate the tree that is most likely to colonize areas vacated by spruce-fir forests as the latter migrate upward in elevation. The end result would be further spread of exotic weeds up the mountain slopes (these weeds are highly aggressive and will spread to high elevations once tree cover is lost) (Amaranthus and Perry, 1987).

As with losses of forest cover discussed earlier, extensive death of ponderosa pine forests would alter habitats, regional hydrology, water quality, and carbon stores. Ponderosa pine forests are heavily used by animals. Thomas et al. (1979) list 135 species that use ponderosa stands for feeding, and 95 species that use them for breeding; few rely solely on ponderosa forests. One animal that does depend on ponderosa pine for most of its food is the tassel-eared squirrel (*Sciurus aberti*), which is native to the southern Rockies (Keith, 1965). Extensive loss of ponderosa pine in the Southwest would very likely drive that species toward extinction. Effects on most other animals, indeed on all ecological factors, would depend on whether ponderosa forests were converted to nonforest vegetation or to other forest types (such as, pinyon-juniper or, barring gypsy moth, oaks). Conversion to nonforest would have the greatest impact. For example, of 35 bird species recorded by Szaro and Balda (1979) in Arizona ponderosa pine, 25 would not breed in clearcuts. The pulse of snags and secondary insects (bark beetles) would favor some bird species in the short run; however; longer term effects would be detrimental to those guilds as well. Ponderosa pine snags are important nest sites for pileated woodpeckers, but other trees might serve as adequate substitutes. Deer and elk would find more summer forage beneath the openings created by tree kill, but less thermal cover and winter forage; the net effect on those animals would depend on what was most limiting in any given area.

Extensive death of ponderosa pine in any one region would significantly affect the hydrologic cycle. According to one model, streamflows in the Southwest would increase by one-third with an 80-percent loss of ponderosa pine cover (Covington and Wood, 1988). Greater flow of water to streams would result in decreased rainfall to downwind areas.

Larch Canker

A primary ecological role of western larch is colonization of disturbed sites at mid- to upper elevations in the intermountain region and northern Rockies. Other species also play that role, especially lodgepole pine and Douglas-fir, and to a lesser extent white pines and Engelmann spruce. While the immediate effect of extensive larch mortality would probably accelerate conversion to late successional forest types, the more serious long-term impact would be loss of redundancy in the early seral tree guild. In essence, the burden of maintaining early successional tree cover in the spruce-fir zone would shift to lodgepole pine, spruce, and on drier sites, Douglas-fir.

Late successional trees in western conifer forests are prone to fire, insects, and diseases, and will become more so if the climate changes as predicted. The early successional tree species play a vital, important ecological role in these ecosystems by maintaining continuity in forest cover, thereby preserving habitat, and protecting soils and watersheds. Though other early seral trees would fill some of the niche vacated by larch, they are unlikely to fill it. Consequently, with the reduced presence of larch, the probability that disturbed spruce-fir stands will convert to relatively persistent nonforest vegetation would increase. Ecological effects would be similar to those discussed earlier for conversion of forest to nonforest, with the severity of the effect critically depending on how effectively other early seral trees replaced larch.

Annosus Root **Disease**

Annosus root disease already causes widespread growth loss and mortality in true fir, old-growth hemlocks (150 years old and older) and ponderosa pine on dry sites. The fungus is capable of infecting a number of other western tree species; however, it appears to cause little mortality or growth loss in these species.

Ecological impacts of an imported strain (or strains) would depend on its aggressiveness compared to strains currently present in the Western United States. For example, a more virulent strain would probably be less restricted to drought-affected habitats and spread more widely throughout ponderosa pine stands than current strains. An introduced strain that successfully infected Douglas-fir, western larch, or lodgepole pine would greatly increase the area affected by the disease. Ecological impacts would include reduced vigor and increased mortality of important early successional tree species, with the same consequences that were discussed in the previous western larch section. A strain that was generally virulent, something that is at least theoretically possible in this fungus, has the potential to seriously disrupt western forests. Even if mortality resulting from the infection were low, trees would be less able to resist other biological and climatic stresses to which they either currently are or will be subjected to.

Spruce **Bark Beetle**

If introduced into Western North America, *Ips typographus* and its virulent fungal associate *Ophiostoma polonica* have the potential to kill spruce over large areas at unprecedented rates. Beetle epidemics triggered by wind storms, droughts, or other disturbances could greatly reduce or even eliminate Sitka and Engelmann spruce from stands where they are now major components.

Sitka spruce occurs mainly in moist, coastal forests. If killed by the spruce bark beetle, it would likely be replaced by western hemlock, western red cedar, and hardwood species, especially red alder.

Engelmann spruce generally occurs in harsher high-elevation ecosystems. If killed by beetles, it would probably be replaced by true firs, mountain hemlock, and lodgepole pine. In some cases, areas of extensive Engelmann spruce stands would not be reforested following a beetle epidemic unless they were planted.

Summary

Exotic pests pose a particular threat because they are generally free of the ecological constraints with which they have coevolved in their native habitat.

Risks associated with all pests are higher now than in the past because of stresses associated with disturbed habitats, reduced populations of natural enemies, and increased anthropogenic agents. The ecological effects of a pest depend on: host generality, the degree to which hosts play some keystone role, and the rate of spread compared to the rate at which attacked ecosystems recover. Extensive tree kill from one or more exotic pests would benefit some animals and threaten others, lower water quality, alter regional hydrology, increase the probability of wildfire, and reduce the carbon storage capacity of western forests. The primary impact of gypsy moths would be on hardwoods, which play a number of keystone roles in western forests; with warmer springs, gypsy moths might also successfully attack Douglas-fir. The nun moth could convert many conifer forests to either hardwoods or nonforest, particularly west of the Cascade Crest, with serious consequences for a number of animals, including spotted owls, salmon, and elk. Under current climatic conditions, the pine wood nematode would affect primarily lower elevation ponderosa pine stands in California and the Southwest, converting them to hardwood scrub or nonforest; at least one animal, the tassel-eared squirrel, would be endangered, and regional hydrology would be significantly altered. Extensive larch mortality caused by larch canker would reduce the presence of an important early-seral tree species, increasing the probability that at least some disturbed sites in the interior West would be captured by weeds. The effect of introduced strains of annosus root disease would depend on whether their host range and environmental tolerances differed significantly from strains currently present in the West. More than one lethal pest would increase the probability of large-scale conversion of western forests to nonforest. It is possible that the combined effects of environmental stress, greater activity of pests already present in western forests, and the introduction of new pests could create a scenario whereby the ecology of western forests would be rapidly degraded.

Chapter 7
Conclusions

Pests introduced into North America through the importation of unprocessed logs from Siberia and the Soviet Far East pose a significant risk to North American forests. A variety of exotic forest pests, including insects, nematodes, and fungi, can be transported on or in logs. Many of these organisms can survive in transit and have a high potential to colonize suitable hosts near ports of entry. The subsequent spread of these exotic pests beyond the colonized area could have severe adverse impacts on the economic and ecological value of North American forest resources.

Because of the numerous factors involved in any pest introduction, it is impossible to predict exactly which organisms might be introduced during log importation. Therefore, the histories of previous pest introductions were examined to provide insight into identifying and assessing the risks associated with the movement of plant material. The Six case histories presented in Chapter 3—on the gypsy moth, chestnut blight fungus, Dutch elm disease fungus, Port-Orford-cedar root rot fungus, pine wood nematode, and white pine blister rust-indicate that although introduced organisms are often innocuous or even unknown in their place of origin, they can have catastrophic effects when introduced into new environments. All but the gypsy moth were unknown as pests in their native habitats. These case histories also provided information on the scope and magnitude of the consequences associated with the importation of forest pests. This provided a basis for understanding and predicting impacts from the establishment and subsequent spread of pests that could be transported with Jogs from Siberia and the Soviet Far East.

A large number of pest species have the potential to be introduced. For this risk assessment, however, not enough time and data were available to evaluate the risks posed by every organism. The specific organisms evaluated during this assessment represent the types of pests that could be introduced on logs as hitchhikers, those that occur in the bark, and those that are within the wood (see tables 4-1, 4-2, and 4-3). This was done to facilitate the APHIS Management Practices Team's evaluation of effective mitigation measures.

Risk assessment profiles were developed for those pests considered to pose the greatest potential risk to North American forests and for which information is available on their life cycle, ecology, invasion ability, and their potential ecological and economic impacts. Mitigation practices developed for these known pests are presumed to be as effective in combating similar unknown pests. Nematodes, larch canker fungus, annosus root disease fungus, Asian gypsy moth, nun moth, and spruce bark beetle were the six pests considered to represent the greatest known risk to North American forests in the event of an introduction. Detailed assessments of the potential consequences of introduction and establishment were prepared for these pests (see Chapters 4, 5, and 6).

The potential economic costs associated with the introduction of these pests are high. These costs would result from reduced yields caused by growth loss, increased mortality, and defects in the host species-problems that lead to reduced stumpage prices. Table 7-1 summarizes the range of potential economic impacts to the commercial timber resources of the Western United States from the introduction and establishment of each pest group considered in the analysis. Note that expenditures for pest control and management should also be expected from such introductions.

Exotic pests pose a particular threat because they are generally free of the ecological constraints with which they have coevolved in their native habitat. The introduction and establishment of any organism could result in extensive mortality rates for host species. The resulting ecological effects on North American forests could include tree species conversions, deforestation, wildlife habitat destruction, degradation of riparian communities, increased fuel loading, and loss of biodiversity.

The following are some of the principal ecological impacts:

- Gypsy moths would affect hardwoods that play key roles in western forests.

Table 7-1. Summary of Economic Costs to the Timber Resources of the Western United States From Introducing Selected Soviet Forest Pests (All Ownerships Consist of Unreserved Timber)

Pest	Host	Economic Cost (millions 1990 $)		Affected Acres (millions)
		Best Case	Worst Case	
Nematodes	*Pinus* spp.	33.35	1,670.00	26.7
Larch canker	*Larix* spp.	24.90	240.60	0.8
Annosus root disease	*Pseudotsuga menziesii* *Larix* spp. *Pinus* spp.	84.20	343.90	9.6
Defoliators	*Pseudotsuga menziesii* *Picea* spp. *Abies* spp. *Tsuga* spp. Other	35,049.00	58,410.00	77.1
Spruce bark beetle	*Picea* spp.	201.00	1,500.00	8.1

- The nun moth would convert many conifer forests to hardwoods or nonforest, with serious consequences for a number of animals, including spotted owls, salmon, and elk.

- The pine wood nematode would affect ponderosa pine stands in California and the Southwest, converting them to scrub or nonforest. At least one animal, the tassel-eared squirrel, would be endangered, and the regional hydrology would be significantly altered.

- Larch canker would reduce the presence of larch, an important early seral species in western forests, increasing the probability that disturbed sites would be invaded by weeds.

- A new strain of annosus root disease would affect Douglas-fir stands, with consequences similar to those created by the nun moth.

- Spruce bark beetle and its associated pathogenic fungus would increase the probability that spruce forests would convert to nonforests.

This risk assessment focused on risks associated with importing larch logs from Siberia and the Soviet Far East. However, parallels can be drawn with other coniferous logs. Many of the organisms assessed have broad host ranges and could be imported on other types of logs. The grouping of organisms for assessing their transport potential can be applied to logs from any tree genera. The process of evaluating the risks associated with the importation of other logs would be the same. Although the magnitude of consequences may be different for any particular type of log, the methods for estimating risk would apply to other genera of logs.

A team of specialists from the U.S. Department of Agriculture (USDA), including members of the Pest Risk Assessment Team and the Management Practices Team, traveled to the U.S.S.R. to meet with Soviet scientists and foresters in early July 1991 to discuss the pest risk assessment and to view forest pests, forest harvesting practices, and log handling procedures in the Soviet Far East and Siberia. The USDA team met with forest entomologists and pathologists at V.N. Sukachev Institute of Forestry and Wood in Krasnoyarsk, the Siberian Technological Institute in Krasnoyarsk, and the Far Eastern Forestry Research Institute in Khabarovsk. These discussions and field observations (Appendix L) confirmed that the selection of pests of concern identified during the pest risk assessment process was accurate and that concern about their possible introduction into North American forests was justified (Appendix L).

In summary, importing unprocessed larch logs from Siberia and the Soviet Far East into North America can have serious consequences because of the potential for introducing exotic forest pests. Measures must be implemented to mitigate the risks of pest introduction and establishment.

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Appendix A
List of Pests Intercepted by Other Countries on Logs From the Soviet Union

Insect Species Found in Log (With Bark) of P. *abies* and P. *sylvestri* Imported From the Soviet Union to Sweden

Insect Species	State in Life Cycle	Number of Loads in Which Species Detected
Coleoptera		
Carabidae		
Trachypachus zetterstedti (Gyllenhal)	I	1
Bcmbidion guttula (Fabricius)	I	2
Bembidion grapii Gyllenhal	I	1
Dromius quadraticollis Morawitz	I	1
Trichocellus placidus (Gyllenhal)	I	1
Synfomus truncatellus (Linnaeus)		1
Hydrophilidae		
Cercyon analis (Paykull)		
Helophorus granularis (Linnaeus)	I	1
Leiodidae		
Agathidium atrum (Paykull)	I	
Staphylinidae		
Philonthus varians (Paykull)	I	
Philonthus carbonarius Gravenhorst		
Gnbrius vernalis (Gravenhorst)		1
Gabrius toxotes Joy		
Nudobius lentus (Gravenhorst)	I	1
Quedius mesomelius (Marsham)	I	
Qucdius boopoides Munster	I	1
Othius myrmecophilus Kiesenwetter		1
Megarthus sinuatocollis Lacordaire		2
Proteinus brachypterus (Fabricius)	I	1
Acrulia inflata (Gyllenhal)		
Omalium rugatum Mulsant & Rey	I	1
Omalium excavatum Stephens		1
Omalium caesum Gravenhorst	I	2
Phloeonomus lapponicus (Zetterstedt)	I	3
Phloeonomus pusillus (Gravenhorst)	I	3
Acidota crenata (Fabricius)		
Phloeocharis subtilissima Mannerheim		
Anotylus rugosus (Fabricius)	I	
Tricophya pilicornis (Gyllenhal)	I	
Mycetoporus lepidus (Gravenhorst)	I	1
Mycetoporus rufescens (Stephens)		
Lordithon trinotatus (Erichson)	I	
Sepedophilus lit forms (Linnaeus)	I	3
Sepedophilus testaceus (Fabricius)		

Sepedophilus constans (Fowler)	1	1
Tachyporus chrysomeiinus (Linnaeus)	1	1
Oxypoda *opaca* (Gravenhorst)	1	1
Oxypoda umbrata (Gyllenhal)	1	2
Oxypoda skalitskyi Bernhauer	1	1
Oxypoda haemorrhoa Mannerheim	1	1
Phloeopora testacea (Mannerheim)	1	2
Geostiba circellaris (Gravenhorst)	1	1
Afheta melanocera (Thomson)		1
Atheta fungi (Gravenhorst)	1	2
Afhefu sodalis (Erichson)	1	2
Atheta trinofatu (Kraatz)	1	1
Atheta atramentaria (Gyllenhal)	1	2
Atheta hypnorum (Kiesenwetter)	1	1
Atheta graminicola (Gravenhorst)	1	1
Atheta pygmaea (Gravenhorst)	1	1
Afhefa obfuscata (Gravenhorst)	1	1
Afhefu parens (Mulsant & Rey)	1	1
Afhefa deformis (Kraatz)		1
Afhefa nigra (Kraatz)		1
Afhefu myrmecobia (Kraatz)	1	1
Afhefa laticollis (Stephens)		1
Atheta lateralis (Mannerheim)		1
A theta pertyi (Heer)	1	1
Atheta sordida (Marsham)		1
Atheta aterrima (Gravenhorst)		1
Dinaraea aequata (Erichson)		2
Dinaraea linearis (Gravenhorst)		1
Amischa analis (Gravenhorst)	1	1
Drusilla canaliculatus (Fabricius)		1
Leptusa pulchella (Mannerheim)		1
Pachygluta ruficollis (Erichson)		1
Anomognathus cuspidatus (Erichson)		1
Homalota plana (Gyllenhal)		1
Placusa complanata Erichson		3
Placusa tachyporoides Waltl		1
Placusa depressa Mäklin	1	1
Placusa incomplefu Sjöberg	1	2
Placusa atrata (Sahlberg)		2
Stenus clavicornis (Scopoli)		1
Stenus humilis Erichson	1	1
Bryaxis puncticollis (Denny)	1	1
Pselaphidae		
Euplectus karsteni (Reichenbach)		1
Histeridae		
Plegaderus vulneratus (Panzer)		1
Helodidae		
Cyphon variabilis (Thunberg)		1
Cyphon pubescens (Fabricius)		1
Elateridae		
Athous subfuscus (Müller)	1	1
Cleridae		
Thanasimus formicarius (Linnaeus)	1	1

Nitidulidae		
Melighetes aeneus (Fabricius)	I	1
Epuraea boreella (Zetterstedt)	I	1
Epuraea unicolor (Olivier)	I	2
Epuraea rufomarginata (Stephens)	I	3
Epuraea abetina J. Sahlberg	I	1
Epuraea bickhardti Saint-Claire Deville	I	2
Epuraea pygmaea (Gyllenhal)		2
Glischrochilus quadripunctatus (Linnaeus)	I	2
Pityophagus ferrugineus (Linnaeus)	I	1
Rhizophagidae		
Rhizophagus bipustulatus (Fabricius)	I	1
Monotomidae		
Monotoma longicollis (Gyllenhal)	I	1
Cucujidae		
Dendrophagus crenatus (Paykull)	I	1
Silvanus bidentatus (Olivier)	I	3
Silvanoprus fagi (Guerin-Meneville)	I	2
**Uleiota planata* (Linnaeus)	I	1
Cryptophagidae		
Cryptophagus abietis (Paykull)	I	1
Cryptophagus dentatus (Herbst)	I	3
Cryptophagus dorsalis Sahlberg	I	1
Atomaria procerula Erichson	I	3
Atomaria peltata Kraatz	I	1
Atomaria fuscata (Schönherr)	I	1
Atomaria lewisi Reitter	I	2
Atomaria beroliensis Kraatz	I	1
Atomaria pulchra Erichson	I	1
Atomaria atrata Reitter	I	1
Cerylonidae		
Cerylon deplanatum Gyllenhal	I	1
Corylophidae		
Sacium pusillum (Gyllenhal)	I	2
Orthoperus mundus Matthews	I	1
Latridiidae		
Enicmus transversus (Olivier)		1
Enicmus histrio Joy & Tomlin	I	1
Aridius nodifer Westwood	I	1
Corticaria rubripes Mannerheim	I	2
Corticaria pubescens (Gyllenhal)	I	1
Corticaria lateritia Mannerheim	I	1
Corticarina fuscula (Gyllenhal)	I	1
Colydiidae		
Lasconotus jelskii (Wankowicz)	I	1
Mycetophagidae		
Litargus connexus Fourcroy	I	2
**Mycetophagus salicis* Brisout de Barneville	I	1
Pythidae		
Pytho depressus (Linnaeus)	L,I	1
Tenebrionidae		
Corticeus suturalis Paykull		1
Corticeus linearis Fabricius		1

Anaspidae		
Anaspis rufilabris (Gyllenhal)		
Tetratomidae		
Tefrufoma ancora Fabricius	I	1
Cerambycidae		
Tetropium castaneum (Linnaeus)	L,i	2
Callidium coriaceum (Paykull)	I	2
Monochatnus galloprovincialis (Olivier)	I	1
Monochamus sutor (Linnaeus)	L,I	2
Acanfhocinus aedilis (Linnaeus)	i	1
Acanthocinus griseus (Fabricius)	I	1
Chrysomelidae		
Hydrothassa marginella (Linnaeus)	I	1
Chaetocnema concinna (Mar-sham)	I	1
Curculionidae		
Anthonomus pinivorex Silverberg		1
Scoly tidae		
Tomicus pinipwda (Linnaeus)	I	3
Hylurgops palliatus (Gyllenhal)	L,I	5
Hylurgops glabratus (Zetterstedt)	L,I	2
Hylastes brunneus Erichson		
Hylastes cunicularius Erichson	I	1
Hylastes opacus Erichson	I	
Pityogenes chalcographus (Linnaeus)	L,I	5
Orthotomicus proximus (Eichhoff)	L,I	4
Orfhofomicus suturalis (Gyllenhal)	L,I	4
Xylechinus pilosus (Ratzeburg)	I	
Polygraphus subopacus Thomson		
Carphoborus rossicus Semenov	I	1
Crypturgus pusillus (Gyllenhal)		2
Crypturgus cinereus (Herbst)	I	1
Dryocoefus autographus (Ratzeburg)	I	1
Dryocoetus hectographus (Rei tter)	L,I	1
Trypodendron lineatum (Olivier)		3
lps duplicafus (Sahlberg)	L,I	4
lps typographus (Linnaeus)	L,I	4
Hemiptera		
Dufouriellus ater (Dufour)	I	1

Notes: Six different shipments were inspected.
L = larvae/pupae, I = adults, * = not indigenous to Sweden.

Lists of Pests Intercepted on Logs Imported From the U.S.S.R. Into China (Reported by Department of Pest Quarantine, Peoples Republic of China)

Blastophagus spp. (pine bark beetles)
Hemiberlesia pifysophila Takagi (pine stem scale)
Hyphantria cunea (Drury) (American White Moth)
Ips typographus L. (spruce bark beetles)
Monochamus alternatus Hope (pine black ink wood borer)
Pissodes nitidus Roelofs (red wood weevil)

Pityogenes bistridentatus Eichh (Russian pityogenese bark beetles)
Pityogenes bidentatus Herbst. (two-teeth Pityogenes bark beetles)
Pityogenes bidenfafus Herbst.
Polygraphus sachalinensis Egger
Pteleobius uittatus F. (elm xylem bark beetles)
Scolytus multistriatus (Marsham) (European elm bark beetles)
Scolytus ratzeburgi Janson (birch phloem bark beetles)
Scolytus scolytus Fabricius (European elm small bark beetles)
Bursaphelenchus xylophilus (Steimenter & Buhrar) Nickle (pine nematode wilt)
Ceratocystis fagacearum (Bretz) Hunt (oak wilt)
Ceratocystic ulmi (Buisman) Moreall (Dutch elm disease)

Bark Beetles Found on Soviet Timber Imported Into Japan

Larix

Cryphalus latus Eggers
Dryocorfes baicalicus Reitter
Ips cembrae (Heer)
Orthotomicus laricis (Gyllenhal)

Picea

Hylurgops glabratus (Zetterstedt)
Hylurgops palliatus (Gyllenhal)
Hylurgops transbnicalicus Eggers
Polygraphus gracilis Niijima
Polygraphus jezoensis Niijima
Polygraphus subopacus Thomson
Carphoborus teplouchovi Spessivtseff
Dendroctonus micans (Kugelann)
Crypturgus pusillus (Gyllenhal)
Crypturgus tuberosus Niijima
Dryocoetes autographus (Ratzeburg)
Dryocoetes hectographus Reitter
Dryocoetes rugicollis Eggers
Pityogenes chalcographus (L.)
Ips acuminatus (Gyllenhal)
Ips duplicatus (Sahlberg)
Ips typographus (L.)
Orthotomicus suturalis (Gyllenhal)
Orthotomicus golovjankoi Pjatni tzky
Trypodendron lineatum (Olivier)
Xyleborus pfili (Ra tzeburg)

Note: *Trypodendron lineatum* (Olivier) and *Xyleborus pfili* (Ratzeburg) are xylomycetophagous ambrosia beetles and others are phloeophagus bark beetles.

Abies

Hylurgops glabratus (Zetterstedt)
Polygraphus oblongus Blandford
Xylechinus pilosus (Ratzeburg)

Dryocoetes sfriatus Eggers
Dryocoefes hectographus Reitter
Dryocoetes rugicollis Eggers

Pinus

Hylurgops interstitialis (Chapuis)
Hylurgops spessiwzeffi Eggers
Ips acuminafus (Gyllenhal)
Ips duplicatus (Saahlberg)
Ips sexdenfafus (Boerner)
Trypodendron lineafum (Olivier)

Notes: Abundant species are *Ips typographus, Pityogenes charchographus,* Orfhotomicus *golovjankoi,* and *Polygraphus jezoensis* in *Picea; Polygraphus proximus* in *Abies; lps cembrae* and *Dryocoetes baicalicus* in *Larix*; and *Ips acuminatus* in *Pinus.*

The most important bark beetles are *Ips typographus* in *Picea; Polygraphus proximus* in *Abies; lps cembrae in Larix;* and *Ips acuminatus* in *Pinus.*

Scolytidae Found in Siberian Timber

Scolytus ratzeburgi Janson
Hylurgops glabaratus (Zetterstedt)
Hylurgops interstitialis (Chapuis)
Hylurgops palliatus (Gyllenhal)
Hylurgops spessiwzeffi Eggers
Hylurgops fransbaicalicus Eggers
Polygraphus gracilis Niijima
P. *jezoensis* Niijima
P. proximus Blandford
P. subopacus Thomson
Carphoborus teplouchovi Spessivtseff
Xylechinus pilosus (Ratzeburg)
Dendroctonus micans (Kugelann)
Blastophagus minor (Hartig)
Cryphalus latus Eggers
Crypturgus pusillus (Gyllenhal)
C. *tuberosus* Niijima
Dryocoetes autographus (Ratzeburg)
D. striatus Eggers
D. baikalicus Reitter
D. hectographus Reitter
D. rugicollis Eggers
Pityogenes chalcographus (Linne.)
Ips acuminufus (Gyllenhal)
Jps duplicatus (Sahlberg)
Ips typographus (Linne.)
Ips cem brae (Heer)
Ips sexden ta tus (Boerner)
Orthotomicus suturalis (Gyllenhal)
O. larcis (Gyllenhal)

0. *golovjankoi* Pjatnitzky
Trypodendron lineatum (Olivier)
Xyleborus pfili (Ratzeburg)

List of Pests Intercepted on Siberian Timber in Korea

Asemum striatum
Leiopus stillatus
Tetropium castaneum
Ips acuminafus
Ips sexdenfafus
Ips cembrae
Scolyfus ratzeburgi
Hylurgops inferstitialis
Pityogenes seirindensis

Appendix B
Letters of Correspondence Between APHIS and the Forest Service

United states Department of Agriculture
Pore3 t Service
Washington Office
14th & Independence SW
P.O. Box 96090
Washington, DC 20090-6090

Reply To: 3400

Date: OCT 5 1990

Dr. James W. Glosser
Administrator
Animal and Plant Health Inspection Service
U.S. Department of Agriculture
Washington, DC 20250

Dear Dr. Glosser:

As you know, California and the Pacific Northwest forest industries are seeking alternative sources of sawtimber to offset expected harvest reductions from Federal lands. Considerable interest is being expressed in importing pine and larch logs Prom the Siberian forests of the USSR. We know of at least two trial shipments of Scots pine that entered through California, Those shipments Here embargoed by the California Department of Agriculture and fumigated before proceeding to their destination. Much of our information on this activity came to us through the cooperative efforts of your State and National Headquarters' staffs.

While the Forest Service supports forest Industry efforts to locate new supplies of raw materials, we are concerned about the potential for the introduction of exotic forest pests. Forest Service scientists who have traveled extensively throughout the USSR warn us that prospects are excellent for successful introduction and establishment of pests originating from tbat area into North America, since we have similarities in host species and pest genera.

We anticipate strong, continued interest by the forest industry in importing logs from Siberia and possibly other regions of the Soviet Union. We are requesting that APKIS proceed with the development of regulations to minimize the risk of introducing exotic forest pests as a result of this activity. Forest Service research scientists and pest management specialists are available to provide information and to help develop the necessary regulations. Dr. Kenneth Knauer, Assistant Director, Forest Pest Management, will coordinate our participation in this effort. He can be reached at FTS 453-9600.

Sincerely,

for F. DALE ROBERTSON
Chief

United States
Department of
Agriculture

Animal and
Plant Health
Inspection
Service

Subject Importation of Siberian Logs from Soviet Siberia

Date: DEC 05 1990

To. Kenneth Knauer, Assistant Director
Forest Pest Management
Forest Service
Auditors Building, 2S
Washington, D.C. 20250

As indicated in our memorandum dated November 20 to F. Dale Robertson, we are providing further information concerning the subject issue.

APHIS developed a provisional assessment for use in current efforts by a team of State and Federal regulatory and forestry agencies developing a management strategy for the importation of Siberian logs. Ongoing active involvement by your Agency is crucial to the success of this team. We view this team's efforts as the initial step toward resolving the larger issue of importation of logs. The team has determined that an expanded technical assessment is required. Because of the recognized leadership and technical credibility of the Forest Service, we request that your Agency take the lead in development of this assessment.

Discussions to this point have identified the following risk communication requirements of such a document:

- Zdentify the exotic organisms with potential to be pests that may move with forest products from Siberia.
- Assess the potential of colonization of groups or individual pests during the process of importing, processing, and utilizing logs.
- Assess the relative potential impacts of organisms identified should they become established.

As you are aware, there is considerable interest within the technical community in this issue as well as a wide array of individuals who could contribute in this effort. We would like to meet with you at your earliest convenience to determine the scope and plan of action for this effort. Please contact Michael J. Shannon, Chief Operations Officer of our Planning and Design staff, at 436-8716.

B. Glen Lee
Deputy Administrator
Plant Protection and Quarantine

United States Department of Agriculture

Animal and Plant Health inspection Service

Washington, DC 20090-6464

Subject: Tmportation of Siberian Logs from Soviet Siberia

Date: OV 2

To: F. Dale Robertson, Chief
Forest Service

This is in response to your timely letter of October 5 expressing concern about the potential pest hazards associated with the importation of logs from Soviet Siberia. It is important that the Animal and Plant Health Inspection Service (APHIS) react in a judicious manner to this new avenue of risk to American forestry. We appreciate the opportunity to work with your staff in addressing this important issue.

APHIS and the Forest Service have worked together on this issue before. In 1983, an assessment was made of the exotic pest threat associated witt wood products. One outcome of this effort was a proposal for regulating various types of wood products, including logs from temperate areas of the world. At that time such imports were rare. Now that trade patterns have changed, it is appropriate that we reexamine the need For such regulation. This matter was discussed at the October 1990 meeting of the North American Forestry Commission where interest and concern were expressed by the Canadian, Mexican, and U.S. participants. It would be appropriate to seek solutions to this problem cooperatively with Mexico and Canada.

APHIS conducted a meeting on November 6 in San Francisco to evaluate alternatives for importation of Siberian logs which would minimize the risk of introducing exotic pests. Participants included representatives from APHIS headquarters and field units. Forest Service, State regulatory agencies, Agriculture Canada, and various industries. In the process of developing an approach to managing the hazards associated with Siberian logs, we will address the need for and probable content of a Federal regulation.

We will contact Dr. Knauer of your Forest Pest Management staff to begin developing a joint position addressing this issue of mutual concern. We appreciate the opportunity to work with your scientists and technical specialists in resolving this issue.

James W. Glosser
Administrator

cc:
K. Knauer, FS, Washington, DC

Appendix C
Estimated Potential Volume of Soviet Log Imports to the United States

Summary

The following estimations of potential Soviet log imports to the United States are based upon University of Washington (CINTRAFOR) publications; discussions with Dr. Thomas Waggener, University of Washington; and data gathered from a survey of timber companies and trading companies negotiating with the Soviet Union for trade in forest products.’ Survey data were gathered in confidence and can only be shared in the aggregate at this time. The purpose of estimations of potential imports is for use by the U.S. Department of Agriculture Pest Risk Assessment Team to better understand the potential scope of importation of logs from the Soviet Union. An interesting caveat arises from one assumption in particular. The assumption that Soviet economic and political changes will stay on course implies that Soviet and American intentions in forest products trade will proceed to conclusion. However, if Soviet changes do stay on course, one may conclude that a free market system with a real pricing mechanism would be established and that the ruble would become convertible on the world market. If this happens, predictions about Soviet forest products trade with the West would become difficult because no historical background exists for the transformation of command economies to free market economies.

Assumptions

Estimates given in this appendix are based on the following assumptions:

- Volume estimates assume no significant capital investment in Soviet forest industry infrastructure.
- All U.S. imports would be in log form.
- No significant changes would occur in labor structure of the Soviet Far East and Siberia.
- No significant barriers to importation instituted by the United States.
- “Bonafide” U.S. companies would be successful in negotiations for timber contracts with the Soviet Union.
- Survey data are assumed to be accurate (company import target variations = 0).
- No unsurveyed companies are included (100 percent survey).
- Stated intentions of companies are true for the short run.
- For companies unable or unwilling to estimate volumes for U.S. import, a value of zero was used (assumes negative correlation between no volume estimate5 and “bonafide” company).
- Soviet economic and political changes would stay on course.

Estimations of Soviet Timber Imports to the United States

CINTRAFOR Studies

Soviet Far East (year 2000):
- Potential increased output . . . . 800–1,200 mmbf/yr
- Potential percent imported by the U.S. . . . . 5–10 percent/yr
- Potential volume imported by the U.S. from Soviet Far East . . . . 40–120 mmbf/yr
- Above considers problems of: infrastructure constraints
  environmental & ecological constraints
  labor & capital constraints
  physical factors
  economics

Eastern Siberia:
- No current estimates. Currently under study by CINTRAFOR . . . . Xmmbf/yr
- Total CINTRAFOR estimates for all U.S.S.R. . . . . 40-120 mmbf + Xmmbf/yr

Industry Survey

Soviet Far East (6 months or more):
- Potential aggregate volume imported by the U.S. from U.S.S.R. . . . . 200 mmbf/yr

Eastern Siberia (18 months to 5 years):
- Potential aggregate volume imported by the U.S. from U.S.S.R. . . . . 225 mmbf/yr
- Total industry estimates for all U.S.S.R. . . . . 425 mmbf /yr

Range Estimation

Soviet Far East (CINTRAFOR) + Eastern Siberia (Industry) = Total
40–120 mmbf + 225 mmbf = 265-345 mmbf/yr
Soviet Far East (Industry) + 225 mmbf = 425 mmbf/yr
Potential annual volume imported by the U.S. from U.S.S.R. . . . . 265-425 mmbf/yr

Appendix D
Soviet Forest Resources and Host Timber Species Profiles

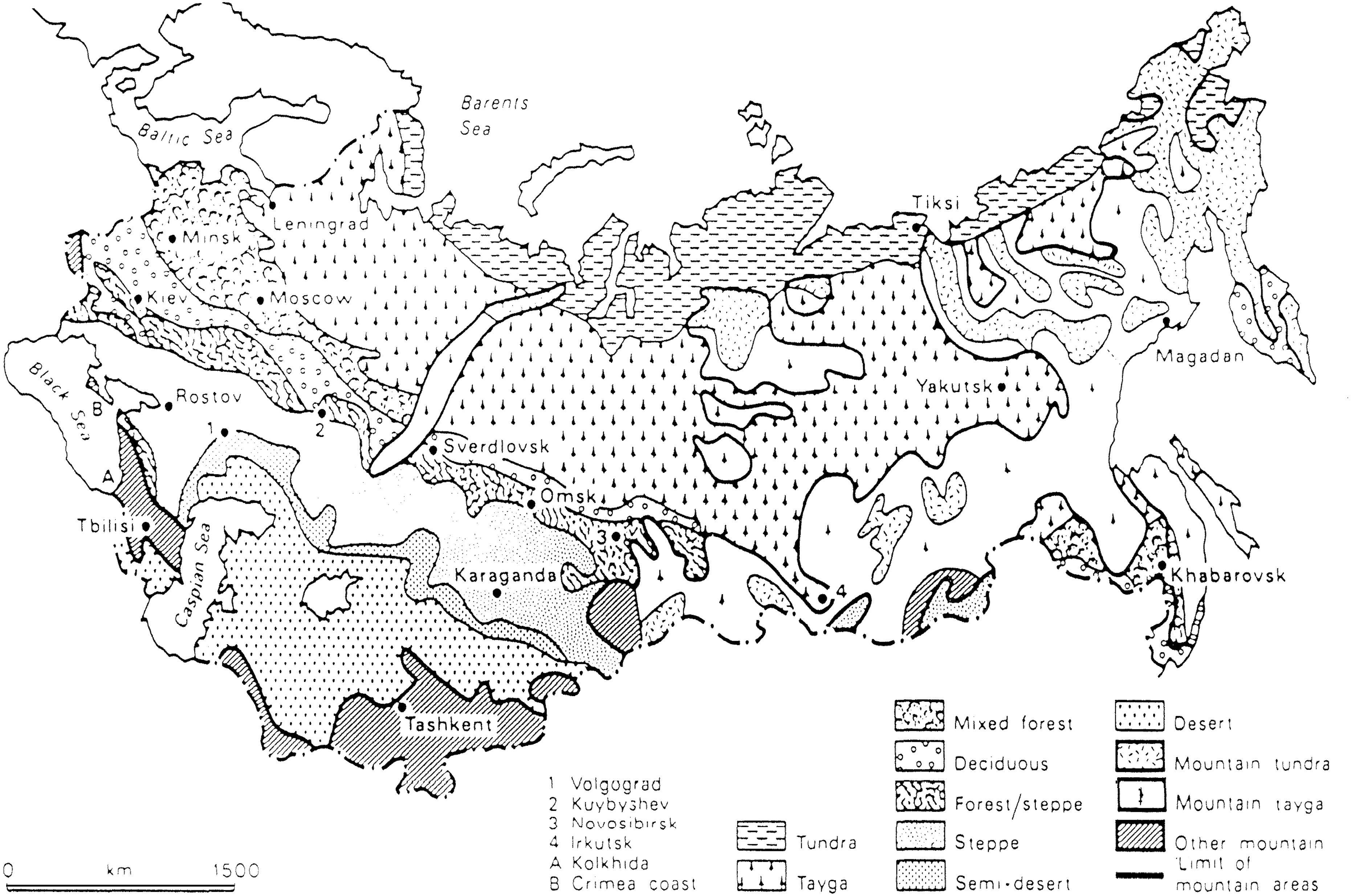
Soviet Forest Resources

The Soviet Union has the largest forest resources, by far, of any country in the world. Altogether the Soviet Union has approximately 1,259.4 million hectares of forested land. This represents about 56 percent of the country's area. Stocked productive land accounts for 810.9 million hectares or more than 36 percent of the total area of the Soviet Union. This represents 22 percent of the world's total forest resource and more than 53 percent of the world's coniferous reserves (Holowacz, 1985). Therefore, the management and rational use of this enormous resource are increasingly becoming a matter of concern in the Soviet Union and abroad.

Although a detailed description of the vegetative zones and physiographic regions of the Soviet Union are beyond the scope of this assessment, it is useful to show the area1 extent of the coniferous forest zone in order to understand the magnitude of Soviet timber resources (See figures D-l and D-2). Generally speaking, the coniferous forest or taiga extends from the Finnish border in the west to the Pacific coast in the Far East. It extends southward into other zones of vegetation along mountain ranges, as in the Southern Urals, and in Siberia and the Far East mainly due to the effects of continentality. Coniferous species also appear in isolated mountain regions to the south, such as the Caucasus and Carpathian ranges of the European U.S.S.R.

The forest resources of the Soviet Union are unevenly distributed throughout the country. The Russian Soviet Federated Socialist Republic (R.S.F.S.R.) alone contains 94.7 percent of the forested land (Kalinin et al., 1985). This distribution has given rise to two distinct timber economies. The first, often referred to as the European-Uralian reserves, is located primarily in the most developed and populated regions of the European U.S.S.R. and West Siberia. These more productive and accessible forests have been utilized for many years, which has lead to severely diminished stocking levels. Products from this region are destined for European markets and used in the national economy. In contrast, the second timber economy of the eastern forests of Siberia and the Far East is located in a sparsely populated region of the country. This region is relatively undeveloped, making the forests, for the most part, large untapped reserves. This region accounts for 33.5 percent of the Soviet forested land, 31.4 percent of the mature coniferous growing stock and nearly 25 years of exploitable hardwood resources (Barr and Braden, 1988). Products from this region are exported mainly to Japan and China and used regionally due to excessive transport costs.

The land supporting valuable stand-forming species covers 688.8 hectares; conifers account for 78.2 percent of this, tolerant hardwoods 5 percent, and intolerant hardwoods 16.8 percent. Approximately 55 percent of the Soviet mature timber volume is classified as potentially accessible forests; of that, 87 percent is made up of degraded European-Uralian growing stock, and only 48 percent of that stock is in the Asian part of the R.S.F.S.R. Nearly 40 percent of Soviet forests are mountainous or "gomiye lesa," with most land sloped greater than 30 percent (Backman and Waggener, 1990). Forty-two percent of the calculated allowable harvest east of the Urals consists of accessible coniferous forests.



Natural zones of the USSR
Source: Based on *Geograficheskiy atlas SSSR dlya 7–8 klassov*, Moscow 1966, pp. 6–7

Figure D-1. Natural Zones of the U.S.S.R.

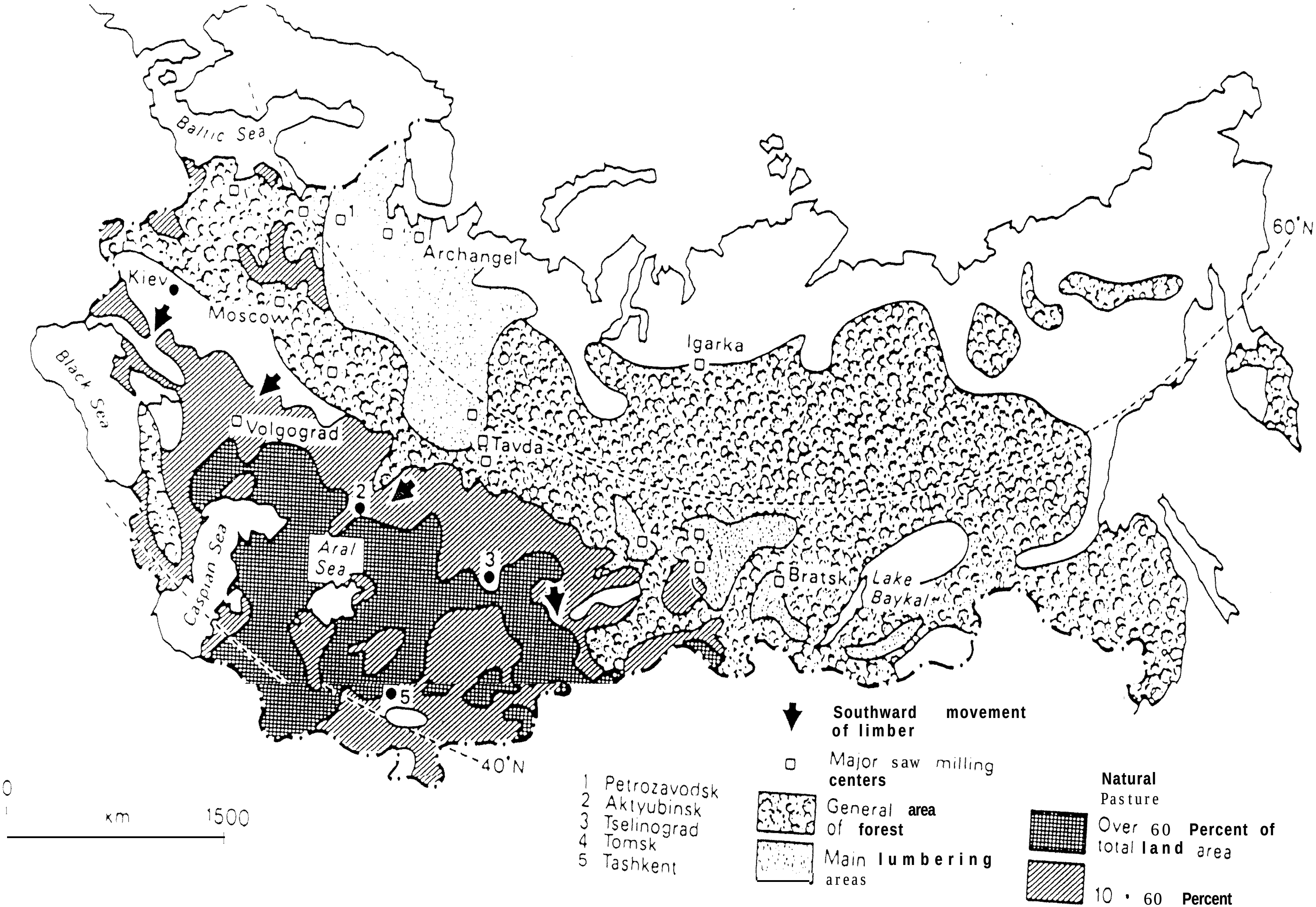


Figure D-2. Natural Pasture and Forestry

Species Distribution

Because of its size and location, the Soviet Union has a wealth of arboreal and floristic diversity. Of the 570 recognized timber species in the U.S.S.R., only 30 are economically significant. Although the hardwood species are important components of the forest inventory, most commercial timber is of a coniferous species generally restricted to the family Pinaceae. Thirty-five members of the family Pinaceae are represented in the Soviet Union. More than 24 species are found in Siberia and the Far Eastern territories of the Russian Republic. Of these, at least 14 are major commercial species that have potential value as exports to the Pacific Northwest (Holowacz, 1985).

The coniferous zone of Siberia and the Far East is characterized by four main genera: *Abies, Larix, Picea,* and *Pinus,* which are further divided along forest types and densities. The dark taiga or "dark conifers" consist of the various spruce-fir associations and stone pine as opposed to the "light conifers" that consist of larch and pines. The "white taiga" often refers to a mixed-wood forest that develops after a disturbance, such as fire or Jogging. This forest is characterized by a strong component of birch and other early successional hardwoods.

Problems of Development

Despite seemingly inexhaustible timber reserves, the Soviet forest products industry lags disproportionately behind other timber producing countries in the West (notably the United States, Canada, Finland, and Sweden) in both the production and use of forest resources. Moreover, the Soviet forest products industry is not proportionate to the size and quality of the country's timber resources and plays an insignificant role in the nationai economy as compared to other industrialized nations (Barr and Braden, 1988).

Many problems exist in the Soviet forest products industry, particularly as they relate to the development of the forest resources in East Siberia and the Soviet Far East. Among the more exigent problems limiting the development of the forest products industry in Siberia and the Far East are the accessibility of timber stands, the lack of adequate infrastructure, the low level of harvesting and manufacturing technology, and the chronic labor shortages of the region. Add this to the inherent costs and problems of working in the extreme climatic conditions of the region and timber harvesting becomes a difficult and often economically unfeasible operation.

During the past decade the central government has encouraged intensive development of the timber economy in an effort to reduce wastes and increase overall production. However, up to this time the Soviet government has been unable to sufficiently direct investment into the forestry sector. This is manifested in the sector's inability to manufacture value-added timber products that meet world market standards. As a result, more than 95 percent of the timber exported from the Far East is in round or raw material form (that is, non-value added), whereas forest products exports of other major timber producing countries show an average of about 12 percent roundwood and raw material exports (Grabovskiy, 1988).

Logging Techniques

Approximately 50 percent of the timber logged annually in the Soviet Union is harvested in the 4 months from December to March (Varaksin, 1971). This is because of the inferior quality of the road surfaces from the upper landings to the lower landings. These roads are most suitable for transport during the heavy frosts of winter. In contrast, during the spring thaw and the wet autumn periods, logging productivity is greatly reduced due to poor soil conditions. However, logs may be stored at upper and tower landings for a considerable period of time until transportation to a processing facility becomes available (Blandon, 1983).

Logging technology in the Soviet Union can be classified into two techniques: (1). conventional logging (felling by chain saw, delimbing by axe, choker, and skidding by tracked vehicle using some log winches), and (2) mechanized logging (feller-buncher/grappie skidder system}. In recent years, conventional logging practices have come under attack from the central government. This method produces excessive wastes and is labor intensive. On the other hand, the Soviets have been unable to significantly increase the level of mechanization in the forest products industry. It is assumed that foreign technology will play a large role in the future modernization of the industry. Table D-l shows the variations in logging operations according to the types of activities performed on sites during the logging process. The method used depends on the location and accessibility of the timber being harvested and the available equipment and technology.

Transportation

The future development of timber resources in East Siberia and the Soviet Far East is closely tied to the transportation networks of the region-namely the railroads (see figure D-3) and, to a lesser degree, the highways. There are two major railroads in the Eastern Soviet Union. One, the Trans-Siberian line, completed in the early 1900's, has been essential to the early development of the eastern regions. The second, the recently constructed. Baykal-Amur Mainline (BAM) is another important part in the current and future development plans of the region. Indeed, recent logging expansion has occurred in areas adjacent to the BAM. Table D-2 presents data on the basic forest resources of this region and their current use. In addition, many other natural resources (coal, gold, diamonds, and so forth) are found throughout the region.

Another railroad, the Amur-Yakutsk Mainline is currently under construction. Jt will extend from the city of Tynda in Amur Oblast to the northern city of Yakutsk. Only about one-third of the distance has been covered to date (Cardellichio et al., 1989). This railroad will open up large tracts of previously untapped larch reserves north of current logging operations in the Yakutsk A.S.S.R.

The primary railheads in Siberia and the Far East where logs are loaded onto trains and transported to the coast are in the cities of Krasnoyarsk, Irkutsk, Ulan-Ude, Chita, Tynda, and Khabarovsk. Undoubtedly, other railheads will be designated as new logging sites are developed and as rail links are expanded into remote regions.

Soviet Forest Classification

The forests of the Soviet Union are divided into three groups for managing and regulating timber production and forest use. This tripartite classification scheme has been in effect since April 1943 and categorizes forests according to their significance in the national economy. In general, Group 1 and 2 forests are managed for resource conservation and environmental protection and Croup 3 forests are used by the timber industry. Group 1 forests currently represent about 20 percent of the total forested area. This group is the most protected of the forested areas. All of Group 1 forests are considered nonexploitable; however, some sanitary and selective cutting is permitted.

Group 2 forests occupy approximately 7 percent of the forested area. This management group includes restricted forests where some degree of regulated harvesting is allowed (Cardellichio et al., 1989). The remainder of Soviet forests are classified into Group 3. This makes up about 73 percent of the total forested area (Kalinin et al., 1985). These forests are suitable for commercial exploitation. Group 3 forests comprise 45 percent of the European state forest area and 84 percent of that in Asia (Barr and Braden, 1988). For a more complete discussion of this classification scheme, see Kalinin et al., 19%; Chapter 3, Barr and Braden, 1988; or the "Fundamental Forestry Legislation of the U.S.S.R. and Union Republics."

Table D-1. Variations of the Logging Process in the U.S.S.R.

Operation	Skidding Whole Trees Hauling			Skidding Tree Length Hauling		Skidding and Hauling
	Whole Trees	Tree Length Logs	Length Assortment	Tree Length	Length Assortment	Length Assortment
Cutting unit						
Tree felling	+	+	+	+	+	+
Limbing	–	–	–	+	+	+
Bucking	–	–	–	–	–	+
Skidding	+	+	+	+	+	+
Upper landing						
Limbing	–	+	+	–	–	–
Bucking	–	–	+	–	+	–
Sorting of roundwood	+	–	+	–	+	–
Decking	+	+	+	+	+	+
Loading	+	+	+	+	+	+
Hauling on forest roads	+	+	+	+	+	+
Lower landing						
Unloading	+	+	+	+	+	+
Limbing	+	–	–	–	–	–
Bucking	+	+	–	+	–	–
Sorting of roundwood	+	+	–	+	–	–
Loading on train or water transport	+	+	+	+	+	+

Note: + = does occur during harvesting.
– = does not occur during harvesting.

Source: Gorunov and Sadovnichii, 1985.

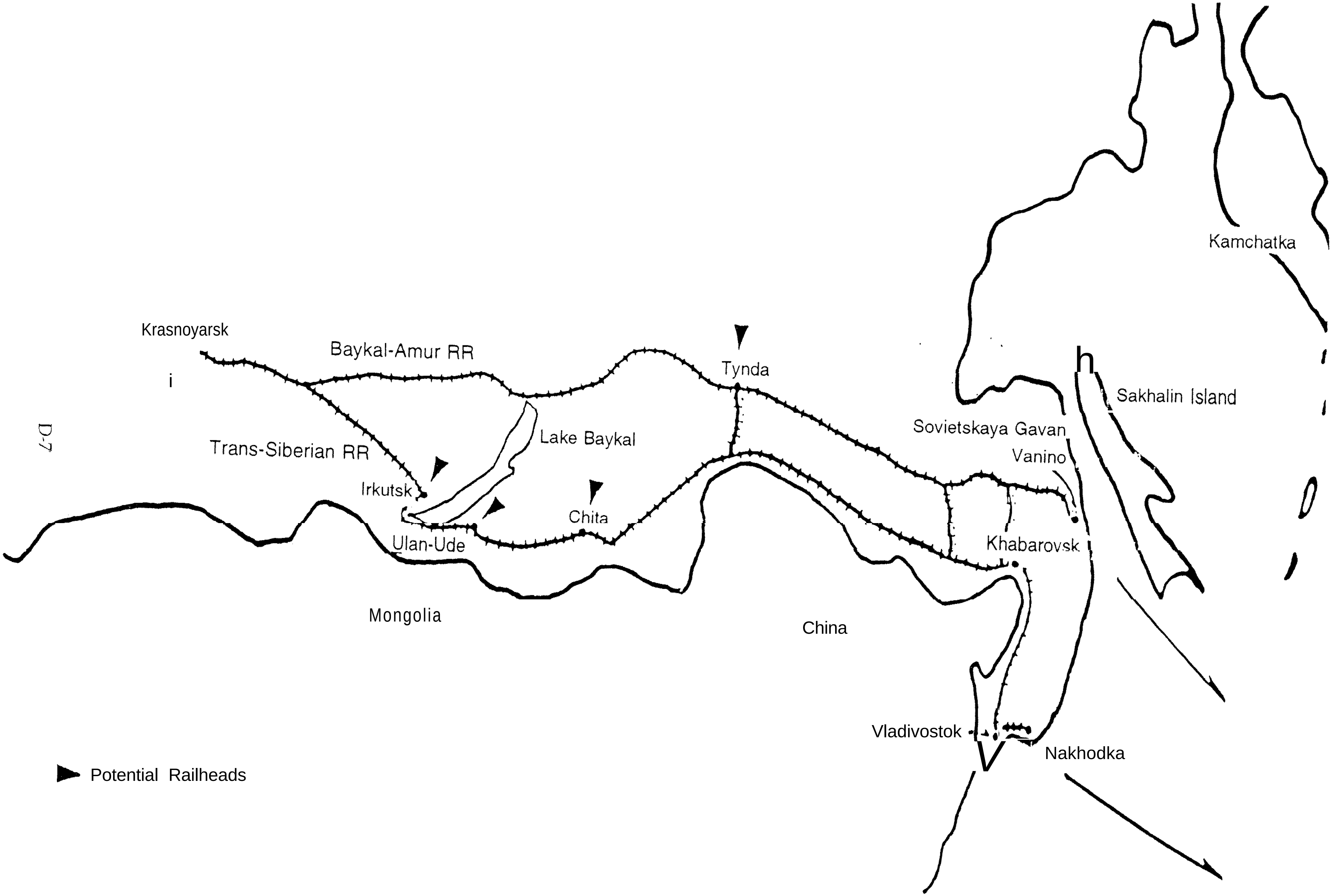


Figure D-3. Potential Flow of Timber for Export to the United States

Table D-2. Forest Resources in the Baykal-Amur Mainline Zone and Their Use

Republics, Oblasts and Krays	Mature and Overmature Stands: Area in (million ha)	Mature and Overmature Stands: Reserves in (billions m^3)	Marketable Volume, (billions m^3)	Calculated Allowable Cut, Million m^3: Total	Calculated Allowable Cut, Million m^3: Incl. Conifer Stocks	Current Volume Logging (million m^3)
Irkutsk Oblast	71.2	2.0	1.6	29.3	25.5	2.4
Buryat A.S.S.R.	3.3	0.4	0.2	7.6	7.4	0.8
Chita Oblast	4.8	0.5	0.4	5.4	5.4	--
Amur Oblast	6.4	0.8	0.6	78.6	15.1	2.5
Yakutsk A.S.S.R.	22.1	2.9	2.0	35.2	34.8	1.0
Khabarovsk Kray	11.0	2.1	1.5	36.3	31.7	9.8
Total	58.8	8.7	6.3	132.4	119.9	16.5

Note: -- Not available.

Source: Kiryukhin and Loginov, 1986.

Forest Zonation of the Coniferous Taiga

The boreal coniferous forest zone or taiga is characterized by four subzones distinguished by spatial distribution and the flora. Except for the extreme maritime regions, forest productivity and species diversity are a direct function of latitudinal gradient and elevation (Kurnayev, 1973). The taiga consists of the following subzones:

- Pretundra Sparse or Spacious Taiga Subzone-A transitional area from tundra to forest that is characterized by sparse stands of extremely low productivity and tundra-like ground cover. Permafrost and gley podzolic soils are dominant in this region.

- Northern Taiga Subzone-This subzone consists of somewhat denser but still quite dispersed conifer forests. The ground cover consists of mosses or lichens on the frozen soil. Numerous herbaceous species and heaths such as crowbery, bog-bilberry, and ledum grow in marshy areas of the more southern subzones.

- Central Taiga Subzone-This area is covered by dense conifer stands of somewhat higher productivity class III. Green moss, principally whortieberry, dominates the understory, and the soils are typical podzols.

- Southern Taiga Subzone—Commercially important conifer stands of high productivity (classes I and II) are typical of this zone. There is a well-developed grassy ground cover of boreal, nemoral species, and weakly developed mosses. The grasses are almost steppe-like and present a fire hazard in the fall. Deciduous forest zones with a narrow-leaved overstory and broad-leaved understory begin at the southern end of the subzone. The soils are of the old sod-podzol classification.

The following criteria were used for selecting conifer species in these profiles. Tree species profiled are located in the Soviet Far East or Eastern Siberia. Because of economic considerations, timber exported to the Western United States is expected to come only from these areas of the Soviet Union.

In addition to the genus *Larix* spp., the following are the primary export species (listed by genera): *Abies* spp., *Picea* spp., and *Pinus* spp. Profiles of Larix spp. are followed by *Pinus* spp., *Abies* spp., and *Picea* spp. respectively. For simplification of the risk assessment process, closely related species may be grouped together under their appropriate genera. However, representative species were selected for some genera because their host infestations are species specific. These genera were selected by industry, university, and government representatives because of their high potential for export to the United States.

Host Timber Profile

Family Pinaceae Lindl. Genus *Larix* Milk-Larch

Most Soviet exports to the Pacific Northwest will be *Larix* spp., or larch, from the relatively untapped boreal reserves in Eastern Siberia and the Far East. Therefore, the first profile presented focuses on the genus *Larix*. Other potential host species, from *the* genera *Abies*, *Picea*, and *Pinus* are listed after the *Larix* spp. in this appendix.

The genus *Larix* reaches its greatest global concentration and diversity in the Soviet Far East. More than half the world's larch species grow in the U.S.S.R. Larch forests cover vast areas; more than 40 percent of the commercial timberlands in the U.S.S.R. are larch. The greatest distribution of larch forest occurs in Eastern Siberia and the Far East region, accounting for almost 50 percent of the forest resources (Barr and Braden, 1988). Larch forests in the U.S.S.R. exceed 274 billion hectares, with wood reserves of more than 28 million cubic meters (m"). The largest larch forests are found in Eastern Siberia (78.6 percent) and in the Far East (19.4 percent) (Tseplyayev, 1965).

Depending on the taxonomic sources (Sokolov et al., 1977), most references cite 11 larch species in the U.S.S.R., with 9 occurring in Siberia and the Far East. Larch species are geographically distributed as follows:

European-Uralian Soviet Union and Western Siberia:

- *L. decidua* Mill ssp. polonica Racib.-European or Polish larch
- *L. siberica* Ledeb.-Siberian larch
- *L. sukaczewii* Djil. Dyl.—Sukachev's larch

Eastern Siberian and Far Eastern Soviet Union.

- *L. amurensis* B. Kolesn.—Amur larch
- *L. czekanowskii* Szaf.—Czekanowskii larch
- *L. gmelinii* (Rupr.) or *L. dahurica* Turcz. et Trautv.—Daur larch
- *L. kurilensis* Mayr.—Kuril larch
- *L. lubarskii* Sukacz.—Lubarski larch
- *L. maritima* Sukacz.—Maritime larch
- *L. ochotenisis* B. Kolleen—Okhotskaya larch
- *L. olgensis* A. Henry-Olgenskaya larch

Most of these species are limited in their range and economic importance. Larch appears in many varieties and ecotypes that are not different morphologically, but differ considerably in tolerance to unfavorable soil and temperature conditions. Because of their geographic distribution and accessibility, three tree species are commercially important and represent the most likely exports to U.S. markets. These major species, *Larix sibirica*, *Larix gmelinii (dahurica)*, and *Larix amurensis* are indistinguishable from other local larch species.

***Larix sibirica*—Siberian larch-Listvennitsa sibirskaya**

Range: Siberian larch grows mostly in Western Siberia, where it occupies significant areas; from the permafrost limits on the northern border to the edge of the semidesert in the south (Kalinin et al., 1985). The range of Siberian larch extends east into the northeastern European U.S.S.R., east into the western half of Siberia, north to the lower reaches of the Yenisey River (69” 40’) and Pyasina River (70” 15′), and south to the western foothills of the Altay, Saur, and Tarbagatay ranges (47° north latitude). Larch grows at elevations of up to 2,500 meters in the Saur mountains.

Silvics: Like North American larches, *L. sibirica* is a relatively fast growing, deciduous, and intolerant conifer. Siberian larch is often found in permanently frozen ground and frequently in deep organic soils or peat bogs. Siberian larch has more selective soil nutrient requirements, especially calcium, than other conifers. On deep, well-drained soils, larch develops a deep root·system with strong lateral roots, but in areas with frozen soils, the root system is shallow and the tree is subject to windthrow.’

Larch is found in pure stands and often in association with other boieal conifers such as *Picea obovata, Pinus sibirica, Abies sibirica,* and shade intolerant hardwoods. Natural regeneration through seeding on burned-over areas is common. However, on these areas, because of the less selective demands, former larch stands are replaced by pine. The typical successional pattern after disturbance is birch and aspen, followed by pine and larch.

Larch is monoecious, it flowers in the spring, and produces seeds at the age of 72 to 15 years in open stands. However, in closed stands, 20 to 50 years is more common. Large seed crops are produced at intervals of 3 to 5 years.

Growth rate:	age (years)	70	20	50	100	750
	height (meters)	*2.8*	*7.8*	*17.6*	*27.0*	*32.7*

Like all larches, Siberian larch is characterized by rapid, early growth and good form. Larch reaches a volume of 300 to 400 m^3 per hectare on only the best sites.

Insects and Disease Pathogens: See Appendix H.

Height: 40 to 45 meters

Diameter: Up to 1.5 meters

Maximum Age: 400 to 450 years (oldest documented tree-900 years)

Wood Characteristics:	Moisture content	Air dry
	Specific gravity	*0.56*
	psi MOR (Modulus of Rupture)	*1,200*
	psi MOE (Modulus of Elasticity)	*1.45*
	psi compression parallel	5,545

Logging, Transport, **and Storage:** Larch is generally harvested in the winter (skidded log or tree lengths) and processed on secondary landings, where it may be cold-decked in storage for up to 9 months or more (Gorunov and Sadovnichii, 1985). The heaviness of the wood prevents it from floating. Thus, transport to processing facilities depends on the railway system. Special procedures, such as hot water thawing before sawing, are used for larch and other boreal species.

Due to extreme butt flair or swelling (sometimes exceeding 50 to 70 centimeters), longer saws and felling time are required for logging. Sparse crowns make delimbing easier but also result in greater breakage, particularly under extreme temperature conditions. Branches and tops of standing timber are brittle and create a safety hazard for loggers in the cold weather (Kalinin et al., 1985).

Primary and Secondary Uses: Larch is dense, heavy, durable, extremely strong, and resistent to decay, Siberian larch is used for poles, mine props, marine pilings, sawtimber, parquet, export logs, pulpwood, chips, and firewood. It is used in fine woodworking for beautifully textured decorative material (Kalinin et al., 1985). Larch bark is used for tanning and dying substances as well.

Although larch or tamarack is now regarded as a low-value softwood in other parts of the world, larchwood was so popular in the mid-19th century that a severe restriction on its use was imposed in the Russian Empire. During the past three centuries, larch was used in the construction of water works in St. Petersburg and Venice, in churches in Poland, and in barrel manufacturing in Germany. Larchwood was used for making the floors of the Kremlin in Moscow, the doors and windows at the Winter Palace in St. Petersburg, and for structural materials in building St. Basil's Cathedral (Exportles, 1986).

Unfortunately, larchwood has a high resin content that tends to degrade equipment and make harvesting larch unprofitable. In the mid-1980's, the Japanese industry made a technological breakthrough that led to moderate success in using larch for veneer to replace lauan in plywood (Barr and Braden, 1988).

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: Moderate to high

Larix dahurica Turcs.—Daurian larch-Listvennitsa daurskaya
or
Larix grnelinii (Rupr.)—Gmelini larch-Listvennitsa gmelini

Range: The eastern boundary of the Siberian larch territory marks the transition to Daurian larch. There is some degree of hybridization at this interface zone that creates Czekanowskii larch (*L. czekanowskii* Szaf.) Daurian larch exceeds the range of *L. sibirica*. It is the dominant eastern larch species and is widespread in Eastern Siberia and the Soviet Far East. In the North, it grows throughout the Irkutsk Oblast to the northern edge of forest vegetation where it acquires shrub-like characteristics. It grows on a variety of sites from river bottoms to a maritime climate and at high elevations. Its southern range extends into Manchuria and Northern Japan.

There is some confusion over the taxonomic difference between Daurian and Gmelini larch. Although the two species are now classified as one, according to a personal communication with Elias, 1991, Gmelini larch does not appear in the south of the Kamchatka peninsula, although Daurian larch is present. Daurian larch is one of the most frost-tolerant species in the U.S.S.R., and that explains the widespread distribution of Daurian larch in extreme climates.

Silvics: Like Siberian larch, *L. gmelinii* is a relatively fast-growing, deciduous, and intolerant conifer. L. *gmelinii* is distinguished from *L. sibirica* by its mature cones that have smaller scales and fewer scales, smaller seeds, and shorter, lighter needles (Kalinin et. al, 1985). The height and diameter of this larch is less than *L. sibirica*. Otherwise, their phenological and silvical characteristics are similar.

Insects and Disease Pathogens: See Appendix H.

Height: 30 to 35 meters (4 to 6 meters on poor sites)

Diameter: 0.8 to 1.0 meters

Maximum Age: 400 to 450 years

Wood Characteristics: Moisture content kiln dry (10 to 15 percent, based on 1990 U.S. industry tests of Daurian larch harvested in the Irkutsk area).

Specific gravity	0.64
psi MOR	1,205.00
psi MOE	1.86
psi compression parallel	2,914.W

Logging, Transport, and Storage: The same logging methods and processing used for *L. sibirica* are used to harvest *L. gmelinii*. *L. gmelinii* is often susceptible to frost cracks on the bole that result in dangerous splintering of the main stem during felling operations.

Primary and Secondary Uses: Primary and secondary uses of *L. gmelinii* are the same as for *L. siberica*. According to British sources, the quality of Daurian larch is outstanding and is used widely due to its moisture-resistant properties, as compared to a tropical hardwood such as greenheart (*Ocotea rodiaei*). Because of its slow growth cycle, the wood is extremely dense with as many as 25 to 30 rings per inch.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: High

***Larix amurensis*—Amur** larch-Listvennitsa amurskaya

Range: *L. amurensis* has a limited range restricted to the southeastern comer of the Soviet Union, which consists of Amur Oblast, southern Khabarovsk Kray, and part of the Maritime Kray of the Far East. Although the Amur and Ussuri Rivers mark the southern boundary of the U.S.S.R., the range of *L. amurensis* extends into Northern Manchuria.

Silvics: Like other Soviet larches, *L. amurensis* grows fast and is tolerant of drought, frost, insects, disease, soil compaction, and fire (Tseplyayev, 1965). It does not require much moisture and prefers calcareous soils. Morphologically and taxonomically, *L. amurensis* is an extraordinary species, but its origin may be attributable to hybridizations with *L. gmelinii*, *L. maritima*, and *L. olgensis* (Sokolov et al., 1977). It is more sensitive to frost and grows poorly on boggy sites. It regenerates well in clearcuts and after prescribed bums. Because of its southern range, it can be found growing with Mongolian oak (*Quercus mongolica*) and other tolerant broad-leaved species on river terraces of the Amur River and its tributaries. *L. amurensis* is often found with other conifers of the Soviet Far East, such as *Pinus koraiensis*, *Picea ajanensis*, and *Abies nephrolepsis*.

Insects and Disease Pathogens: See Appendix H.

Height: 30 to 35 meters (4 to 6 meters on poor sites)

Diameter: 0.8 to 1.0 meters

Maximum Age: 400 to 450 years

Wood Characteristics:

Moisture content	Air dry
Specific gravity	N/A
psi MOR	N/A
psi MOE	N/A
psi compression parallel	N/A

N/A = Not available.

Logging, Transport, and Storage: The same logging and processing methods used for *L. sibirica* and *L. gmelinii* are also used for *L. amurensis*. A somewhat milder climate and easier access to a port reduces the storage and transport time for *L. amurensis*, compared to *L. sibirica* and *L. gmelinii*.

Primary and Secondary Uses: *L. amurensis* has the same uses as *L. sibirica* and other larches.

Importance to Soviet Timber Economy: Important

Potential Export Value to Pacific Northwest: High

Family Pinaceae **Lindl.** Genus *Pinus* L.-Pine

Pines are some of the most valuable commercial tree species in the northern coniferous zone of the Soviet Union. Pines constitute 23.5 percent of the Soviet Union's totai commercial timberland. Approximately 110 million hectares of pine are potentially exploitable, which represents a reserve of 15 billion m^3 (Tseplyayev, 1965).

The highest proportion of common, or Scots pine, stands (P. *sylvestris*) occurs in the Northwest and Western Siberia. Scots pine forests in the Transbaykal and Far East region are dense, slow-growing stands with low site quality. More than 2 million hectares of Aldan pinewoods in the Yakutsk Autonomous Soviet Socialist Republic (A.S.S.R.) and Khabarovsk Kray are of considerable economic significance and may be harvested for their export potential (Tseplyayev, 1965).

Of the 14 species of the genus *Pinus* native to Eurasia, 8 are indigenous to the Soviet Union, according to Sokolov et al. (1977). However, Tseplyayev (1965) has documented all 14 species present in the Soviet Union. Five *Pinus* species are present in Siberia and the Far East. Pine species are geographically distributed as follows and appear in order of economic importance:

European-Uralian Soviet Union and Western Siberia:

- P. *sylvestris*—Scots pine, Scotch pine, red pine, common pine, redwood, Russian pine
- P. *cembra*—European cedar pine
- P. *brutia*—Calabrian pine
- *P. pallasiana* D. Don--Crimean pine

Eastern Siberian and Far Eastern Soviet Union:

- *P. sylvestris*—Scots pine, Scotch pine, red pine, common pine, redwood, Russian pine
- *P. sibirica* Du Tour--stone pine, cedar, cedar pine
- P. *koraiensis* Siebold et Zucc.-Korean cedar, Korean cedar pine, Manchurian cedar pine
- *P. funebris* Kom. or P. *densiflora* Siebold et Zucc.-funeral pine
- P. *pumila* (Pall.) Regel—Japanese stone pine

Of these, only *two* species, *Pinus sylvestris* and *Pinus sibirica* (which is restricted mainly to the Asian region), are commercially important. Korean pine, or as it is sometimes called, Manchurian cedar pine (*Pinus koraiensis*), is also of regional significance, but it is a slow-growing species and cutting is now banned in the Soviet Union.

***Pinus sylvestris* L.—Scots** Pine, Scotch pine, red pine, redwood, common pine, Russian pine-Sosna **obyknovennaya**

Range: The Scots pine has the widest range of any pine species in the world. It is found throughout the Soviet Union from the Kola Peninsula (70° N. latitude) and White Sea to the southern slopes of the

Verkhoyansk Range and the Sea of Okhotsk. Its territory includes the Altay mountain range and extends into Central Asia (as far south as 48” 20′ N. latitude). The southern border of this pine’s range in the European Soviet Union extends into southern Volyny and the Kiev Obiast through Dnepropetrovsk, Saratov, Kuybyshev, and the Cheiyabinsk Oblasts. The Scots pine is also found in the eastern Crimea and Transcaucasia. It often grows in patches or strips referred to as a pine "bor."

Silvics: The silvics of Scots pine are well documented, because of its commercial importance in Western Europe and its cultural history of tree improvement. However, because of its large geographic range, the species is polymorphic and a number of distinct varieties or ecotypes are recognized; this may explain the discrepancy in the number of pine species in the Soviet Union. On dry sandy soils, considerable areas are covered with sparse pine stands of poor quality. Except for junipers, the understory is absent and the ground cover is an uninterrupted carpet of lichen and forest mosses. On sandy podzolized soils with more moisture, the growth is better. Podzolized soil with a neutral pH or podzolic soils with a hardpan (compacted soil layer) often have rich herbaceous flora. On such soils, pine is often found with other tree species, such as *Picea obovata, Larix* spp., *Pinus sibirica,* and *Abies sibirica.* Pine grows well on rich chemozem, cool sphagnum bogs, and areas of permanently frozen subsoil.

Scots pine is a two-needled, hard pine with a variable form and commercial value. Primeval forests of the northern taiga are growing with a clean bole and symmetrical crown with fine branches. Southern varieties grow faster, but are characterized by wider crowns and thick horizontal branches. However, open growth stands of Scots pine have knotty branches, deformed boles, and low commercial value. Natural regeneration of pine is prolific after fire; most of the mature even-aged stands were established as a result of forest fires. Scots pine begins to reproduce at 30 to 40 years, but reliable seed production only begins at 60 to 70 years. Small round cones, 2.5 to 7 cm in length, produce approximately 1,000 seeds at 3- to 5-year intervals, but this is dictated by climatic conditions. In northern regions, the interval between seed years may be as long as 10 to 30 years.

Insects and Disease Pathogens: See Appendix H.

Height: 20 to 40 meters

Diameter: Up to 1.0 meters

Maximum Age: 350 to 400 years

Wood Characteristics:	Moisture content	12 percent
	Specific gravity	0.46
	psi MOR	1,290.00
	psi MOE	1.45
	psi compression parallel	6,875.00

Logging, Transport, and Storage: The Scots pine is generally harvested in the winter, skidded log or tree length, and processed on secondary landings, where it may be cold-decked in storage for 9 months or longer (Gorunov, 1985). Pine is almost as dense as larch (particularly the old growth), but it usually floats. Rail and water transport are used to bring the pine to market. The crown is more developed with longer branches on the south side of the tree. During severe cold, the tree trunk can split and splinter as far down as 1 to 1.5 meters off the ground. Brittle branches often break off and shatter when they hit the ground.

Primary and Secondary Uses: According to British sources (Buikeley, 1978), the forests of the Krasnoyarsk region of Eastern Siberia produce the finest quality redwood in the world. The extreme climate of the central Siberian plateau causes the slow growth that results in beautifully textured, close-grained redwood (Angaa or kondo pine). Structural timber, poles, industrial cut stock, and pulpwood are the primary uses of Scots pine.

pine supplies many chemical compounds and naval stores, such as turpentine, resin, pitch, rosin, and others. Pine needles are a source for chlorophyll-carotene, compounds for perfume, and wood meal for livestock or wood-concrete bricks (Kalinin et al., 1985). Naval stores and chemical products are extracted from the stumps for 10 to 15 years after the timber is harvested.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: Moderate to high

Pinus sibirica Du Tour-Siberian pine, stone pine, cedar, cedar pine-Sosna kedrovaya sibirskaya

Range: Except for some areas in Northeastern European Russia, the range of *P. sibirica* is restricted to Asia. This pine is found throughout most of Siberia and occurs widely in the Urals. Its range extends throughout an area circumscribed by the upper reaches of Vychegda River, the northern Urals at 66" north latitude, the lower Oh and Yenisey (at 68" 12'), the upper reaches of the Aldan River, northern Mongolia, the Altay (48" 15') mountains, and the southeastern Urals (57" north latitude). The Siberian pine is found at elevations up to 2,500 meters.

Silvics: Stone pine forests occupy more than 23 million hectares in the Soviet Union. P. *sibirica* is a shade-tolerant, five-needle, soft pine that is often found growing with *Abies sibiricu* and *Picea obovata,* making up the dark taiga. It also grows with various *Larix* spp. and shade-intolerant hardwoods. These large diameter, old-growth stands are partially protected against harvesting.

In its natural range, P. *sibirica* is found at mountaintops, along water courses, and in peat bogs along river valleys. P. **sibirica** is a tolerant species that grows on a variety of soils, but it grows best on level, deep, rich, and well-drained loams. in *sphagnum* bogs, it tolerates the excessive moisture and grows better than Scots pine. In the Soviet Far East, it grows on permafrost soils. It suffers catastrophic damage from forest fires and shows little or no ability to regenerate directly on burned areas. The natural regeneration of stone pine seems to be the most difficult silvicultural problem. This is accomplished most successfully through the predation and deposition of seed by birds and small mammals.

At maturity (plus or minus 50 years), *P. sibirica* flowers from May to June and the cones mature after 18 months. It produces seeds every 2 to 3 years and sometimes every 5 to 6 years. Although it produces fruit for as long as 250 to 300 years, its maximum fruiting occurs between 100 and 150 years (Kalinin, 1985).

Insects and disease pathogens: *Dendrolimus sibiricus,* the silkworm moth, is the most dangerous pest of *P. sibirica* in Siberia. See Appendix H for detailed descriptions of the pests of genus *Pinus in* the U.S.S.R.

Height: 40 to 45 meters

Diameter: 1 to I.5 meters

Maximum Age: 500 years

Wood Characteristics:	Moisture content	N/A
	Specific gravity	N/A
	psi MOR	N/A
	psi MOE	N/A
	psi compression parallel	N/A

N/A = Not available

Logging, Transport, and Storage: Both rail and water transport are used to bring Siberian pine to market.

Primary and Secondary Uses: Siberian pine provides valuable timber for industrial cut stock, joinery, and the pencil industry. It has a fragrant, resinous odor, hence the common Russian misnomer of "cedar" or "cedar-pine." Its durable, soft wood is good for woodworking. The sapwood is yellowish-white and the heartwood is light pink (Kalinin et al., 1985).

The seeds and cones, or "nuts" as they are called locally, are collected by the Siberian population for human consumption and oil. From 1 hectare of old stone pine, 50 to 200 kilograms of nuts may be harvested. From 1 ton of nuts, 200 kilograms of oil or pine nut butter can be produced. The best crop yields are in open stands 80 to 150 years old.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: Moderate to high

Family Pinaceae **Lindl.** Genus ***Abies*** Mill.--True fir

The true firs occupy 2.3 percent of the forest area of the Soviet Union, and 95 percent of the exploitable fir forests occur in Siberia and the Soviet Far East. Among the commercial tree species, the genus *Abies* or true firs has a species (Sokolov et al., (1971) lists 10 species); 6 species are localized, well-distributed, and represented in the Asian taiga. These species are geographically distributed as follows and appear in order of economic importance:

European-Uralian Soviet Union and Western Siberia:

- *A. sibirica* Ledeb-Siberian fir
- *A. alba* Mill;--Silver or European fir
- *A. nordmanniana*—Caucasian fir

Eastern Siberian and the Soviet Far East:

- *A. sibirica* Ledeb-Siberian fir
- *A. holophylla* Maxim-Wholeleaf fir
- A. *nephrolepsis*—(Trautv.) Maxim-Amur, Khingan, or Whitebark fir
- *A. gracilis* Kom.-Slender fir
- *A. mayriana* (Miyabe et Kudo)—Mayerova fir
- *A. semenovii* B. Fed tsch.—Semenova fir
- *A. sachalinensis* Fr. Schmidt-Sakhalin fir

Localized distribution and domestic consumption importance make it hard to determine which species may be exported to the United States or the Pacific Rim. All six Soviet Far Eastern firs have been profiled, but more information is available about A. *sibirica* and A. *holophylla* because of their wide range, higher value, and greater export potential.

Abies sibirica **Ledeb.—Siberian** fir-Pikhta sibirskaya

Range: The Siberian fir is the most common Russian fir and occurs over large areas in Northeastern European Soviet Union, the Urals, throughout much of Siberia (from the Baykal region into the Altay Mountains), and southward into Mongolia and China. The western and southern range coincides with that of the Siberian larch (*Larix sibirica),* but it does not penetrate as far north as the larch. It grows to an elevation of up to 2,400 meters in the Altay Mountains. Siberian fir occupies 13.6 million hectares of forest land in the Soviet Union, with reserves of 2 billion m^3.

Silvics: Siberian fir is most abundant on deep, rich, and well-drained soils with adequate moisture. It is less tolerant of unfavorable conditions than spruce and does not grow well in marshy conditions (Kalinin et al., 1985). Siberian fir grows on rocky soil at upper elevations. It grows in pure and mixed stands and is more windfirm (able to withstand strong winds) than spruce. In mixed stands, it is most commonly associated with Siberian spruce (*Picea obovata*) and Siberian stone pine (*Pinus sibirica)* in the classic dark taiga. It has a deep, wide-spreading root system and is relatively windfirm.

Cones are produced after 15 to 78 years in open stands and 60 to 70 years in dense forests. Forty-five percent of the seeds from this species germinate. The species is very shade tolerant and regenerates well either by seed or vegetatively in deep shade. Mature trees retain needles for 7 to 10 years.

Siberian fir grows slowly for the first 10 to 15 years and rapidly thereafter. Its overall growth compared to spruce and pine is relatively slow. It grows well outside its geographic area, particularly as an ornamental species in the Soviet Union.

Insects and Disease Pathogens: According to Soviet sources, at age 70 to 80, 60 percent of Siberian fir is affected by an undetermined form of trunk rot and suffers from wind blast. See Appendix H for more information.

Height: 30 meters

Diameter: 50 to 80 centimeters

Maximum Age: 200 to 250 years

Wood Characteristics:		
	Moisture content	N/A
	Specific gravity	N/A
	psi MOR	N/A
	psi MOE	N/A
	psi compression parallel	N/A

N/A = Not available.

Logging, Transport, and Storage: Rail and water transport are used to bring Siberian fir to market.

Primary and Secondary Uses: The technical value of the wood is marginal and, consequently, is primarily used for pulpwood and not construction. The bole of A. sibirica is thin and smooth with resin blisters. The wood is soft, light, and without heartwood or resinous substances. Like all fir trees, the bark and needles are used for chemical byproducts, such as balsam oil and other ethereal oils.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: Moderate to high

Abies holophylla Maxim.-Wholeleaf fir-Pikhta **tsel'nolistnaya,** or manchurskaya, **primorskaya**

Range: The wholeleaf fir is found in the far south of the Maritime Oblast of the Far East in the mountain elevations below 500 meters.

Silvics: *A. halophylla* forests are divided into upland and lowland forests; upland forests are periodically dry, cool, and humid and lowland forests are humid and moist. This fir commonly grows in a floristically rich community along the Pacific Coast. This fir variety is extremely fast growing and shade tolerant.

Insects and Disease Pathogens: See Appendix H.

Height: 40 meters

Diameter: Up to 2 meters

Maximum Age: 450 years

Wood Characteristics:		
	Moisture content	212 percent
	Specific gravity	0.39
	psi MOR	9,440
	psi MOE	1.32
	psi Compression Parallel	4,635

Logging, Transport, and Storage: The same procedures used for other conifers are used for the wholeleaf fir.

Primary and Secondary Uses: *A. holophylla* is used for pulpwood and possibly sawtimber.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: Moderate to high

***Abies nephrolepis* (Trautv.)** Maxim.-White bark **fir—Pikhta** belokoraya, **podocheshuynaya, and amurskaya**

Range: The white bark fir is found in the mountains of the Far East, in the Primorskiy (Maritime) Kray. This tree is also found in regions of the Amur River (I'riamur'ye); the southern shore of the Sea of Okhotsk; the mountains; Central Kamchatka; the Sakhalin, lezo, and Southern Urals; North Korea; East Manchuria; and South Yakutsk A.S.S.R. (the Aldan River). This fir grows to an elevation of up to 1,200 meters or more.

Silvics: White bark fir often grows in association with *Picea ajanensis* in a cool and humid climate. 'This fir grows relatively quickly.

Insects and Disease Pathogens: This fir is subject to rot at an early age. (See Appendix H.)

Height: 25 meters

Diameter: 50 centimeters

Maximum Age: 150 to 200 years

Wood Characteristics:		
	Moisture content	N/A
	Specific gravity	N/A
	psi MOR	N/A
	psi MOE	N/A
	psi compression parallel	N/A

N/A = **Not available**

Logging, Transport, and Storage: No information available.

Primary and Secondary Uses: A. *nephrolepis* is used for pulpwood and possibly sawtimber.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: Moderate to high

Abies sachalinensis Fr. Schmidt-Sakhalin fir-Pikhta sakalinskaya

Range: Sakhalin fir grows throughout Sakhalin Island and extends to the Schmidt peninsula. It is the basic coniferous species in the southern Kuril Islands. This fir has a vertical range up to 1,000 meters,

Silvics: A. *sachalinensis* often grows in association with *Picea ajanensis* in a cool and humid climate. It grows relatively quickly and is ecologically similar to *A. nephrolepis*. After 200 years of growth, it occupies the upper canopy of the mature forest.

Insects and Disease Pathogens: *A. sachalinensis* is subject to rot at an early age. See Appendix H.

Height: 40 meters

Diameter: Undetermined

Maximum Age: 250 years

Wood Characteristics:	Moisture content	N/A
	Specific gravity	N/A
	psi MOR	N/A
	psi MOE	N/A
	psi Compression Parallel	N/A

N/A = Not available

Logging, Transport, and Storage: Rail and water transport are used to bring *A. sachalinensis* to market.

Primary and Secondary Uses: *A. sachalinensis* is used for pulpwood and possibly sawtimber.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: Moderate to high

Abies gracilis **Kom.—Slender** fir-Pikhta **stroinaya** or tonkaya

Range: *A. gracalis* is found in the Far East; primarily Kamchatka peninsula and near the mouth of the Ceml'nachik River.

Silvics: This fir grows in a limited range along the Pacific Coast in a cool and humid climate. It is ecologically similar to other Soviet Far East true firs and regenerates in the organic matter of old rotten logs. This tree is more frost tolerant than other fir species. Relic populations remaining in the Soviet Union are of little commercial value,

Insects and Disease Pathogens: *A. gracilis* is subject to rot at an early age. See Appendix H.

Height: 15 to 16 meters

Diameter: Undetermined

Maximum Age: Undetermined

Wood Characteristics:	Moisture content	N/A
	Specific gravity	N/A
	psi MOR	N/A
	psi MOE	N/A
	psi compression parallel	N/A

N/A = not available.

Logging, Transport, and Storage: No information available.

Primary and Secondary Uses: The slender fir has no commercial uses.

Importance to Soviet Timber Economy: Minor

Potential Export Value to Pacific Northwest: Low

Abies mayriana Miyabe et Kudo-Mayriana fir-Pikhta maira

Range: The Mayriana fir is found in the Far East, Southern Sakhalin, and the Kuril Islands. It is also found along the Seml'nachik River. It is found 100 meters above mean sea level.

Silvics: A. *mayriana* grows in a limited range along the coast in a cool and humid climate. Ecologically and structurally, this fir occupies the same spatial and temporal distribution in the canopy as *Picea ajanensis*. It regenerates in pure stands after harvesting.

Insects and Disease Pathogens: A. *mayriana* is subject to rot at an early age.

Height: 35 meters

Diameter: Undetermined

Maximum Age: 240 years

Wood Characteristics:	Moisture content	N/A
	Specific gravity	N/A
	psi MOR	N/A
	psi MOE	N/A
	psi compression parallel	N/A

N/A = Nut available

Logging, Transport, and Storage: No information available.

Primary and Secondary Uses: A. *mayriana* is probably used for pulpwood.

Importance to Soviet Timber Economy: Minor

Potential Export Value to Pacific Northwest: Low

Family Pinaceae **Lindl.** Genus *Picea* **Dietr.—Spruce**

The genus *Picea* is an extremely important component of the Eurasian taiga. Spruce grows on 80 million hectares with a reserve of 12 billion m³. It occupies 11.9 percent of the commercial timberlands and is the fourth most common species after larch, pine, and birch. The most extensive areas and greatest reserves of spruce are found in Northern European Russia, the Urals, and the Soviet Far East. Eight species grow in the Soviet Union, according to Sokolov et al. (1977), although Tseplyayev (1965) has documented 11. Five species of *Picea* occur in the Asian U.S.S.R. Spruce species are geographically distributed as follows and appear in order of economic importance.

European-Ural&n Soviet Union and Western Siberia:

- P. *abies* (L.) Karst.—Whitewood, European, or Norway spruce
- P. *fennica* (Regel) Kom.—Finnish spruce
- P. *orientalis* (L.) Link-Eastern or Caucasian spruce

Eastern Siberian and Far Eastern Soviet Union:

- *P. obovafa* Ledeb. or P. *sibirica*—Siberian spruce
- P. *ajanensis* (Lindl. et Gord.) Fisch. ex Carr.—Jeddo spruce
- *P. schrenkiana* Fisch. et Mey.—Shrenk's or Tien-Shan spruce
- P. *koraiensis* Nakai-Korean spruce
- *P. glehnii* (Fr. Schmidt) Mast--Glenn's spruce

Three of these species have commercial importance, *Picea obovata, Picea ajanensis,* and *Picea koraiensis. Picea abies,* found only in European Russia, is of major economic significance and is related closely to P. *obovafa.* The botanical characteristics of the two species are not radically different, except for the cone formation. Their general habitats, ecological requirements, and silvical features are almost identical. *P. abies* dominates the European Russian taiga, while P. *obovafa* occurs less frequently in the Eastern Siberian taiga, probably because of more adverse climatic conditions. Growth conditions and timber productivity are more favorable in European Russia.

Another indigenous Spruce, *P. ajanensis,* a native of the Soviet Far East, is one of the most interesting species from a ecological and commercial perspective. It grows to a height of 50 meters and a diameter of 1.5 meters; with exceptional specimens reaching an age of 350 years. Depending on the spruce's resistance to insects and disease, it plays an important role in domestic spruce sawtimber production and the export market. Because of its importance to the Siberian or Ussuri tiger habitat, harvesting this species is prohibited in the Soviet Union.

Picea obovata Ledeb.-Siberian spruce-Yel' **sibiriski**

Range: The range of the Siberian spruce extends from Northeastern European U.S.S.R. through the Urals to Siberia, with periodic occurrences along the Amur River, in the Transbaykal, and in the Sayan and Altay mountains up to 2,000 meters. In the west it grows with pine, birch, and aspen; in the Cis-Ural to the Yenisey River, it usually grows in association with Siberian fir *(A. sibirica)* or stone pine (P. *sibirica*). East of the Yenisey River, it occurs mostly in river valleys and is a rare tree in the Pacific maritime region.

Silvics: In general, the range of the Siberian spruce is more closely connected with climate and particularly with precipitation than is pine, for example. This spruce does not occur in the steppes and in regions with low precipitation and humidity. It grows best in well-drained, sandy loams, or alluvial soils. Occasionally it is found on dry, sandy sites, but its growth is usually poor.

Fruiting begins in May or June at age 30 to 50 years and the seeds mature in October. Cones open in February or March during sunny weather and dry winds. The winged seeds are distributed 10 to 25 meters in windy weather. Seed dispersal on hard crusted snow or ice may exceed a few kilometers.

The spruce seed germinates in the spring and growth is slow. It usually grows at a rate of 4 to 5 centimeters per year until the tenth year when it reaches a height of 1 to 2 meters (Kalinin et. al, 19X.5). From 10 to 15 years, P. *obovata* will grow at a rate of 30 to 70 centimeters per year. Like most boreal spruces, self pruning is poor and the branching pattern is dense with small diameter branches. It will grow up to 1 to 2 meters after 40 to 60 years in the understory of mature stands and responds well to release.

This spruce has shallow rooting and is subject to windthrow, particularly in seed tree cuts or shelterwoods. Like other spruce, it is shade tolerant (although less shade tolerant than *P. ajanensis* or *A. nephrolepsis*) and natural regeneration of spruce is prolific under the shelter of over-wood. A mid-range or second age-class of spruce is found almost everywhere in the forests, particularly on favorable soil conditions.

Insects and Disease Pathogens: See Appendix H.

Height: 30 to 35 meters

Diameter: Undetermined

Maximum Age: 200 to 300 years

Wood Characteristics:	Moisture content	N/A
	Specific gravity	N/A
	psi MOR	N/A
	psi MOE	N/A
	psi compression parallel	N/A

N/A = Not available

Logging, Transport, and Storage: Spruce is less dense than other conifers and floats easily for water transport. Its dense branching increases limbing time, particularly in manual operations where axes are used for delimbing. Merchantable range for commercial operations is 12 to 18 centimeters in diameter. This material is brittle and results in excessive breakage in cold weather. Due to branch distribution, felling is dangerous in windy weather because the entire root wad may uproot (Kalinin et al. 1985). In terms of insects and disease pathogens, root compaction and residual damage are serious problems in mechanized operations.

Primary and Secondary Uses: Siberian spruce is used for sawtimber for construction grade lumber, pulpwood, and export logs. The bark is used for tanning extracts used in the leather industry. Approximately 1 ton of bark can be extracted from 1 hectare of spruce woodland.

Importance to Soviet Timber Economy: Major

Potential Export Value to Pacific Northwest: High

Appendix E
Pest Risk Assessment Methodology

Introduction

The complete pest risk assessment methodology, as developed by USDA Animal and Plant Health Inspection Service (APHIS), is presented in this section even though the specific pest risk assessment on Soviet larch may not incorporate all of the methodology's feedback loops. The purpose for presenting the "total" methodology is to provide guidance for potential future log pest assessments.

To achieve the level of quality desired, the pest risk assessments should be:

- Comprehensive-review the subject in detail and identify sources of uncertainty in data extrapolation and measurement errors. The assessment should evaluate the quality of its own conclusions. The assessment should be flexible to accommodate new information.

- Logically Sound-up-to-date and rational--reliable, justifiable, suitable, unbiased, and sensitive to different aspects of the problem.

- Practical-commensurate with the resources made available.

- Conducive to Learning—have enough scope to have carry-over value for conducting similar assessments in the future.

- Open to Evaluation-recorded in sufficient detail so that the process could be repeated with similar results by independent reviewers.

Figure E-l outlines the pest risk assessment methodology for the importation of logs. Details of the information shown in figure E-l are described in the following pages of this section.

Collect Information on Imported Logs

The following information should, to the extent that resources will allow, be gathered on the imported logs:

- exact species and their origin(s);
- amount to be imported;
- value of importing the logs into the United States;
- distribution (time of importation, transit times, and destination) after importation;
- intended use of logs (i.e., wood chips, pulp, lumber);
- importation process and history of process (i.e., storage of logs, harvest times and methods, and logging practices);
- history of past interceptions (including foreign countries) of Siberian log imports; and
- past and present regulations for importing Siberian logs (including foreign countries).

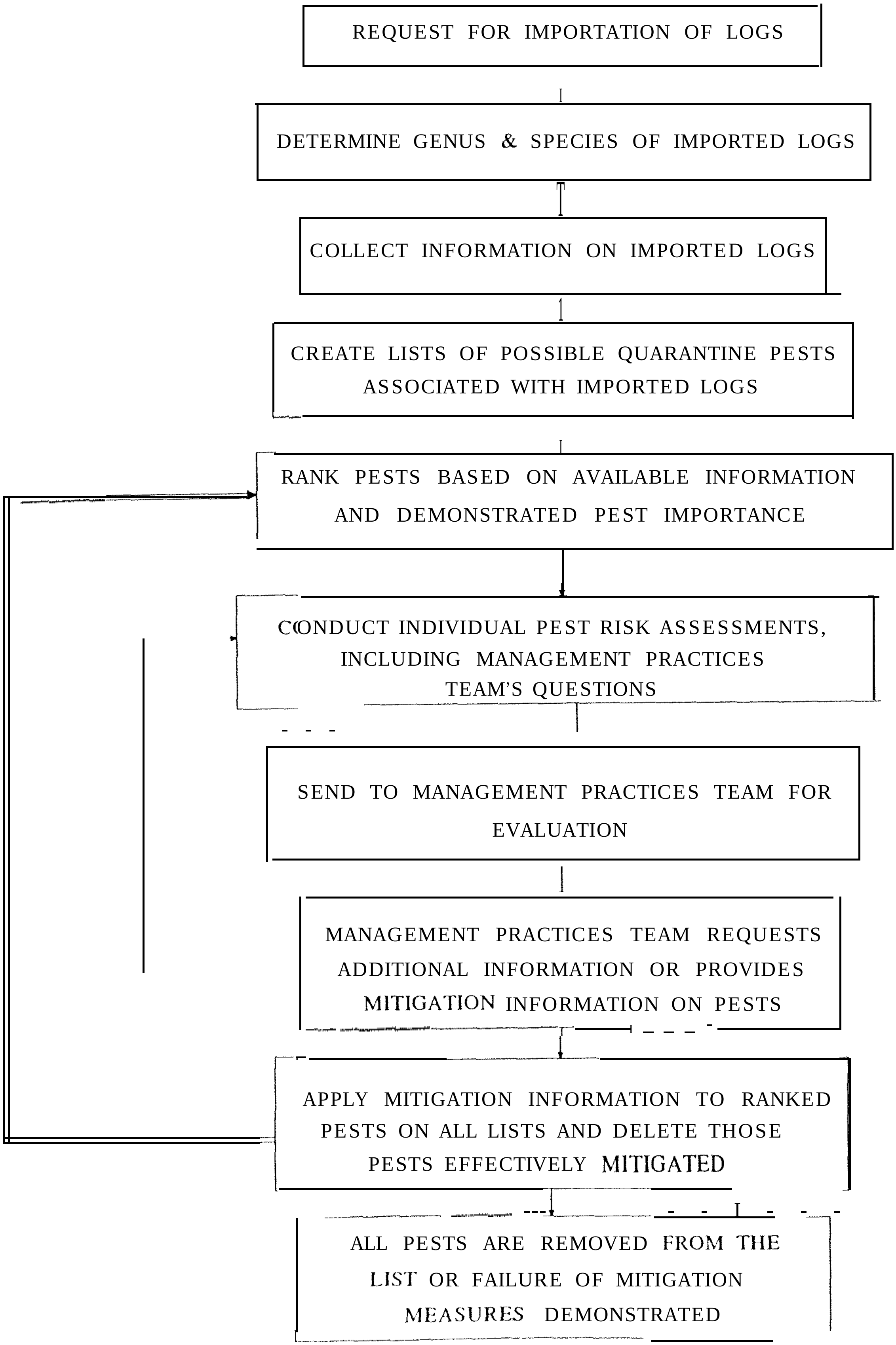


Figure E-1. Pest Risk Assessment Process

Create Lists of Possible Quarantine Pests Associated With Imported Logs

When creating lists of possible pests, make the following determinations:

(1) Determine what pests or potential pests are associated with the logs from the producing region.
(2) Determine which of these pests merit further evaluation, using table E-1.
(3) Produce a preliminary list of possible quarantine pests from (2) categories la, lb, 1c, and 2a. Taxonomic confusion or uncertainty should also be noted on the list.
(4) Divide list into ecological groups depending upon where the organism is most likely to be found (i.e., on the bark, in or under the bark, in the wood).

The listing of the organisms showing where the pests are located in the log will place the various pest organisms into groups that correspond to the Management Practices Team's mitigation categories.

Table E-l. Categories of Pests

Category	Pest Characteristics	Place on List
1a	Foreign, not present in country	Yes
1b	Foreign, in country, and capable of further expansion	Yes
1c	Foreign, in country, and reached probable limits of range, but genetically different enough to warrant concern or able to vector a foreign plant pest	Yes
1d	Foreign, in country, and reached probable limits of range, but not exhibiting any of the other characteristics of 1c	No
2a	Native, but genetically different enough to warrant concern or able to vector a foreign plant pest and/or capable of further expansion	Yes
2b	Native, but not exhibiting any of the characteristics of 2a	No

Kank Pests Based on Available Information and Demonstrated Importance

Rank pests in each list placing those pests first (1) on which the most biological information is available on life cycle, ecology, and invasion ability, and (2) which demonstrate a known economic importance. Rank those pests last for which biological information and pest importance are unknown. The ranking of pests will require some subjective judgment, but it is not important which specific pest is first or second on the list as long as they are both about equal using the two criteria listed above.

Conduct Specific Individual Pest Risk Assessments

Conduct a pest risk assessment on the highest ranked pest(s) on each list. The actual number of pests on a given list that will be assessed at any one time will depend upon the time available and number of lists needing to be assessed. Individual pests are evaluated, on the pest risk assessment form (figure E-2), using the risk elements listed below. Information on the pests should be matched with the appropriate risk element. This will help evaluate the amount of information and uncertainty, for a specific pest, for each of the risk elements. Responses to the various elements can be as specific or as general as time and information allow.

The pest risk model and standard risk formula, showing how the various risk elements interrelate, are illustrated in figure E-3.

Summary of the Pest Risk Assessment

Risk elements are underscored in the following text. The statements below asking for actual probability or impact are not attainable goals. Their function is to direct the known pest information into the risk assessment process. Getting an overall "feel" of the probability or impact is a more pragmatic goal.

A. Probability of Pest Establishment

Pest with Host at Origin

(1) Determine probability of pest being on, with, or in the imported plant commodity at the time of importation.

Entry Potential

(1) Determine probability of pest surviving in transit.

(2) Determine probability of pest being detected at port of entry under present quarantine procedures.

Colonization Potential

(1) Determine probability of pest coming in contact with an adequate food resource.

(2) Determine probability of the pest coming in contact with appreciable environmental resistance.

(3) Determine probability of pest to reproduce in the new environment.

PEST RISK ASSESSMENT FORM Reference # ____

Scientific Name of Pest ________________

Scientific Name of Host(s) ________________

Specialty Team ________________
Assessors ________________
Dated Started by Assessors ________________ Completed ________________

Pest Risk Assessment (Including References)

Summary of natural history and basic biology of the pest—

Specific information relating to risk elements:

A. Probability of Pest Establishment

1. Pest with Host at Origin-

2. Entry Potential-

3. Colonization Potential-

4. **Spread** Potential—

B. Consequences of Establishment

5. Economic Damage Potential-

6. Environmental Damage Potential—

7. Perceived Damage (Social and Political Influences)–

Estimated Risk for Pest—

Additional Remarks--

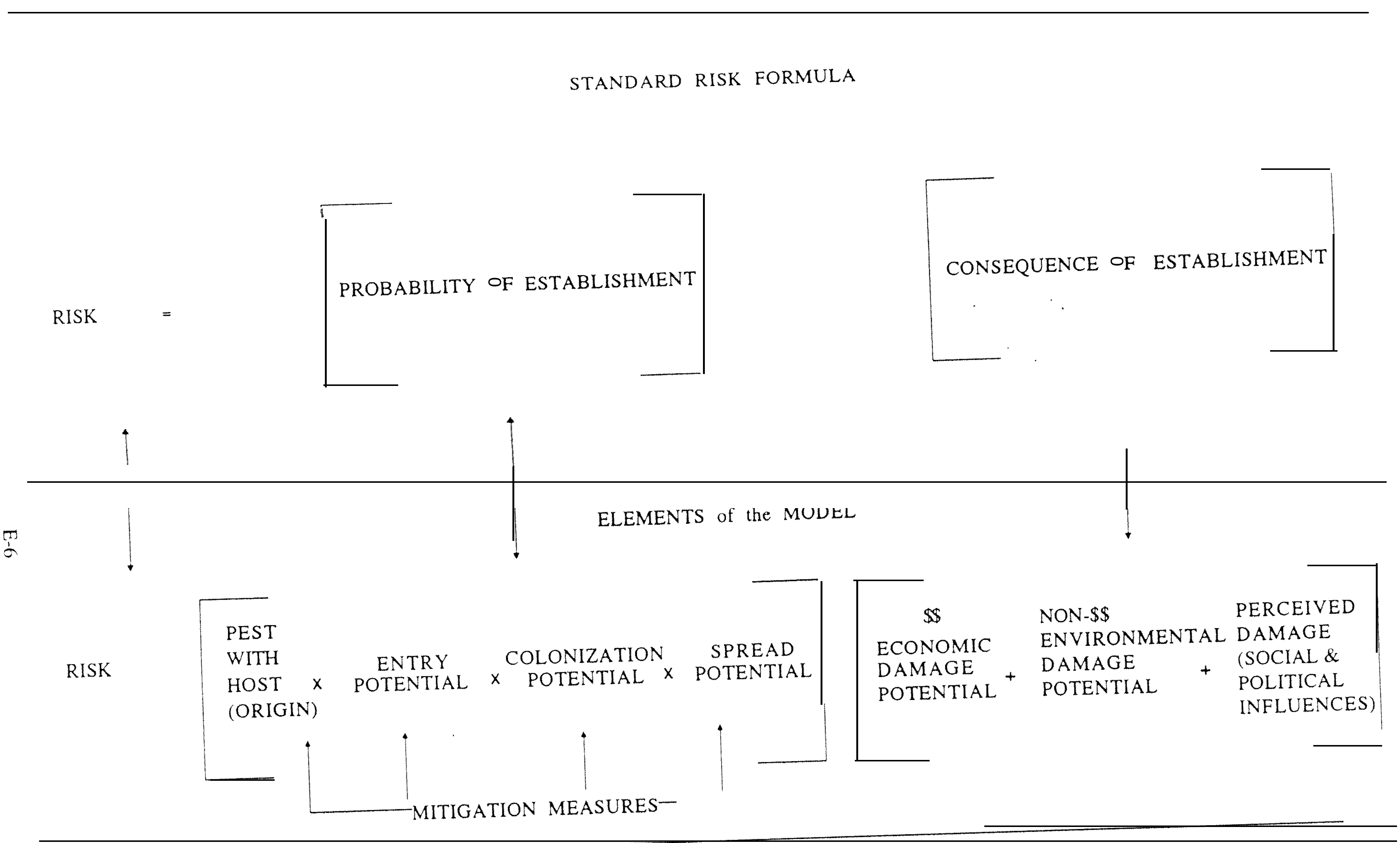
≈≈≈≈≈≈≈≈≈≈≈≈

Date Received by Management Practices Team Completed

Approved Mitigation Procedure—

Additional Remarks---

Figure E-2. Pest Risk Assessment Form



Notes: For model simplification the various elements are depicted as being independent of one another. The order of the elements in the model does not necessarily reflect the order of calculation.

Figure E-3. Model for Assessing Pests on Imported Logs

Spread Potential

(7) Determine probability of pest to spread beyond the colonized area.

(2) Estimate the range of probable spread.

B. Consequences of Establishment

Economic Damage Potential

(1) Determine economic impact if established, including the cost of living with the pest.

Environmental Damage Potential

(1) Determine environmental impact if established

Perceived Damage (Social and Political Influences)

(1) Determine impact from social and/or political influences. Record the information for each pest under the individual elements. Quality and amount of uncertainty should also be addressed under the individual elements.

There is no proven way to calculate the effects of the various elements into a combined final risk number or statement. A good risk assessment is as much art as science. The best that can be done, at this time, is to have the assessors subjectively determine the risk based on the scientific information under each element. Include a brief statement at the end of the pest risk assessment form about the subjective “total” amount of risk of the pest (i.e., risk is low, medium, or high).

In addition, the assessors will have to complete the biological questions requested by the Management Practices Team along with each pest risk assessment form.

When assessors complete the pest risk assessment form and answers to the specific biological questions supplied by the Management Practices Team for a specific pest, they should forwarded them to the Management Practices Team.

Requests for Additional Information

If the Management Practices Team requires further biological information, it can request the information from the Core Assessment Team. This cycle will continue until the Management Practices Team can provide either an effective mitigation measure or determines that the known mitigation measures have failed.

If the Management Practices Team determines an effective mitigation measure that can be used on the pest, detailed information about the mitigation measure is returned to the Core Assessment Team. (See figure E-4.)

Failure of mitigation measures or the need to supply experimental data to show efficacy in existing mitigation measures on the initial risk assessments may stop or cause a hiatus in the risk assessment process.

Apply Mitigation Information to Ranked Pests on All Lists

The returned mitigation measure(s) is (are) assumed to he required for the importation of the logs.

The mitigation measure(s) may now be used (if possible) to eliminate other pests on the various lists. Those pests remaining on the list(s) are ranked again and the process is repeated, as indicated by the double-line arrow in figure E-1.

Again, if mitigation measures fail on the initial risk assessments, this feedback loop (this section) may not be necessary.

All Pests Are Removed From the List or Failure of Mitigation Measures Demonstrated

A single potential failure of the mitigation measure in providing protection against a pest may not stop the assessment process. The Management Practices Team will make this decision in the event of a failure of the mitigation measures. Their decision will be based on the risk of the pest as presented in the pest risk assessment.

It is possible that a few pests will remain on the list because their uncertainty will not allow them to be addressed against the (by that time) applied mitigation measures. Even though the risk is not demonstrated on these pests, their presence will be considered by the Management Practices Team before making any final decision.

Consolidate All Data and Prepare Final Report on the Log Pest Risk Assessment

Both the process of the pest risk assessment and the actual data accumulated should be recorded in the final document.

The document does not have to determine whether the imported logs are to be allowed entry or which mitigation measures should be enforced. The Management Practices Team report will address the entry status of the logs. However, the final report can make recommendations to the Management Practices Team on the overall pest risk of importing the logs.

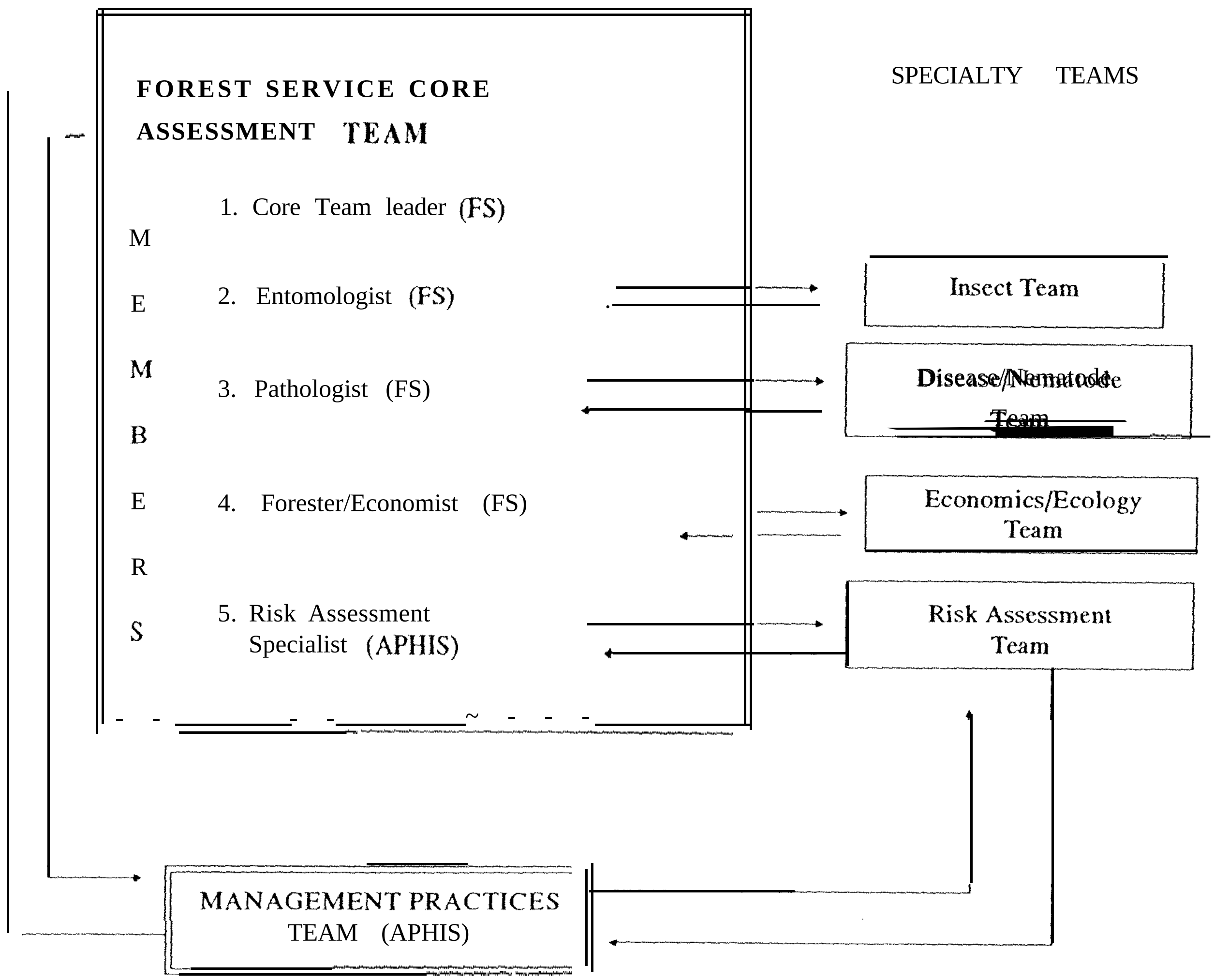


Figure E-4. Siberian Log Pest Risk Assessment Team Structure

Appendix F
Participants of the First Siberian Timber Workshop

Name	Affiliation
Fred Baker	Utah State University
Jerry Beatty	USDA Forest Service
Roy Beckwith	USDA Forest Service
Jon Bell	Agriculture Canada
Alan Berryman	Washington State University
Yuri Bihun	University of Vermont
Harold Burdsall	USDA Forest Service
Ralph Byther	Washington State University
Gary Chastenger	Washington State University
Mo-Mei Chen	University of California, Berkeley
Fields Cobb, Jr.	University of California, Berkeley
Tom Duafala	Balsa Research
George Ferrell	USDA Forest Service
Greg Filip	Oregon State University
Ed Florence	Lewis and Clark University
Bob Gara	University of Washington
Robert Gilbertson	University of Arizona
Don Goheen	USDA Forest Service
John Griesbach	Oregon Dept. of Agriculture
Bob Harvey	USDA Forest Service
Paul Hessburg	USDA Forest Service
Dan Hilburn	Oregon Dept. of Agriculture
Kathleen Johnson	Oregon Dept. of Agriculture
John Kliejunas	USDA Forest Service
LeRoy Kline	Oregon State University
Ken Knauer	USDA Forest Service
Dan Kucera	USDA Forest Service
Jack Lattin	Oregon State University
Willis Littke	Weyerhaeuser
Martin MacKenzie	Self-employed
Fred McElroy	Penninsu-Lab.
Ralph Nevill	Virginia 'Tech.
William Otrosina	USDA Forest Service
Dave Overhulser	Oregon Dept. of Forestry
Catharine Parks	USDA Forest Service
Dick Parmeter	University of California, Berkeley
Tom Payne	Virginia Tech
Jack Rogers	Washington State University

Name	Affiliation
Darrell Ross	Oregon state university
Ken Russell	Washington DNR
Dave Schultz	USDA Forest Service
Michael Shannon	USDA APHIS
Kathy Sheehan .	USDA Forest Service
Eugene Smalley	University of Wisconsin
Dick Smith	USDA Forest Service
Gary Smith	USDA APHIS
Jeff Stone	Oregon State University
Borys Tkacz	USDA Forest Service
Allan Van Sickle	Forestry Canada
Bill Wallner	USDA Forest Service
Boyd Wickman	USDA Forest Service
Wayne Wilcox	University of California, Berkeley
David Wood	University of California, Berkeley

Appendix G
Participants of the
Second Siberian Timber Workshop

Name	Affiliation
Fred Baker	Oregon State University
Jerome Beatty	USDA Forest Service
Alan Berryman	Washington State University
Yuriy Bihun	University of Vermont
Dave Cleaves	Oregon State University
Donald Flora	USDA Forest Service
Don Goheen	USDA Forest Service
Kurt Gottschalk	USDA Forest Service
John Crobey	Humboldt State University
Bob Harvey	USDA Forest Service
Tom Holmes	USDA Forest Service
Bob Housley	USDA Forest Service
Kathleen Johnson	Oregon Dept. of Agriculture
Alan Kanaskie	Oregon Dept. of Forestry
Ken Knauer	USDA Forest Service
Dan Kucera	USDA Forest Service
Joe Lewis	USDA Forest Service
Rob McDowell	USDA APHIS
Bill McKillop	UC Berkeley
Robert Morris	Louisiana Pacific Corp.
Ralph Nevill	Virginia 'Tech
Jay O'Laughlin	University of Idaho
Richard Orr	USDA APHIS
Tom Payne	Virginia Tech
Ken Russell	Washington Dept. of Natural Resources
Micheal Shannon	USDA APHIS
Phil Szmedra	USDA ERS-AIPS
Borys Tkacz	USDA Forest Service
Carol Tuszynski	USDA APHIS
Bill Wallner	USDA Forest Service
Thomas Waggener	University of Washington
Marc Wiitala	USDA Forest Service

Appendix H
Pests and Pathogens on Coniferous Trees of the Eastern Soviet Union

I. Siberian Region

Main Species of Bark Beetles (Scolytidae)

A. Larch Forests

Larix gmelini (Rupr.) Rupr.

Dryocoetes baicalicus Reitt.
Ips acuminatus Eichh.
I. duplicatus Sahlb.
I. sexdentatus Boem.
I. *subelongatus* Motsch.
I. typographus Lin.
Orthotomicus starki Spess.
Pityogenes baicalicus Egg.
P. chalcographus L.
P. irkutensis Egg.
Pityuphthorus micrographus L.
Polygraphus sachalinensis Egg.
Scolytus *morawitzi* Sem.
Trypodendron lineatum Ol.

Larix sibirica Ledeb.

Ips acuminatus Eichh.
I. duplicatus Sahlb.
I. sexdentatus Boern.
I. subelongatus Motsch.
I. typographus Lin.
Orthotomicus starki Spess.
Pityogenes baicalicus Egg.
P. chalcographus L.
Pityophthorus micrographus L.
Polygraphus sachalinensis Egg.
Typodmdron lineatum 01.

B. Spruce and Fir Forests

Picea obovata Ledeb.
Abies sibirica Ledeb.

Carphoborus teplouchovi Spess.
Cryphalus abietis Katz.
C. saltuarius Wse.
Dendroctonus micans Kug.
Dryocoetes autographus Ratz.
Hylastes cunicularius Er.
Hylurgops glabratus Zett.
Ips acuminatus Eichh.
I. duplicatus Sahlb.
I. typographus L.
Orthotomicus laricis F.
0. starki Spess.
0. suturalis Gyll.
Phthorophloeus spinulosus Rey
Pityogenes bidentatus Hbst.
P. *chalcographus* L.
P. quadridens Hart.
Pityophthorus morosovi Spess.
P. *traegardhi* Spess.
Polygraphus poligraphus L.
P. punctifrons Thoms.
P. subopacus Thoms.
Trypodendron lineatum 01.
Xylechinus pilosus Ratz.

C. Pine Forests

Pinus sibirica Ledeb.

Dryocoetes autographus Ratz.
Hylastes opacus Er.
H. opacus Er.
Hylurgops glabratus Zett.
H. palliatus Gyll.
Ips duplicatus Sahlb.
1. sexdentatus Boern.
Orthotomicus golovjankoi Pjat.
0. *laricis* F.
0. *proximus* Eichh.
0. suturalis Gyll.
Pityogenes bidentatus Hbst.
P. chalcographus L.
P. quadridens Hart.
Pityophthorus micrographus L.
Polygraphus subopacus Thorns.
Trypodendron lineatum 01.

D. Scotch Pine Forests

Pinus sylvestris L.

Blastophagus minor Hart.
B. piniperda L.
Carphoborus cholodkovskyi Spess.
Dendroctonus micans Kug.
Hylasfes ater Payk.
H. opacus Er.
Hylurgops glabratus Zett.
H. spessivtzevi Egg.
Ips acuminatus Eichh.
I. sexdenfafus Boer-n.
Orthofomicus laricis F.
0. *proximus* Eichh.
0. suturalis Gyll.
Pityogenes bidentatus Hbst.
P. chalcographus L.
P. irkutensis Egg.
P. *quadridens* Hart.
Polygraphus poligraphus L.
Trypodendron lineatum 01.

Wood Borers **(Cerambycidae)**

A. Tundra Larch Forests

Larix gmelini (Rupr.) Rupr.

Acanthocinus carinulatus Gebl.
Acmaeops pratensis Laich.
A. septentrionis Thorns.
A. smaragdula F.
Anoplodera sequensi Reitt.
Asemum sfriafum L.
Callidium coriaceum Payk.
Judolia sexmaculata L.
Monochamus impluviatus Motsch.
M. *sutor* L.
M. *urussovi* Fisch.
Pogonocherus fasciculatus Deg.
Tefropium gracilicorne Reitt.

B. Larch Forests

Larix sibirica Ledeb.

Acanthocinus carinulatus Gebl.
Acmaeops sepfenfrionis Thorns.
A. smaragdula F.
Anoplodera sequensi Reitt.
A. variicornis Dalm.
Asemum sfriatum L.
Callidium chlorizans Sols.
C. violaceum L.
Clyfus ariefoides Reitt.
Cornumutila quadrivitfata Gebl.
Gaurofes virginea L.
Judolia sexmaculata L.
Leptura arcuafa Panz.
Monochamus impluviatus Motsch.
M. salutarius Gebl.
M. *sufor* L.
M. urussovi Fisch.
Nivellia extensa Gebl.
Pogonocherus fasciculatus Deg.
Rhagium inquisitor L.
Strangalia affenuafa L.
Tetropium gracilicorne Reitt.
Xylotrechus altaicus Gebl.

C. Spruce and Fir Forests

Picea obovafa Ledeb.
Abies sibirica Ledeb.

Acanthocinus griseus F.
Acmaeops pratensis Laich.
A. septenfrionis Thorns.
Anoplodera sequensi Reitt.
Arhopalus rusticus L.
Asemum sfriafum L.
Clytus ariefoides Reitt.
Evodinus borealis Gyll.
Judolia sexmaculata L.
Molorchus minor L.
Monochamus salutarius Gebl.
M. sutor L.
M. *urussovi* Fisch.
Pogonocherus fasciculatus Deg.
Pronocera brevicollis Gebl.
Rhagium inquisitor L.
Sapwda interrupta Gebl.
Spondylis buprestoides L.
Strangalia affenuafa L.
Tefropium castaneum L.

D. **Pine Forests**

Pinus sibirica Ledeb.

Acmaeops angusticollis Gebl.
A. septentrionis **Thorns.**
A. smaragdula F.
Anoplodera rufiventris Gebl.
A. rubra L.
A. sequensi **Reitt.**
Arthopalus rus ticus L.
Asemum striatum L.
Callidium coriaceum Payk.
Clytus ariefoides Reitt.
Evodinus borealis Gyll.
Monochamus salutarius Gebl.
M. sufor L.
M. urussovi Fisch.
Pogonocherus fasciculatus Deg.
Rhagium inquisitor **L.**
Tetropium casfaneum **L.**
Tragosoma depsarium **L.**

E. Scotch Pine Forests

Pinus sylvestris L.

Acanthocinus aedilis **L.**
A. griseus F.
Acmaeops marginata **F.**
Anoplodera rubra L.
A. virens L.
Arhopalus rusticus L.
A. tristis F.
Asemum striatum L.
Callidium violaceum L.
Clytus arietoides Reitt.
Evodinus borealis Gyll.
Gaurotes virginea L.
Judolia sexmaculata L.
Monochamus galloprovincialis 01.
Pachyta quadrimaculata **L.**
Pogonocherus fasciculatus Deg.
P. *ovatus* Goeze
Pronocera brevicollis Gebl.
Rhagium inquisitor L.
Spondylis buprestoides L.
Tragosoma depsarium L.

Flatheaded Borers (Buprestidae)

A. Pine Forests

Pinus sylvesfris L.

Phaenops cyanea

Weevils (Curculionidae)

A. Larch Forests

Hylobius abietis L.
H. moria

B. Spruce **and** Fir Forests

Pissodes cembrae Motschulaky

C. Pine Forests

Pissodes cembrae Motschulaky

Wood Wasps **(Siricidae)**
(Siberia and Far East)

A. Tundra Low Density Forests

Paururus noctilio F.
Urocerus gigas L.

B. Spruce, Fir, and Pine Forests

Paururus ermak Sem.
P. juvencus L.
P. mongolorum Sem. et Cuss.
P. noctilio F.
Trernex *safanas* Sem.
Urocerus antennatus Marl.
U. gigas L.
Xeris specfrurn L.
Xoanon mysta Sem.

C. Fir Forests

Paururus ermak Sem.
P. juvencus L.
P. noctilio F.
Tremex safanas Sem.
Uroccrus gigas L.
Xeris spectrum L.

D. Larch Forests

Paururus ermak Sem.
P. juvencus L.
P. mongolorum Sem. et Guss.
P. noctilio F.
Urocrrus antennatus Marl
U. gigas L.
U. umbra Sem.
Xeris spectrum L.

E. Scotch Pine Forests

Paururus juvencus L.
P. noctilio F.
Urocerus gigas L.
U. tardigradus Ced.

F. Coniferous and Broad-Leaf Larch Forests

Paururus ermak Sem.
P. *juvencus* L.
P. mongolorum Sem. et Cuss.
P. noctilio F.
Urocents antennatus Marl.
U. gigas L.
Xeris spectrum L.
Xiphydria eborata Knw
Xoanon matsumurae Roh.
X. mysta Sem.

II. Seacoast Forests Region (Far East)

Main Species of Bark Beetles (Scolytidae):

A. Larch Forests

Larix gmelini (Rupr.) Rupr.

Cryphalus lafus Egg.
Dryocoefes *baicalicus* Reitt.
D. *hectographus* Reitt.
D. rugicollis Egg.
lps acuminafus Eichh.
1. duplicafus Saheb.
I. sexdentatus Boern.
Orthofomicus laricis Fabr.
0. *suturalis* Gyll.
Pityogenes chalcographus L.
Polygraphus sachalinensis Egg.
Trypodendron lineatum 01.

Larix olgensis Henry

Cryphalus lafus Egg.
Dryocoetes baicalicus Reitt.
D. hectographus Reitt.
D. rugicollis Egg.
lps acuminafus Eichh.
1. duplicatus Saheb.
1. sexdentafus Boem.
Orthotomicus laricis Fabr.
0. sufuralis Gyll.
Pityogenes chalcographus L.
Trypodendron lineatum 01.

B. Spruce and Fir Forests

Picea jezoensis Carr.

Blastophagus puellus Reitt.
Dryocoetes hectographus Reitt.
D. rugicollis Egg.
Hylurgops glabratus Zett.
H. *palliatus* Gyll.
Ips acuminatus Eichh.
I. sexdentatus Boern.
I. *typographus* L.
0. golovjankoi Pjat.
0. *laricis* Fabr.
0. suturalis Gyll.
Pityogenes chalcographus L.
Polygraphus jezoensis Niis.
P. punctifrons Thorns.
P. sachalincnsis Egg.
P. subopacus Thorns.
Trypodendron lineatum 01.
7'. proximum Niis.
Xylechinus pilosus Ratz.

Picea koraiensis Nakai

Dryocoetes hectographus Reitt.
D. rugicollis Egg.
Hylurgops palliatus Gyll.
Ips acuminatus Eichh.
1. *sexdentatus* Boem.
I. subelongatus Motsch.
1. typographus L.
Orthafomicus golovjankoi Pjat.
0. laricis Fabr.
0. suturalis Gyll.
Pityogenes chalcographus L.
Polygraphus jezoensis Niis.
P. punctifrons Thoms.
P. sachalinensis Egg.
Scolytus morawitzi Sem.
Trypodendron lineatum 01.
T. proximum Niis.

Abies holophylla Maxim.

Dryocoetes hectographus Reitt.
D. rugicollis Egg.
D. striatus Egg.
Ips duplicatus Saheb.
Hylurgops palliatus Gyll.
Orthotomicus golovjankoi Pjat.
Pityogenes chalcographus L.
Polygraphus proximus Blandf.
P. sachalinensis Egg.
Trypodendron lineatum 01.

Abies nephrolepis (Trautv.) Maxim.

Dryocoetes hectographus Reitt.
D. *rugicollis* Egg.
D. striafus Egg.
Hylurgops palliatus Gyll.
Orthofomicus golovjankoi Pjat.
0. *laricis* Fabr.
Pityogenes chalcographus L.
Polygraphus proximus Blandf.
P. sachalinensis Egg.
Trypodendron lineatum 01.

C. Pine Forests

Pinus koraiensis Sieb. et Zucc.

Blastophagus pilifer Spess.
Dryocoetes hectographus Reitt.
Hylastes *parallelus* Chapusis
H. plumbeus Blandf.
Hylurgops imitator Reitt.
H. interstitialis Chap.
H. spessivtzevi Egg.
Ips acuminatus Eichh.
I. scxdentatus Boern.
I. typographus L.
Orthotomicus golovjankoi Pjat.
0. laricis Fabr.
0. proximus Eichh.
0. suturalis Gyll.
Pityogenes chalcographus L.
Trypodendron lineatum 01.

Pinus sylvestris L.
P. sylvestris mongolica Litv

Blastophagus pilifer Spess.
Dryocoetes hectographus Reitt.
Hylastes attenuatus K.
Hylurgops imitator Reitt.
H. *interstitialis* Chap.
Ips acuminatus Eichh.
I. sexdentatus Boem.
I. typographus L.
Orthotomicus laricis Fabr.
0. *suturalis* Gyll.
Pityogenes chalcographus L.
Polygraphus sachalinensis Egg.
Trypodendron lineatum 01.

A. Larch Forests

Larix gmelini (Rupr.) Rupr.

Acanfhocinus aedilis L.
A. carinulatus Gebl.
Arhopalus rusticus L.
Asemum striatum L.
Callidium aeneum Deg.
C. violaceum L.
Cyrfoclyfus capra Germ.
Monochamus salutarius Gebl.
M. *urussovi* Fisch.
Pogonocherusfasciculatus Deg.
Rhagium *inquisitor* L.
Tetropium castaneum L.
T. *gracilicorne* Reitt.
Xylutrechus altaicus Gebl.

B. Spruce and Fir Forests

Picea jezoensis Carr.

Acanfhocinus aedilis L.
A. carinulatus Gebl.
A. griseus F.
Arhopalus rusticus L.
Asemum striatum L.
Callidium violacrum L.
Cyrfoclyfus capra Germ.
Monochamus salutarius Gebl.
M. *sutor* L.
M. *urussovi* Fisch.
Pogonocherus fasciculatus Deg.
Rhagium inquisitor L.
Semanotus undatus L.
Tetropium castaneum L.
T. gracilicorne Reitt.

Picea koraiensis Nakai

Aranthocinus aedilis L.
A. carinulafus Gebl.
A. griseus F.
Arhopalus rusticus L.
Asemum striatum L.
Callidium violaceum L.
Cyrtoclytus capra Germ.
Monochamus salufarius Gebl.
M. sutor L.
M. urussovi Fisch.
Pogonocherusfasciculatus Deg.
Rhagium inquisitor L.
Tefropium casfaneum L.

Abies holophylla Maxim.

Acanthocinus aedilis L.
A. carinulatus Gebl.
Arhopalus rusficus L.
Asemum sfriatum L.
Callidium violaceum L.
Monochamus salutarius Gebl.
M. sufor L.
M. urussovi Fisch.
Pogonocherus fasciculafus Deg.
Rhagium inquisitor L.
Tetropium casfaneum L.
T. gracilicorne Rei tt.

Abies nephrolepis (Trautv.) Maxim.

Acanfhocinus aedilis L.
A. carinulafus Gebl.
A. rusticus L.
Asemum striatum L.
Callidium violaceum L.
Monochamus salutarius Gebl.
M. *sufor* L.
M. urussovi Fisch.
Tetropium castaneurn L.
T. gracilicorne Reitt.

C. Pine Forests

Pinus koraiensis Sieb. et Zucc.

Acanthocinus aedilis L.
Arhopalus rusticus L.
Asemum sfriatum L.
Callidium violaceum L.
Cyrfoclytus capra Germ.
Monochamus salutarius Gebl.
M. urussovi Fisch.
Pogonocherus fasciculatus
Rhagium inquisitor L.
Tetropium castaneum L.
T. *gracilicorne* Reitt.

Pinus sylvestris L.

Acanthocinus aedilis L.
A. carinulatus Gebl.

Arhopalus rusticus L.
Asemum striatum L.
Callidium violaceum L.
Cyrtoclytus capra Germ.
Monochamus *salutarius* Gebl.
M. sufor L.
M. *urussovi* Fisch.
Pogonocherus fasciculatus
Rhagium inquisitor L.
Tetropium castaneum L.

Flatheaded Borers (Buperstidae)

A. Larch Forests

Larix gmelini (Rupr.) Rupr.

Ancylocheira sibirica Fleisch.
A. strigosa Gebl.
Anfhaxia quadripunctafa L.
A. reticulata Motsch.
Chysobothris chysosfigma L.
Melanophila acuminafa Deg.
Phaenops guttulata Gebl.

B. Spruce and Fir Forests

Picea jezoensis Carr.

Ancylocheira sibirica Fleisch.
A. sfrigosa Gebl.
Anthaxia quadripunctafa L.
A. reficulafa Motsch.
Chrysobothris ch rysostigma L.
Melanophila acuminafa Deg.
Phaenops guitulata Gebl.

Picea *koraiensis* Nakai

Ancylocheira sibirica Fleisch.
A. strigosa Gebl.
Anfhaxia quadripuncfata L.
A. reticulata Motsch.
Ch rysobothris ch ysosfigma L.
Melanophila acuminata Deg.
Phaenops guttulata Gebl.
Abies holophylla Maxim.
Anthaxia quadripuncfafa L.
A. reticulafa Motsch.
Chrysobothris ch ysosfigma L.
Melanophila acuminata Deg.

Abies nephrolepis (Trautv.) Maxim.

Anfhaxia quadripunctafa L.
A. reticulata Motsch.
Ch rysobothris ch ysosfigma L.

C. Pine Forests

Pinus koraiensis Sieb. **et** Zucc.

Ancylocheira sibirica Fleisch.
A. strigosa Gebl.
Anthaxia quadripuncfata L.
A. reticulafa Motsch.
Ch ysobothtis chrysostigma L.
Melanophila acuminata Deg.

Pinus sylvestris var. *mangolica* Litv.

Ancylocheira sibirica Fleisch.
A. strigosa **Gebl.**
Anthaxia quadripuncfafa L.
A. reficulafa Motsch.
Ch ysobothris ch ysostigma L.
Melanophila acuminafa Deg.

Weevils (Curculionidae)

A. Larch Forests

Larix gmelini (Rupr.) Rupr.

Hylobius albosparsus Boh.
Pissodes gyllenhali Gyll.

B. Spruce and Fir Forests

Picea jnoensis Carr.

Cyptowhynchus electus Roel.
Hylobius albosparsus Boh.
H. haroldi Faust.
H. piceus Deg.

H. pinastri Gyll.
Pissodes gyllenhali Gyll
Sipalinus gigas F.

Picea koraiensis Nakai

Cryptorrhynchus electus Roel
Hylobius albosparsus Boh.
H. *haroldi* Faust.
H. piceus Deg.
H. pinasfri Gyll.
Pissodes gyllenhali Gyll.

Abies holophylla Maxim.

Niphades variegafus Roel.
Sipalinus gigas F.
Meland yidae spp.

Abies nephrolepis (Trautv.) Maxim.

Niphades variegafus Roel

C. Pine Forests

Pinus koraiensis Sieb. et Zucc.

Cryptorrhynchus electus Roel.
Hylobius albosparsus Boh.
H. haroldi Faust.
H. pinasfri Gyll.
Pissodes gyllenhali Gyll.
Sipalinus gigas F.

Pinus sylvestris **var.** *mangolica* Litv.

Hylobius albosparsus Boh.
Pissodes gyllenhali Gyll.

Blazed Tree Borer (Melandryidae)

A. Larch Forests

Larix gmelini (Rupr.) Rupr.

Serropalpus barbafus L.

Wood Wasps (Siricidae)

A. Larch Forests

Larix gmelini (Rupr.) Rupr.

Paururus ermak Sem.
P. juvencus L.
Urocerus antennatus Marl.
U. gigas L.
Xoanon mysfa Sem.

B. Spruce and Fir Forests

Picea jezoensis Carr.

Paururus *ermak* Sem.
P. juvencus L.
Urocerus *antennatus* Marl.
U. gigas L.

Picea koraiensis Nakai

Paururus ermak Sem.
P. juvencus L.
Urocerus anfennafus Marl.
U. gigas L.
Xoanon mysfa Sem.

Abies holophylla Maxim.

Paururus ermak Sem.
P. juvencus L.
Urocerus anfennafus Marl.
Xoanon mysfa Sem.

Abies nephrolepis (Trautv.) Maxim.

Paururus ermak Sem.
P. juvencus L.
Urocerus anfennafus Marl.
U. gigas L.
Xoanon mysta Sem.

C. Pine Forests

Pinus koraiensis **Sieb. et Zucc.**

Paururus ermak **Sem.**
P. juvencus L.
Urocerus anfennafus **Marl.**
U. *gigas* L.
Xoanon mysta **Sem.**

Pinus sylvestris **var.** *mangolica* **Litv.**

Paururus ermak **Sem.**
P. *juvencus* L.
Urocerus anfennafus Marl.
U. gigas L.
Xoanon mysta Sem.

Pathogens

(Pathogens of Coniferous Trees in the Eastern Soviet Union)

A. Larch (*Larix* **spp.)**

Hypodermella laricis
Meria laricis
Melampsoridium betulinum
Melampsora larici-capraearum
Melampsora larici-epitea
Melampsora larici-populina
Melampsora larici-fremulae
Melampsora populnea
Hymenochaete abiefina
Lachnellula willkommii
Phacidiopycnis pseudotsugae
Columnocysfis abietina
Fomifopsis officinalis
Fomifopsis pinicola
Ganoderma lucidum
Hapalopilus fibrillosus
Hirschioporus abiefinus
Hymenochaete tabacina
Ischnoderma resinosum
Laetiporus sulphreus
Phell inusignarius
Phellinus pini
Phellinus torulosis
Pholiofa destruens
Polyporus squamosus
Armillaria spp.
Heterobasidion annosum
Inonotus circinatus
lnonotus heinrichii
lnonotus tomentosus
Phaeolus schweinitzii
Polyporus osseus

B. Spruce (*Picea* **spp.)**

Lachnellula calyciformis
Lachnellula subsilissimus
Ascocalyx **spp.**
Paicula **spp.**
Lophodermium macrosporum
Chrysomyxa ledi-ledi
Chrysomyxa ledi-rhododendri
Chrysomyxa woroninii
Ch ysomyxa pirolata
Puccini&rum areolatum
Heterobasidion annosum
Phaeolus schweinifzii
lnonotus tomentosus
Phellinus pini
Phellinus chrysoloma
Phellinus weirii
Armillaria **spp.**

C. Fir *(Abies* **spp.)**

Lachnellula **spp.**
Puccini&rum goepptertianum
Pucciniastrum epilobi
Uredinopsis spp.
Melampsora **spp.**
Melampsorella **spp.**
Ophiostoma **spp.**
Heterobasidion annosum
Phaeolus schweinitzii
lnonotus tomentosus
Phellinus pini
Phellinus ch rysoloma
Armillaria **spp.**
Phellinus weirii

D. Pine (*Pinus* spp.)

Cronartium flaccidum
Cronartiurn spp.
Lachnellula spp.
Ophiosfoma SQQ.
Heterobasidion annosum
Bursaphelenchus SQQ.
Phaeolus schweinitzii
Jnonotus tomentosus
Phellinus pini
Armillaria SQQ.
Phellinus weirii
Phellinus torulosus

E. Scotch Pine (*Pinus sylvestris)*

Lagenidiales

Lagenidium pygmaeum Zopf. (dust coat)
Phytophthoru cactorum Lev. and Cohn (seedling)
Ph. cinnamomi Kands. (seedling)
Pythium aphanidermatum (seedling)
P. debaryanum Hesse (seedling)
P. irregulare Buism. (seedling)
P. pyrilobum Trow. (seedling)
P. ultimum Trow. (seedling)
P. torulosum F. (seedling)

Mucorales

Thamnidium elegans Link

Eurotiales

Elaphomyces cervinus (Pers.) Schrot (seed)
Ceratocystis (Ophiostoma) (lumber)
C. *minor* (Hedge.) Hunt (lumber)
C. *piceue* (Muxh.) Bakshi (lumber)
C. pini (lumber)
C. pilifera (lumber)

Sphaeriales

Herpotrichia juniperi (Duby.) Petrak. (needle) (lumber)
H. nigru Karst. (lumber)
Niesslia vermicularia Zer. (branch)
N. pusilla (Fr.) Sch. (needle dryed, branch)
Spharia pinastri Fr. (branch)

Xylariales

Coniochaeta malacotriha (Niessl.) Trav. (branch, lumber)
Rosellinia helena (Fr.) Sch. (Root)
R. obliquata Wint. (cone's scales)
Hypoxylon diuthrausfon Rehm. (branch)

Allantosphacriales

Calosphaeria abietis Krieger (bark)
C. *ligniaria* (Grev.) Mass. (lumber, bark)
Diaporthe eres Nits. (bark)
Valsa collicula (Worm) Cke. (bark)
V. decumbens (Sch.) Nits. (bark)
V. pini (Alb. et Schw.) Fr. (bark)
V. superficiales Fr. (bark)
Valsella ubietis (Rostr.) Munk. (branch-dried)

Melanosporarales

Melanospora chioneu (Fr.) Cda (bark and rotted wood)

Hyporcreales

Calonectria cucurbitula (Fr.) Sacc. (bark and rotted wood)
Gibberella suabinetii (Mont.) Sacc. (seedling)
Hypocrea alutaceae (Pers. ex Fr.) Ces. (needle and seed)
Nectriu cinnabarina (Tode) ex Fr. (branch)
N. cucurbitula (Tode) ex Fr. (branch)
N. viridescens Booth (branch)
Ophionectria scolecospora Bref. (needle, branch)

Pezizales

Rhizinu undulata Fr. (root)
Desmazierella acicola Lib. (needle)
Discina perlata (Fr.) Fr. (trunk)
Peziza calycina Fr. (trunk)
P. resinae Fr. (trunk)
Pseudoplectania melaena Fr. (branch)

Phacidiales

Corcophacidium pini (Schw. ex Fr.) Rehm. (branch)
Hypodermella ampla Fr. (needle)
H. arcuata Dark (needle)
H. cerina D. (needle)
H. concolar L. (needle)
Hypodermella Jimitata (needle)
H. montana F. (needle)

H. *pedatum* D. (needle)
II. *sulcigena* (Rostr.) Tubeuf (needle)
Lasiostictis fimbriata (Schw.) Baumber (needle)
Loyhodermium brachysporum Rostr. (needle)
I,. *durilabrum* Darker (needle)
L. nitens Darker (needle)
L. pinastri (Sch.) Chev. (needle)
Phacidium convexum Deam (needle)
P. infestans Karst. (needle)
P. planum Davis (needle)
Pseudographis pinicola (Nyl.) Rehm (bark)

Ostropales

Naemacyclus niveus Sacc. (needle)
Stictis fimbriata Schw. (cone)

Helotiales

Mitrula pusilla (Nees.) Fr. (branch)
Sclerotinia graminearum Elen.
Orbilia chryzocoma (Bull.) Sacc. (branch)
Cenangium abietis (Pers.) Duby
C. *acicolum* Rehm
C. atropurpureum Cash
Cenangium ferruginosum Fr.
C. *pinicola* (Reb.) Karst. (branch)
Crumenula abicfina Lagerb. (branch)
C. *sororia* Karst.
Dermatea pini Phill. et Harkn. (branch)
Tympanis buchsii Rehm. (branch)
T. confusa Nyl. Conn. (branch)
T. *hypopodia Nyl.* Conn. (branch)
T. pinastri Tul. (branch)
Dasyscypha agassizzi (Berk ex Curt.) Sacc. (branch)
D. arida Sacc. (branch)
D. *calyciformis* (Willd.) Rehm.
D. *ellisiana* (Rehm) Sacc. (branch)
D. oblongospora Hahn ex Ayers. (branch)
D. *pini* (Brunch.) Hahn ex Ayers. (branch)
D. pulverulentus (Lib.) Sacc.
Lachnellula calycina Sacc. (branch)
L. chrysophthalma (Pers.) Karst. (branch)
L. flavorirens (Bres.) Dennis (branch)
L. fuscosanguonea (Rehm) Dennis (branch)
L. pini (Brunch.) Dennis (branch and stem)
L. pseudofarinacea Dennis (branch)
Pezizella lythri Sacc.
P. minuta Decern.
Phialea acuum (Alb. et Schw.) Rehm.
Biatorella resinae (Fr.) Mudd.
Pragmopora amphibola Massal.

Scleroderris lagerbergii Germ.
Tryblidiopsis pinastri (Pers.) Karst. (branch)

Dothideales

Physalospora obtusa (Schw.) Cke.
Phaeocryptopus pinastri (Ell and Sacc.) Petz.
Scirrhia acicola (Dear-n) Siggers
Scirrhia pini Funk.
Scorias spongiosa (Schw.) Er.
Cucurbitaria pithyophila (Fr.) de N. (branch)
Botryosphaeria ribis Gross. (branch)

Capnodiales

Capnodium pini Berk. et Curt. (branch)

Hysteriales

Hypoderma brachysporum (Rostr.) Tubeuf.
H. conigenum Cooke
H. desmazierii Duby
H. pallidula Br.
H. pinicola Brunch.
Hypoderma saccatum Dark. (branch)
Hysterium contorfum Ditt. (branch)
H. crispum Fr. (branch)
H. elatinum Fr. (branch)
Hysterographium now Caesariense (Ell.) Roum.
Lophium rnytilinum Pers. ex Fr. (branch)

Aphyllophorales

Aleruodiscus amorphus (Pers.) Rab.
A. polygonius (Pers.) H. et L.
Amylostereum areolatum Fr. Boidin (bark, lumber)
Athelia galzinii (Bourd.) Donk.
Cavulicium macconii (Burt) John Erikss et Boid ex Parm. (branch)
Corficium byssinum (Karst.) Mass.
C. centrifugum (Lev.) Bres. (log)
C. *evolvens* Fr. (branch)
C. *laeve* Br. (lumber)
C. *mutabile* Bres. (lumber)
C. *ochroleucum* Bres. (lumber)
C. pelliculare Karst. C. pertenue Karst.
C. sulphureum Fr.
C. *terrigenum* Bres. (lumber)
C. teutoburgense Brinkm. (lumber)
Cytidia albo-melea (Bond.)
Gloecystidium alutaceum (Sch.) Bourd. et Galz. (lumber)
Gloecystidium inaequale H. et L. (bark, lumber)
G. ochraceum (Fr.) Litsch. (bark, lumber)

G. sphaerospora (H. et L.) Bourd. et Galz.
Glocoporus amorphus f. molluscus (Fr.) Killern.
Gl. dichrous (Fr.) Bres.
Hyphodontia arguta Erikss.
H. subalutaceae (Karst.) Erikss.
Metulodontia cremeo-alutacea Parm.
Peniophora agrillaceae Bres. (branch)
P. cremea Bres.
P. flavoferruginea (Karst.) Ltisch.
P. *gigantea* (Fr.) Mass.
P. serialis (Fr.) H. et L.
P. subalutacea (Karst.) H. et L. (stem)
P. *velutina* (Fr.) Cooke (stem)
Phlebia gigantea
Phlebiella candidissima (Schw.) Bond. et Sing.
Trerhispora candissima (Schw.) Bond. et Sing.
Stereum abietinum (Pres. ex Fr.) Epicr.
S. pini (Fr.) Fr.
S. rugisporum (Ell. et Ev.) Burt.
S. sanguinolentum Alb. et Schw.
Botryobasidium bortryosum (Bres.) Jo Erikss.
R. *subcoronatum* (Hohn) Donk.
Sarcodon fuligineo-albus (Fr.) Quel.
S. *imbrieatum* (Fr,) Karst.
S. laevigatum (Fr.) Quel.
Thelephora fibriata Schw.
T. laciniafa
T. terrestris Ehrenb.
Tomentella isabellina (Fr.) H. et L.
T. *ochracea* Fr.
T. subfusca (Karst.) H. et L.
Clavaria afflata Lagger.
C. apiculata Fr.
C. *purpurea* Fr.
Clavariadelphus ligula (Fr.) Donk.
C. *truncatus* (Quel.) Donk.
Mucronella calva (Fr.) Fr. (lumber)
M.' *subtilis* Karst. (bark, lumber)
Pistillaria fusifornmis Kauf.
P. paradoxa (Karst.) Comer
Pterula multifida Fr.
Typhula abietina Corner
Kavinia bourdofii (Bres.) John Erikss. (lumber)
K. hirnantia (Schw.) John Erikss. (lumber)
Lentaria delicata (Fr.) Corner (lumber)
L. epichnoa (Fr.) Corner (lumber)
L. micheneri (Berk. et Curt.) Corner (lumber)
Lentaria soluta (Karst.) Pil. (lumber)
L. virgata (Fr.) Corner (lumber)
Ramaria apiculata var. *compacta* (Bourd. et Gatz.) Comer
R. crispula (Fr.) Quel. (branch)
R. flaccida (Fr.) Ricken
R. invalii (Cott. et Wakef.) Donk.
Auriscalpium vulgare (Fr.) Karst.
Hydnum auriscalpium Fr. (lumber)
H. niveum Fr.
H. repandum Fr.
H. tornenfosum Sch.
Odontia ambigua Karst.
0. arguta (Fr.) Quel.
0. bicolor Alb. et Schw.
0. *floccosa* (Erikss.) Nicol. (lumber)
0. *fusco-atra* (Fr.) Bres. (branch)
0. *grisea* Bres.
0. hydnoides (Cook. et Massae) Hohn (bark, lumber)
0. *lactea* Karst.
0. *papillosa* Karst.
0. *queletii* Bourd. et Galz. (branch)
0. soloewskii Jack. (lumber)
Radulum byssinum Bres. (lumber)
R. orbiculare Fr. (branch, stem)
R. pendulum Fr. (branch, stem)
R. quercinum (branch, stem)
R. spathulatum Bres. (lumber)
Xylodon candidum (Ehr.) Bourd.
Merulius aureus Fr. (branch)
M. himanfioides Fr. (lumber)
M. *molluscus* Fr. (lumber)
M. *pinastri* (Fr.) Burt. (lumber)
Meruliporia taxicola (Pers.) Bond. et Sing. (branch)
Serpula lacrymans (Wulf. et Fr.) Bond.
S. minor (Fr.) Bond.
S. pinastri (Fr.) Bond.
S. *silvester* (R. Falck) Bond.
Abortiporus borealis (Fr.) Sing.
Amylocytis lapponicus (Rom.) Bond. et Sing. (bark, lumber)
Amyloporia lenis (Karst.) Bond. et Sing.
A. xantha (Fr.) Bond. et Sing. (lumber)
Bjerkandera adusfa (Willd. ex Fr.) Karst.
B. fumosa (Pers. ex Fr.) Karst. (lumber)
Ceraporia taxicola (Pers.) E Kom. (lumber)
Chaetoporellus aurens (Peck.) Bond. (stem)
C. radulus (Pers.) Bond. et Sing. (lumber)
C. rixosus (Karst.) Bond. et Sing.
C. subacidus (Peck) Bond. et Sing. (lumber)
Coniophora arida (Fr.) Karst. (branch)
C. cerebella (Pers.) Sch.
C. puteana (Schum. ex Fr.) Karst. (lumber)
Coniophorella byssoidea Fr. (lumber)
C. *olivaceae* Karst. (branch)
Coniophorella umbrina (Alb. et Schw.) Bres. (branch)
Coriolellus anceps (Peck.) Parm. (lumber)
C. flavescens (Bres.) Bond. et Sing. (lumber)
C. *serialis* (Fr.) Murr.

C. *squalens* (Karst.) Bond. et Sing.
C. *subsinuosus* (Fr.) Bond. et Sing.
Coriolus cervinus (Schw.) Bond. (lumber)
C. hoehnelii (Bres.) Bond. et Sing.
C. sinuosus (Fr.) Bond. et Sing.
C. vaporarius (Fr.) Bond. et Sing. (lumber)
C. *subsinuosus* (Fr.) Bond. et Sing. (lumber)
Fibuloporia bomoycina (Fr.) Bond. et Sing.
F. mollusca (Pers.) Bond. et Sing.
F. reficulata Pers. Bond. (lumber)
F. vaillantii (Dc. *ex* Fr.) Bond. et Sing. (stem, lumber)
F. unita var. *multistratosa* Pil. (lumber)
Fomitopsis annosa (Fr.) Karst.
F. crassa (Karst.) Bond. (stem)
F. officinalis (Vill.) Bond. et Sing. (stem)
F. pinicola (Schw. ex Fr.) Karst.
F. rosea (Alb. et Schw. ex Fr.) Karst.
F. stellae (Pil.) Bond.
F. *subrosea* (Weir.) Bond. et Sing. (lumber)
Funalia trogii (Berke.) Bond. et Sing. (lumber)
Gloeophyllum odoratum (Fr.) Jmaz. (lumber)
G. sepiarium (Fr.) Karst. (lumber)
G. *trabeum* (Fr.) Murr. (lumber)
Hapalopilus aurantiacus (Rostr.) Bond. et Sing.
H. fibrillosus (Karst.) Bond. et Sing.
H. *nidulanus* (Fr.) Karst. (branch)
Jrpex lacteus (Fr.) (stem)
Laetiporus sulphureus (Fr.) Bond. et Sing. (stem)
H. ochraceo-lateritius (Bond.) Bond. et Sing. (lumber)
Hirschioprus abietinus (Fr.) Donk. (lumber)
H. *fusco-violaceus* (Ehr.) ex Fr. Donk. (lumber)
Osmoporus odoratus (Wulf.) Sing. (lumber)
0. protractus (Fr.) Bond.
Oxyporus ravidus (Fr.) Bond. et Sing.
0. *pearsonii* (Pil.) E. Knm.
Podoporia sanguinolanta (Alb. et Schw.) Hohn
P. vitrea (Fr.) Dvnk.
Polyporus picipes (Fr.) Karst. (Stem)
Polystictus circinatus (Fr.) Karst.
P. circinatus var. *trigueter* Bres.
P. *tomentosus* (Fr.) Karst. (stem)
Poria placenta (Fr.) Cke.
P. vulgaris (Fr.) Ckc.
P. weirii Cke.
Trametes heteromorpha (Fr.) Bres. (lumber)
Tyromyces albellus (Peck.) Bond. et Sing.
T. albidus (Sch. ex Secr.) Murr. (lumber)
T. caesius (Sch. ex Fr.) Murr. (lumber)
T. cinerascens (Brrs.) Bond. et Sing.
Tyromyces destructor (Schrad.) Bond. et Sing.
T. erubescens (Fr.) Bond. et Sing,
T. floriformis (Quel.) Bond. et Sing. (bark, lumber)
T. fragilis (Fr.) Donk.
T. kymatodes Donk. (stem)
T. *lacteus* (Fr.) Murr. (stem)
T. leucomalleus Murr.
T. mollis (Fr.) Karst.
T. resupinatus (B. ex Pil) Bond. et G.
T. semipileatus (Peck.) Murr.
T. semisupinus (Berk. et Kurt.) Murr.
T. sericeo-mollis (Ram.) Bond. et Sing.
T. stipticus (Fr.) Coll. et Ponz.
T. tephroleucus (Fr.) Dank.
T. *trabeus* (Rost.) Bourd et Jalz.
T. *undosus* (Peck) Murr. (stem)
Ganoderma applanatum (Pers. ex Wallr.)
Hymenochaete fuliginosa (Pers.) Bres.
Inonotus hispidus (Bull ex Fr.) Karst. (stem)
1. *radiatus* (Sow. ex Fr.) Karst.
Ischnoderma resinosum (Fr.) Karst. (stem, lumber)
Phaeolus schweinitzii (Fr.) Pat.
Phellinus contiguus (Pers.) Bourd. et Galz. (stem, lumber)
P. *demidoffii* (Lev.) Bond. et Sing. (stem, branch)
P. hartigii (All. et Sch.) Bond.
P. isabellinus (Fr.) Bourd. et Galz. (stem.)
Phellinus nigrolimitatus (Rom.) Bourd. et Galz.
P. pini (Thor-e et Fr.) Pil.
P. pini Til. var. *tipicus* Pil. *f. pithyusa* Negr.
P. pini var. *abietis* (Karst.) Pil. (branch, stem)
P. pini Pil. var. *abietis* Karst. *f. caucasicus* Nigr.
P. pini var. *pini* (Thore et Fr.) Pil. (stem)
Cyphella vernalis Weinm. (bark, lumber)
C. digitalis Alb. et Schw.
C. *griseo-pallida* Weinm.
Schizophyllum commune Fr. (stem)

Agaricales

Armillariella mellea (Fr.) Karst.
Catathelasma imperiale (Fr.) Sing.
Clitocybe aurantiaca (Fr.) Stud.
Collybia dryophila (Fr.) Kumm.
C. maculata (Fr.) Kumm.
Lentinus lepideus (Fr.) Fr.
L. sulcatus Berk.
L. *squamosus* H.
L. vulpinus (Fr.) Fr.
Lepista nuda (Fr.) Cke.
Tricholoma flavovirens (Fr.) Lund.
T. portentosum (Fr.) Quel.
Tricholomopsis rutilans (Fr.) Sing.
Pholiota adiposa Fr.
P. *flammans* (Fr.) Kumm.
Stropharia aeropharia (Fr.) Fr.
Cortinarius violaceus (Fr.) Fr.

Paxillus atrotomentosus (Fr.) Fr. (stem, lumber)
P. acheruntius Fr.
P. *involutus* (Fr.) Fr. (stem, lumber)
P. panuoides (Fr.) Fr.
Gomphidius rutilus (Fr.) Lund. et Nant.
Boletus edulis f. pinicola (Vitt.) Vassilk.
Leceinum percandidum (Vassilk.) Watling
Suillus bovinus (Fr.) 0. Kuntze
S. *granuiatus* (Fr.) 0. Kuntze
S. *luteus* (Fr.) S. F. Gray
S. *piperatus* (Fr.) 0. Kuntze
Russula aurata Fr.
R. *decolorans* (Fr.) Fr.

Tulasnellales

Tulasnella araeosa Bourd. et Galz.
T. fuscoviolaceae Bres.
T. *violaceae* (Johan, Olsen) Juel.

Dacrymycetales

Arrhytidia involuta (Schw.) Coker
Calocera cornea (Fr.) Fr.
C. visoca (Pers.) Fr.
Cerinomyces alfaicus Parm.
C. *canadensis* Jacks et Martin
C. crustulinus ((Bourd.) et Gats) Martin
Ditiola brunnea (Martin) Kennedy
D. nuda Berk. et Br.
Dacrymyces chrysocomus (Fr.) Tul.
D. dicfyosporus Martin
D. deliquescens (Merat) Duby
D. *estonicus* Raitv.
D. ovisporus Bref.
D. palmatus (Schw.) Bres.
D. tortus Fr.
Guepiniopsis merulinus (Pers.) Pat.

Tremellales

Ditangium cerasi (Tul.) Cost. et Duf.
Exidiu pithya Fr.
E. saccharina Fr.
E. testaceae Raitv.
Exidiopsis calcea (Pers.) Wells.
E. fugacissima (Bourst. et Galz) Sacc. et Trott
Protodontia piceicola (Kuhn.) Martin
Pseudohydnum gelatinosum (Fr.) Karst.
Stypella papillata Moller
Tremella encephata (Willd.) Pers. (branch)
T. foliaceae Fr.
T. translucens Gordon

Auriculariales

Septobasidium linderi Couch
S. pinicola Snell.

Uredinales

Coleosporium apocynaceum Cke.
C. *campanulae* (Pers.) Lev.
C. crowellii Cumm.
C. euphrasiae (Schum) Wint.
C. helianthi Arth.
C. inconsipicuum Hedge et Long.
C. *inulae* (Kze.) Rabenh.
C. *ipomoeae* (Sch.) Arth.
C. laciniariae Arth.
C. *melampyri* (Rebent) Karst.
C. pefasifis (DC.) Lev.
C. pinicola Arth.
C. *pulsatillae* (Str.) Lev.
C. rhinanthacearum Lev.
C. *senecionis* Kickx.
C. solidaginis (Sch.) Thuem.
C. *sonchi* (Str.) Lev.
C. sonchi-arvensis (Pers.) Lev.
C. tcrebinfhinaceae (Sch.) Arth.
C. tissilaginis (Pers.) Lev.
C. vernoniae Berk. et Curt.
Cronarfium cerebrum Hedge et Long.
C. coleosporioides Hedge et Long. (branch)
C. compotniae Arth. (branch)
Cronartium flaccidum (Alb. et Schw.) Wint. (branch, stem)
C. himalayense W.
C. *quercus* Schrot f. sp. fusiforme Sch.
C. ribicola (Lasch.) Fisch. v. Waldh. (stem, branch)
C. sfrobilinurn Hedge et Hohn.
Endocronartium harknessii Hir.
Melampsora pinitorquea (Fr.) Rostr. (branch, stem)
Peridermium comptoniae (Link.) Chev.
P. fusiforme Chev. (branch, stem)
P. kurilense (Link.) Chev. (branch, stem)
P. montezumae Cummis sp. nov. (branch)
P. *cerebrum* Chev. (branch, stem)
P. *pini* Lev. et Kleb. (branch)
P. pyriforme L. (branch, stem)
P. stalactiforme L. (branch, stem)

Moniliales

Aspergillus flavus Link.
A. glaucus Link.

A. *herbariorum* F.
A. *niger* V. Tiegh.
A. *wentii* Wehm.
Botrutis cinrrea Pers. *ex* Fr.
Fusoma pinii Harting
Helicomyees condidus Sacc. (branch)
Penicillium coryophilum Dietr.
P. glaucum Link.
P. luteum Jukal
Trichoderma viride var. *kirhanense* (lumber)
Krap. Pol. Sizova
Trichothecium roseum Link.
Verticicladiella sp.
Verticillum albo atrum Rke. et Berth.
V. terrrestre Pke. et Berth.
Alternaria alternata (Fr.) Keissl.
A. humicola Qud. (lumber)
A. tenuis Nees. emius Neerg.
Cercospora pinidensiflorae
Cladosporium herbarum Link. ex Fr.
Helicosporium phaeosporum (Fres.) Sacc.
Nigrospora gallarum (Nol.) Potl.
Phialophora fastigiata (Lager. et Melin) Conant. (lumber)
Pullularia pullulans (De-By) Berkhout (lumber)
Rhinocladiella atrovirens Nannf. (lumber)
Sporodesmium cladosporioides Cda. (lumber)
Stachybotrys macrocarpa L. (lumber) (lumber)
Trichoporium hetermorphum Nannf. (lumber)
Leptographium lundbergii Lager-h. (lumber)
Aegerita torulosa Sacc.
Bacfridium flavum Kze. (branch)
Exoporium pyrosporum Hohn et Melin (branch)
Fusarium bulbigenum W.
F. lateritium Nees f. pini Hepting
F. martii App. et Woll.
F. oxysporurn Sch. var. aurantiacum (Dk.) Wr.
F. sporotrichioides Sherb.
Tuberculina maxima Rostr. (branch)

Melanconiles

Cryptosporium lunasporum Linder
C. pinicola Linder
Cylindrosporium acicola Bres.
Cloeosporium pineae Bub.
G. *pini* Oud.
Monochaetia pinicola Dean.
Pestalotia funerea Desm.
P. hartigii Tub.
P. peregrina Ell. et Martin.
P. truncata var. *lignicola* Grove
Phragmotrichum chailletii Kze.
Sfilbospora pinicola Berk.
Truncatella truncata (Lev.) Stey

Sphaeropsidales

Zythia cucurbitula Jacz. (branch)
Z. resinae (Ehr.) Karst. (branch)
Brunchorstia destruens Erikss.
B. pinea (Karst.) Hohn
Leptothyrium pinastri Karst.
L. stenosporum Dearn.
Leptostroma pinastri Desm.
Coniofhyrium *dispersellum* Farst. (branch)
C. pini Qudem.
Cytosporu curreyi Sacc. (branch)
C. kazachstanica Sch. (branch)
C. kunzei Sacc.
C. pinastri Fr.
Diplodia conigena Desm.
Diplodia megalospora Berk. et Curt. (branch)
D. natalensis P. Evans (branch)
D. pinea Kickx.
D. sapinea (branch)
D. *thujeae* West. (branch)
Diplodiella crustaceae Karst. (branch)
D. pini-silverstris All. (branch)
D. pityophila Sacc. et Penz.
Dothistroma pini Herb.
D. septospora Hulb.
Haplosporella pini Fk. (branch)
Helicomyces candidius Sacc.
Hendersonia acicola Munch et Tub. (branch)
H. folicola (Berk.) Fekl.
H. pini (branch)
H. *strobilina* Curr.
H. thujae Died. (branch)
Hendersonula pini Died. (branch)
H. pinicola Dearn. (lumber)
Hermiscium antiquum (Cda.) Sacc. (lumber)
Phoma ucicola (Lev.) Sacc.
P. bacteriophilla Pk. (branch)
P. *cembrae* Karst.
P. douglasii Oud. (branch)
P. eguttulata Karst.
P. geniculafa Sacc. (branch)
P. harknessii Sacc. (branch)
P. inopinata Oud. (branch)
Phoma juniperi (Desm.) Sacc.
P. *piciana* Karst.
P. pinastrella Sacc.
P. pinastri (Oud.) Sacc. (branch)
P. pinicola Saw.
P. strobiligena Desm.

A

Phomopsis conorum (Sacc.) Died. (branch)
P. occulta (Sacc.) Trav.
P. sfrobi Syd. (branch)
Rhabdospora mirabilissima (Pk.) Dearn.
R. pini Berk. et Curt.
Rhisosphaerella pini Maubl.
Sclerophoma pini Gucev. sp. n.
S. *pithya* v. Hohn (branch) (branch)
S. pithyophila (Corda) Hohn
S. *pityella* (Sacc.) Hohn
Septoria acuum Oudem.
S. *pinicola* Dean.
S. spadicea Pat.
Sphaeronaetna aciculare Fr. (branch)
S. piliferum Sacc. (bark, lumber)
S. *pithyum* Sacc. (stem, branch)
Sphaeropsis ellissii Sacc. (branch)
S. malorum Pk. (branch)
Biatoridina pinasfri Golov. et Zchzedr. (branch, stem)
Discula brunneo-tingens H. Meyer (lumber)
D. pinicola (Namn.) Petr. var. mammosa Lagerh. (lumber)
Discula rubra H. Meyer (lumber)
Dothichiza ferruginosa Sacc. (branch)
D. kazachstanica Sch,

Patellina caesia Ell. et Stansf.
Pseudopatellina conigena V. Hohn
Rhizochonia endophyfica var.-*filicata* var *nov.* (branch)
R. *globularis* sp. nov. (branch)
R. *hiemalis* K. (branch)
R. solani Kuhn (branch)

Bacteria

Erwinia multivora Sez. Parf. (stem, root)
Pseudomonas halepensis L. (stem, root)
P. pini Vuil.

Angiospermae

Visum austriacum Wiesb. (branch)
V. sp. (branch, branch)
Arceuthobium pusilum K. (branch)
A. americanum L. (branch)

Viroae

Tobacco mottl virus
Tobacco ringspot virus

Wood Decay and Canker **Diseases of *Abies Sibirica* Ledb.**

Lachnellula calyciformis (Fr.) Dharne.
= *Dasycypha calyciformis* Rehm.
Scleroderris sp.
Lophodermium nerviseguum (D. S.) Rehm.
Herpotrichia nigra Hart.
Aleurodiscus amorphus (Fr.) Schroet.
Calyptospora goeppertiana Kuehn.
Melamsorella caryophyllasearum Schr.
= *M. cerastii* (Pers.) Wint.
Pucciniastrum epilobii Otth.

Bactrodesmium obligum Sutton var. sattonnii Hughesctwhite
Cirrenalia donnae Sutton
Capnobotrys neesii Hughes.
Seiridiurn abietium (Ell. et Ev.) Sutton
Toxosporium camptospermum (Pk) Maublanc
Micropera pinastri Sacc.
Zyfhiostrorna pinastri Karst.
Phoma abirtella-sibirica Schw.
Sclerophoma pithiophila (Cda) Hohn.
Rhizosphaera pini (Corda) Maubl.

Wood Decay

Phellinus hartigii
Armillariella mellea
Heterobasidion annosus
Laetiporus sulphureus
Phaeolus schweinitzii
Fomitopsis pinicola

Ganoderma applanatum
Fomes fomentarius
Gloeosphyllum sepiarium
Schizophyllum commune
Stereum sanguinolentum

Stem Insects in Larch and Pine, and Their Location in the Log

Larch

Acanthocinus griseus (phloem)
Acmaeops septentrirnis (phloem)
Anoplodera variicornis (feed on withered tree)
Asemum amurense (phloem, xylem)
Callidium chlorizans (stem)
C. violacaum (stem)
Dryocoetes baicalicus (stem phloem)
Hylobius abietis (seedling collar and young stem phloem)
H. albosparsus (seedling collar and young stem phloem)
Ips acuminatus (branch phloem)
1. *subelongatus* (stem phloem)
Malanophila guttulata (stem)
Mefanophila acuminata (stem)
Monochamus salutarius (xylem, phloem)
M. sutor (xylem, phloem)
M. urussovi (xylem, phloem)
Pityogenus chatcographus (stem thick branch)
Rhagium (phloem)
Sirex *ermak* (stem xylem)
Tetropium castaneum (xylem, phloem)
T. gracilicornis (xylem, phloem)
Urocerus gigas taiganus (stem xylem)
Xeriss pectrums pectrum (stem xylem)
Xyloterus lineatus (stem xylem)

Pine

Acanfhocinus aedilis (xylem, phloem)
A. griseus (phloem)
Acmaeops septentrirnis (phloem)
Anthaxis quadripunctata (stem)
Arhopalus rusticus (xylem, phloem)
Asemum amurense (xylem, phloem)
Blastophagus minor (stem phloem, shoot)
B. piniperda (stem phloem, shoot)
Buprestis sibirica (stem)
Callidium chlorizans (stem)
Ch ysocot hris sauccedanea (stem)
Dendroctonus micons (trunk phloem)
Hylastes angustutus (stem phloem)
Hylobius albosparsus (seedling collar and young stem phloem)
H. abietis haroldi (seedling collar and young stem phloem)
Ips ucuminutus (stem phloem)
I. *sexdentatus* (stem phioem)
Magdalis (shoot tip)
Melanophila guttulata (stem)
Melanophila acuminata (stem)

Appendix I
Pest Species Profiles

Siberian Forest Pests of Concern on Bark

Insects

Siberian Silk Moth

Scientific Name of *Pest-Dendrolimus* spp.: D. *sibericus* L. (Lepidoptera: Lasiocampidae): similar species, *D. pini* (L.) and D. *punctatus* Walker.

Assessors-Robert Gara

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest-

(a) Biology-Dendrolimus *pini* occurs in pine stands of Northern and Central Europe, eastward into the U.S.S.R., in particular, the Ukraine and into the Urals, and southward into the Caucasus. It occurs in Siberia as far west as the Yenisey. *Dendrolimus* puncfafus extends into the pine stands of Indochina and China. *Dendrolimus sibericus* occurs throughout Siberia where its hosts are larch, firs, pines (especially stone pine, *Pinus sibiricu)* and perhaps spruce. The adults are active from late June through August. Females oviposit 150 to 200 eggs in linear clusters on twigs and needles. Caterpillar activity is noted in July-August when they devour needles up to the fascicles. In fall, about mid-September to early October, the caterpillars are approximately 25 mm long, and they drop to the ground. There they crawl into the litter and enter diapause. In spring, perhaps about April, when soil temperatures reach 4 to 5 "C, the caterpillars emerge from overwintering sites, crawl back up their hosts, and begin to feed on old needles as well as on newly flushing buds. Most of the population begin to pupate in June and July; they form silken cocoons on branchlets intertwined with the foliage. Apparently these insects also pupate in bark crevices.

(b) Impact-Damage by the Siberian silk moth is dramatic because even relatively few larvae can completely defoliate small conifers. Repeated defoliations of conifers result in severe attacks of secondary insects, such as *Ips sublongatus* and various species of Buprestids and Cerambycids, e.g., Monockamus *urussovii on Abies sibirica* and *P. sibirica.*

(c) Plasticity-A characteristic that makes *the Dendrolimus* particularly threatening is their wide ecological niche. They are found on a variety of coniferous hosts and have significant variations in their life cycles to "accommodate" different hosts and climatic conditions. Further indications of this plasticity is notet in the number of different species of the genus found in the coniferous forests of Northern China, e.g., D. *huashanensis,* D. *rubripennis,* and D. *taibaiensis.* Besides these examples, there is considerable taxonomic debate on the affinity of several other Lasiocampid genera that also attack conifers.

A. Probability of Pest Establishment

1) Pest with Host at Origin-D. *sibericus* prefers larch, but Soviet literature often discusses problems with this insect in stone pine and true firs; again attesting to the ecological flexibility of this defoliator. Moreover, because D. *pini* occurs throughout the Western U.S.S.R. and D. *punctatus* in Asia and China, it is conceivable that there may be host and range overlaps with these species, and they too may be found on export material.

2) Entry Potential—*D. sibericus* oviposit during summer on branchlets and even in bark crevices of the bole. Winter logging would greatly reduce the danger of importation of the insect as eggs. However, because the population overwinters in the duff and litter, diapausing larvae could be introduced if sufficient duff, litter, and soil were included in log shipments.

,3) Colonization Potential—The Siberian silk moth is oligophagous as it feeds on several coniferous species. There is no reason to believe they would not infest western larch as well as other North American conifers. Introduction of this insect, therefore, would pose a serious threat to the intensively managed forests of the Pacific Northwest.

4) Spread Potential-Adult *D. sibericus* and *D. pini* are good fliers. Although the larvae do not balloon, they are well known for their crawling tenacity. A relentless spread within their main and secondary hosts would be expected.

B. Consequences of Establishment

1) Economic Damage Potential-Possessing an oligophagous feeding behavior in conifers and the potential presence of host material in most regions of North America constitute a definite economic threat to forests and ornamental plantings. The greatest potential damage would be a reduction in expected yields of intensively managed stands.

2) Environmental Damage Potential-If D. *sibericus* and/or *D. pini* were introduced, and if this event coincided with intensive forest management initiatives, remedial insecticide spraying regimes would be recommended. This possibility could produce environmental hazards.

3) Perceived Damage (Social and Political Influences)—All *Dendrolimus species* are large and voracious feeders and possess urticating hairs. Accordingly, not only would defoliation foster high forest protection costs, but the presence of larvae would cause allergic responses in humans. Undoubtedly, the American public would react strongly against this "high-profile" pest, and the government would be pressured into spending millions in pest eradication programs, and the whole log importing program would be scrutinized.

4) Overall Risk-Because of the transportability of diapausing larvae in duff and litter and the possible inclusion of random egg masses on logs (e.g., trailing edge of a late summer oviposition), the probability of detection would be slight. Successful introduction would gain public attention because late instars are large, ravenous, and covered with urticating hairs.

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Root/Stump Insects

Scientific Name of Pest-Scolytidae, *Hylastes cunicularis, Hylurgus ligniperda, Hylastes ater,* and the Curculionidae *Hylobius abietis*

Scientific Name of Host(s)—

Specialty Team-Entomology
Assessors-Robert Gara

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest —

These insects feed and breed in phloem of logging slash, stumps, stump roots, moribund and dead conifers, and at the root crown of seedlings. Even more importantly, all have the potential to be vectors of diseases associated with intensive management, e.g., the black stain root disease, *Cerutocystis wagneri.*

Hylastes cunicularis Erichson—*Hylastes cunicularis* is distributed throughout Central and Northern Europe, into the Lapland, south to the Caucasus, and east into Siberia; spruces are its principal hosts. From May through June, *H. cunicularis* fly and infest felled stems, stumps, and moribund or recently dead trees. The attacking females construct short galleries with the wood grain (ca. 8 cm long) in the phloem and lay their eggs along the margins of these excavations. Developing larvae feed in the succulent phloem tissues within these galleries and generally do not produce feeding mines. By fall the larvae are fully developed and overwinter as last instars or pupae. Early the following summer, sexually immature female adults emerge and feed at the base of young seedlings or young trees for amino acids and other compounds necessary for ovarian maturation. This feeding behavior often results in a high mortality of recently planted seedlings. This maturational feeding behavior continues until late summer or early fall. Mature adults overwinter in maturational feeding galleries or in the litter at the base of trees. From the next May through June the insects fly and attack new host material. These insects have a 2-year life cycle.

Hylurgus ligniperda (Fab.)-This bark beetle is distributed in pines throughout Europe, into the Caucasus Mountains and Western Siberia. It has already been introduced to other countries involved in intensive forest management, such as Japan, New Zealand, and Chile. Brood galleries, initiated by females, consist of short entry tunnels that lead to a chamber cut in the phloem; mating occurs in these nuptial chambers. Females then construct long egg galleries parallel with the grain. Eggs are laid in notches cut in the walls of the egg gallery and are covered with grass. Eggs are laid over 100 to 200 mm of the gallery; the female will then rest before once more extending the egg gallery. Accordingly, larvae feeding in the phloem are found in at least two sizes. The insects over-winter in the phloem of their hosts as fourth instars and then pupate in late April or early May. They emerge as adults in 2 weeks and begin host selection flights. The main damage of this bark beetle is that the new adults are sexually immature and feed on roots of young pine seedlings until they reach sexual maturity.

Hylastes ater (Paykull)—This scolytid is similar to *H. ligniperda* both in distribution, habits, and damage potential. The population breeds primarily in pines; however, sexually immature adults feed in seedlings of pine, spruce, true firs, Douglas-fir, and larch. *These* insects, together with *H. ligniperda,* have entered many countries that practice intensive forestry, e.g., Chile, New Zealand, Australia, Great Britain, and possibly Canada. Brood galleries consist of short entry tunnels leading to an oblique nuptial chamber where mating takes place. Single egg galleries are dug along the grain by females. About 100 eggs are oviposited in individual notches that the females cut in the lateral walls of the egg galleries. The larvae make feeding tunnels initially at right angles to the egg galleries, but later these become random in direction and eventually obliterate both the early larval tunnels and those made by the parent adults. The insects overwinter as late instars and emerge in late spring as sexually immature adults.

Hylobius abietis (L.)- The large pine weevil occurs throughout the distribution of *Pinus* and *Piceae* in Europe and Siberia. It also is native to Japan and parts of Asia and China. From May to September, females lay eggs in punctures they gnaw in the bark of fresh pine and spruce stumps; but in regions with short growing seasons, they lay eggs from May to the end of July. Each female oviposits from 60 to 100 eggs during this period. Hatching takes place in about 2 weeks, and the larvae bore into the phloem and excavate longitudinal feeding tunnels in the root-phloem. There are five instars that develop over a period of 13 to 14 months. Mature larvae pupate in cells cut into the sapwood (chip cocoons) or in the outer bark. The pupal stage lasts about 2 to 3 weeks, and teneral adults remain in their chip cocoons or cells cut in the bark for an additional 2 to 3 weeks. Then, the sexually undeveloped adults emerge and do maturational feeding on young coniferous seedlings from July through August. For maturational feeding the adults feed on seedling bark and phloem tissues of Douglas-fir, Scotch pine, white pine, Norway spruce, larch, and fir. This feeding causes significant seedling mortality, especially when a harvested area is regenerated soon after timber removal.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-Three members of this ecological group primarily breed in pine, and the fourth breeds in spruce. Because adults of these insects are strongly attracted to resinous odors, it is possible that beetles may be found incidentally on exported larch logs. If pine and/or spruce were in the log mix, the chances of finding the insects within the phloem of their hosts would be high.

2) Entry Potential-If only larch were imported, the entry of this insect group would be potentially low. Inclusion of other coniferous species would markedly increase the entry potential.

3) Colonization Potential-The species, which primarily breed in pine, could colonize stumps, fallen branches, and moribund pines if the material were found around the port of entry. Chances that suitable pine breeding material would be present in Pacific Northwest ports would be minimal except where *Pinus contorta* occurs along the coast from northern California to British Columbia. The large pine weevil and *H. cunicularis* can breed in spruce, and Sitka spruce material is readily available near all Pacific Northwest ports, so the colonization potential for these pests would be high.

4) Spread Potential-The scolytid members of this ecological group are good fliers and concentrate in response to host volatile materials over long distances. I am unsure about the flight capability of the curculionid, but the weevils easily detect odors diffusing through soil and roots of suitable hosts. As long as recently cut or broken host material is available, infestations of these four species can inexorably spread.

B. Consequences of Establishment

1) Economic Damage Potential-The damage potential of these rhynchophorans is high; they would readily breed in pines and spruce breeding material, and maturational feeding would destroy planted seedlings. Worse would be the potential vectoring of the black stain root disease. Seedling and young stand mortality (black stain root rot kills) may not be an immediate problem to the PNW forestry sector. But as carefully planned harvesting operations; thinning regimes; and replanting programs, utilizing expensively selected planting stock, become rout&e forestry practices, little growth loss or stand mortality will be tolerated. In other words, as the economic damage level allowed in intensively managed stands drops, the rhynchophorans in question will become increasingly important economic pests.

2) Environmental Damage Potential-Although the economic damage caused by these insects would not cause environmental problems, one of the suggested control strategies would. Seedling mortality can be reduced by dipping bare rooted seedlings in a slurry containing a pesticide. This potential practice would raise environmental concerns.

3) Perceived Damage (Social and Political Influences)-These rhynchophorans would not reach the attention of the general public because damage caused by these insects is subtle. Either the private forestry sector or governmental agencies that practice intensive forestry would readily see the damage potential of these pests.

4) Overall Risk-If only larch logs are imported, the risk of accidentally introducing these pests is minimal. If pine and spruce logs are included, introduction of these rhynchophorans within the imported material is probable, and the risk would be high.

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Pine Needle Scales

Scientific Name of Pest-Matsucaccus *koraiensis* and *M. matsumurae*

Scientific Name of Host(s)—*Pinus* spp.

Specialty Team—Entomology
Assessors-John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest —

All of the species of this genus are associated with trees of the genus *Pinus* and are found in both the Old and New World (Danzig, 1986). Most of the species are found in North America on pine. At least one species, the red pine scale, has been introduced into the Eastern United States and has become a serious pest of *Pinus resinosa* in plantations (Bean and Godwin, 1955; Hartzell, 1957; Doane, 1965; Kosztarab and Kozar, 1988; Anderson et al., 1976). A number of species are found on pines in Western North America; all native (Furniss and Carolin, 1977). According to Danzig (1986), members of this group of scale insects live under the bark of trees and sometimes on the roots. They are very small insects and quite inconspicuous in appearance. Eggs are laid under bark in the spring by the female. These hatch into a legless nymph. Nymphs that will become females go through a series of molts to the wingless female. Those that will become males molt into a mobile nymph that molts into a pupa; eventually a winged male emerges. The male will seek out the female, mate, and die. This is such an inconspicuous insect that its occurrence often goes undetected for some time. The developing nymphs feed directly on the tree by means of their elongated beak. Because they are wingless in this stage, they sometimes occur in considerable numbers where they are found. Dispersal is normally believed to be via wind. One nymphal stage is legless. This results in rather slow dispersal. Native species of this scale occur over considerable areas, showing that although dispersal may be slow, it does occur. The initial detection and subsequent spread of the red pine scale in southern New England provides useful information about the rate of spread of an introduced species. There are two generations per year of this species in New England. *Matsucoccus koraiensis* Young and Hu is found in Europe, China, Japan, and Siberia. Its natural host is *Pinus koraiensis* (Danzig, 1986).

These very small insects would be easily overlooked. They occur deep under the bark of the tree and could be easily transported. Nymphs overwinter under the bark and mature in spring, and females lay eggs in the spring that will produce both males and females. Eggs are deposited on the trunk. The hibernating stages are the nymphal stages of the male and female. There appears to he only a single generation per year, but the red pine scale has two generations per year in the Eastern United States.

These insects are well documented in the scientific literature, but relatively little is known about the habits of many of the species except those known to be pests (i.e., the red pine scale). In general, data base material on these pests are good, but much remains to be learned about their habits. Because nymphs overwinter, the female deposits eggs under the bark, and these eggs produce both males and females, the risk of transport is high. Detection of these stages under the bark would be very difficult.

Summary of Natural History. These scales overwinter as nymphs under bark; eggs are laid in spring, and they hatch into male and female nymphs. One nymphal stage is legless. The nymphs that will become females continue to molt until the wingless female is produced. The nymphs that will become males molt into a mobile form that molts into a pupa from which the winged male emerges. The male seeks out the wingless female and mates. There may be several generations per year.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-Danzig (1986) does not comment on its pest status in Siberia but indicates that it is found under the bark on the trunks of *Pinus koraiensis*.

2) Entry Potential-High because of the great difficulty in detection on the trunks. The nymphs and likely females would be present as the eggs might be as well.

3) Colonization Potential-Moderate because of the low vagility of the stages. However, at least one species has been introduced into the Eastern United States (the red pine scale).

4) Spread Potential—Potential for spread is moderate compared with many insects, but the great difficulty in detecting the presence of the insect would allow spread before it is even known the insect is there. Only the males are winged. Dispersal is usually via the "crawler" stage (young nymph). One of the nymphal stages is legless.

B. Consequences of Establishment

1) Economic Damage Potential-The damage would be to pines because that is the only group of trees it is known to feed upon. One introduced species is a serious pest of red pine grown in plantations in the Eastern United States, where it kills the trees.

2) Environmental Damage Potential—High. Damage to trees is documented. Spread is slow and difficult to detect.

3) Perceived Damage (Social and Political Influences)—Reduction in tree vigor allows possible attack by other insects/diseases. Will kill the tree. Attacks ornamental species in urban settings too.

Estimated Risk for Pest-High for pines.

Spread Potential

1) Probable Rate of Spread-Low, but well documented in southern New England. It is very difficult to detect insect, so spread may be undetected at first.

2) Estimated Range of Spread -Range of various species of pines. Many species of pines in the western portions of North America. *Pinus contorta* occurs along the coast of Western North America.

3) Damage will be from weakening the trees, sometimes death. Other organisms are then able to attack tree. Will kill trees (Drooz, 1985).

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Shortneedle Evergreen Scale

Scientific Name of Pest—*Nuculaspis tsugae* (Martatt)

Scientific Name of Host(s)—*Abies* spp., *Thuja* spp., *Picea* spp., *Tsuga* spp., and *Taxus* spp.

Specialty Team—Entomology
Assessor-John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest-

According to Danzig (1986), there are five species found in this genus, all inhabiting conifers. *Nuculaspis tsugae* is found in Eastern Siberia and Japan. It lives on the underside of the host needles where its feeding causes chlorosis and early needle drop. It overwinters as a second instar nymph. Crawlers are found from May to July and August to November (there are two generations per year). This species was introduced into the east coast where it is a pest of fir, cedar, spruce, hemlock, and yew. A second species, *Nuculaspis californica,* is believed to be native to North America but may be an introduction (Drooz, 1985). It is known as the black pineleaf scale and is widely distributed. In Western North America it is especially common on ponderosa, Jeffrey, sugar, Monterey, and digger pine. It also attacks Douglas-fir. Heavy infestation may result in the death of the tree. According to Drooz (1985), outbreaks of this species are often associated with air pollution. Generally, this reduces the effectiveness of any form of control. There is a single generation in the north (British Columbia) and two or three generations in the south (California). As indicated above, the scales are found on the needles of the tree but enough damage occurs to kill trees if infestation is heavy enough (Furniss and Carolin, 1.977). All sizes of trees are attacked. The introduction of *N. tsugae* into Western North America would be a serious threat to the 72 species of conifers found there.

Scale insects are small, inconspicuous, and difficult to detect under normal circumstances. They occur on the needles of the trees where the feeding on their tissues causes chlorosis of the tissues, damage, and even death of the trees. This species over-winters as a small nymph and, thus, is quite likely to be moved. Overwintering occurs in the second instar. These nymphs become males or females in the spring.

A single generation occurs in the north, and two or three generations may occur in the southern part of the range. These scale insects are well documented in the scientific literature, not only their occurrence but their role as pests on a variety of conifers. The general data base is quite good because of their pest status. Transport possibilities are high because the insects are small and easily overlooked. Detection would be difficult.

<u>Summary of Natural History.</u> *Nuculaspis tsugae* hibernates as a second stage nymph. These mature in the spring when both males and females are produced. The female lays yellow **eggs.** These hatch **and** one generation is completed by the end of the season. A closely related species, *N. californica,* has several generations per year, depending on the locality. The hosts of *N. tsugae* include fir, cedar, spruce, hemlock, and yew (Drooz, 1985).

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) <u>Pest with Host at Origin</u>—Yes, but populations numbers vary (Danzig, 79%). Found on *Tsuga*.

2) <u>Entry Potential</u>— High because it is very small, difficult to detect, and overwinters as second instar nymphs. These produce males and females in spring.

3) Colonization Potential—Moderate, but the ease of transport enhances the chances of success. The wide host plant range of some species makes colonization likely. This is an insect of rather modest vagility; but at least one species has been introduced.

4) Spread Potential- High if it becomes established. Spread likely by means of wind.

B. Consequences of Establishment

1) Economic Damage Potential-High. Established species attacks the needles, causing yellowing and early drop. Continued infestations will kill the tree. Variety of native and ornamental hosts.

2) Environmental Damage Potential-High. Damage is severe, often leading to the death of the tree.

3) Perceived Damage (Social and Political Influences)—Loss of needles from tree, yellowing of trees, eventual death of tree if infestation persists. Seems to do well as a pest where air pollution is present.

Estimated Risk for Pest-High for host plants.

Spread Potential

1) Probable Rate of Spread-Low but difficult to detect in early stages. Potential for rapid spread along the seaboard is great. Wind dispersal is remarkably efficient for scale insects.

2) Estimated Range of Spread-Throughout entire range of host trees. These are well-adapted organisms. They occur on *Picea, Abies,* and *Tsuga.*

3) Damage will result from feeding on needles, which turn yellow and fall off. Repeated attacks will kill the tree (Drooz, 1985).

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Pseudotsuga Scale

Scientific Name of Pest—*Lepidosaphes pseudotsugae*

Scientific Name of Host(s)—*Picea ajanensis, Ahies sachalinensis, Tsuga* spp., and *Pseudotsuga* spp.

Specialty Team-Entomology
Assessors-John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

This scale insect belongs to a larger group of scales that is well represented in the Soviet Far East. The genus to which it belongs, *Lepidosaphes,* contains a number of pest species on other trees, including *Salix, Populus, Juglans, Betula,* Rosa, *Spiraeu, Fraxinus, Rhododendron, Malus, Crataegus, Prunus,* Corms, *Alms, Ulmus, Physocarpus,* and *Tilia* among the broadleaved trees--all well represented in the Western North America and on *Picea, Abies, Tsuga, Pinus,* and *Pseudotsuga* among the conifers. The life cycle is similar to *Aspidiotus,* with the second instar nymph being the hibernating stage (Danzig, 1986). The nymphs produce both males and females in the spring. The insect occurs on the lower parts of the tree on branches and thin-barked regions of the tree. While not considered a pest in Siberia, its occurrence on *Pseudotsuga* in Japan (Takagi, 1960) suggests a serious potential pest. The fact that other acceptable host plants include *Picea, Abies,* and *Tsuga* simply amplifies the potential pest status (Borchsenius, 1963). The species occurs naturally in Eastern Siberia and Japan (Danzig, 1986; Borchsenius, 1963; Takagi, 1960; Balachowski, 1954).

A closely related species, *Lepidosaphes ulmi,* the oystershell scale, was introduced into North America from Europe and is a serious pest on a wide variety of broadleaved trees, including many important fruit trees (Furniss and Carolin, 1977; Drooz, 1985). While it does not occur on conifers, it documents the possibility of colonization and spread as well as risk of damage.

This is a difficult insect to detect because of its small size and inconspicuous appearance. Hibernation as a second instar nymph on the host makes it even more difficult to detect. This species occurs on the branches and thin-barked parts of the tree on all stages. There appears to be a single generation per year.

The documented range and host associations are well known in the literature, and there is a good scientific base for information on this group. The insect is found on living trees but would be expected to occur on freshly cut logs because they over-winter as second instar nymphs on the host. These nymphs will become both male and female in the spring.

Summary of Natural History. This species hibernates as a second instar nymph on its host. These nymphs become adult males and females the following season. Apparently, there is only a single generation per year. The insect occurs on the twigs, branches, and thin-barked portions of the trunk. Damage is caused by feeding on the tree by means of sucking mouthparts. This species is reported from a number of conifer hosts including *Pseudotsuga.* Related species are serious pests of broadleaved plants.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin- No potential pest status based upon pest status of related species and the host range of this species that includes the major genera of coniferous hosts in Western North America.

2) Entry Potential-High, based upon entry and establishment of related species (oystershell scale). Many potential hosts at entry points.

3) Colonization Potential-High, based upon information on closely related species. Hibernation as both male and female nymphs increases introduction of both sexes.

4) Spread Potential-High because of widespread occurrence of potential conifer hosts in Western North America. The wide spread of the other species introduced suggests similar spread for this species.

B) Consequences of Establishment

5) Economic Damage Potential—Documented damage to trees by related species that have been introduced into North America. This species is not considered a pest at point of origin.

6) Environmental Damage Potential-Damage to trunk, branches, and twigs. Weakening of trees, allows attack by other organisms.

7) Perceived Damage (Social and Political Influences)—Less visible because the insect feeds on the trunk, branches, and twigs.

Estimated Risk for Pest -High because of the broad host range, including *Pseudotsuga* (containing Douglas-fir).

Spread Potential

1) Probable Rate of Spread-Moderate because female lacks wings, but nymphs are spread by wind. Widespread occurrence of oystershell scale shows that dispersal is not difficult.

2) Estimated Range of Spread-Moderate, but possible to calculate if historical records for oystershell scale are examined for Eastern North America.

3) Damage results from feeding on twigs, branches, and trunk. General weakening of tree allows attack by other organisms.

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Cryptomeria Scale

Scientific Name of Pest—*Aspidiotus cryptomeriae*

Scientific Name of Host(s)-Wide variety, including *Abies, Picea, Pseudotsuga, Tsuga, Cupressus, Cryptomeria, Thuja, Taxus, Pinus.*

Specialty Team-Entomology
Assessors-John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Danzig (1986) reported *Aspidotus cryptomeriae* from much of Eastern Siberia, Japan, Korea, parts of China, and Taiwan. It is a typical armored scale and is found on the foliage of the trees. A wide variety of conifer hosts have been recorded in the literature, including species of *Abies, Picea, Pinus, Taxus, Chamaecyparis, Cryptomeria, Keteleeria, Torreya, Juniperus,* and others (Danzig, 1986). On native hosts it is rather widespread but reaches larger populations in more sparsely wooded regions, apparently responding to increased insolation. In some, parts of its range, the species prefers the lower branches, especially where the branches are covered with snow. It has been reported to be a pest of spruce and fir on Sakhalin Island in plantations (Kovalenko, 1965). The second nymphal stage overwinters in Siberia. Adults appear in late July at which time the eggs are laid. This species damages the needles of the host plants upon which it feeds, causing damage to the tree (Murakami, 1970).

This species has been introduced into the Eastern United States, apparently from Japan. It is known to occur in Connecticut, Indiana, Maryland, New York, and Pennsylvania (Drooz, 1985). This establishes the fact that the species can be introduced. Within this region, two generations per year occur, again showing that even though only a single generation occurs in Siberia, more are possible if the climate permits. This scale has a very wide host plant range that includes essentially every genus of conifers found in Western North America from British Columbia to southern California as well as ornamental genera and species.

As with the other scale insects, they are small, inconspicuous animals and are easy to overlook. They spend the winter months on the host as second-stage nymphs. These nymphs will produce both males and females, increasing the risk of introduction. Overwintering occurs as second instar nymphs. In Siberia, only a single generation per year occurs, but in warmer climates, two generations per year occur.

There is good documentation in the literature on this group of scales, chiefly because of their pest status. The general data base on this group is good. Transport possibilities are high because of the dormant stage being found on the host and the fact that there are so many potential host plants in Western North America.

Summary of Natural History. This species hibernates as a second instar nymph on the host. In the spring, these nymphs develop into males (winged) and females (wingless). These mate, and the female lays eggs on the host. In cooler areas, development stops in the fall and overwintering occurs as a second instar nymph. These scale insects feed upon the needles of the plant, causing chlorosis. It is a reported pest of spruce and fir on Sakhalin Island (Kovalenko, 1965). Two generations per year occur in warmer regions (Drooz, 1985). A very wide range of coniferous hosts are known and reported in the literature.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin—Yes, reported pest of spruce and fir on Sakhalin Island by Kovalenko (1965).

2) Entry Potential--Good because the species overwinters on the host as a second instar nymph----both males and females develop from these nymphs. The insect at that stage is very small and difficult to detect.

3) Colonization Potential-High because of the wide range of host plants. Western North America has 72 species of native conifers plus a wide variety of ornamental species, The fact that the species has been introduced into the Eastern United States clearly demonstrates it can be introduced and become established.

4) Spread Potential-Moderate to high in the west because of the much higher percentage of conifers in western forests compared to eastern forests and the greater variety of potential hosts in urban and rural locales.

B. Consequences of Establishment

1) Economic Damage Potential-Documented damage to foliage of the trees at point of origin and in the area of the eastern seaboard where it has been introduced. Thus, economic damage potential already demonstrated.

2) Environmental Damage Potential-Damage to foliage, reduced vigor of trees, makes tree susceptible to damage by other insects and disease. Attacks trees in urban and rural areas.

3) Perceived Damage (Social and Political Influences)—Discoloration of foliage, premature needle drop, potential attack by other pest organisms.

Estimated Risk for Pest -High for a variety of host plants.

Spread Potential

1) Probable Rate of Spread-Moderate but difficult to detect because of small size. May not be recognized in early stages of attack. Spread by wind. Rate of spread partially dependent on host availability-this is much higher in Western North America because of the dominance of conifers in the forest.

2) Estimated Rate of Spread-Determined partly by the conditions stated above. Calculations could be made based upon the information from the eastern seaboard.

3) Damage comes from feeding on the needles, causing chlorosis, premature needle drop, and weakening of the tree. This may allow damage from other pest insects and disease.

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Spruce Scale

Scientific Name of Pest—*Physokermes jezoensis* (Siraiwa)

Scientific Name of Host(s)—*Picea ajanensis, P. korajensis, P. glehnii.*

Specialty Team—Entomology
Assessors-John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest --

Danzig (1986) has determined that the spruce scale is found in many localities in Eastern Siberia. The species was described from southern Sakhalin. This species belongs to a Holarctic genus with at least 5 species found in the Old World. One of these, *Physokermes piceae* (Schrank), has been introduced into North America from Europe. It attacks spruce in the New World (Drooz, 1985; Furniss and Carolin, 1977; Fenton, 1917). The females of *Physokermes* grow on branches and the males on the lower sides of conifers as needles. There is one generation per year. The immature stages overwinter on the tree. The adult females are found in the spring. They retain the eggs in the body cavity. The early instar nymphs appear in late spring and are found on the new growth. Damage to the branches may be severe. Danzig (1986) reports the species as a pest of *Picea* plantations in Siberia. Based upon the habits of *Physokermes piceae* in North America, P. *jezoensis* is a potential pest if introduced into North America. The occurrence of Sitka spruce along the Pacific Coast provides a ready host. The establishment of the European P. *piceae* in North America demonstrates the capability of members of the genus to colonize and spread.

As mentioned for other scale insects, these are small, inconspicuous organisms and are easily overlooked. They do occur on the host and resemble the buds of the plant (Furniss and Carolin, 1977), making detection even more difficult. The overwintering nymphs are extremely small and are found on various parts of the tree, especially the branches and needles. They would be easily transported during the cold season. The overwintering nymphs produce both males and females, thus transporting the nymphs would transport both sexes and increase chances of colonization. Danzig (1986) states that male adults and male pupae have not yet been found. The species may be parthenogenetic, in which case only females are needed for colonization.

There is good documentation of occurrence of this species in the potential export production area (Danzig, 1986). There is also excellent scientific documentation. Scales live on live trees naturally. As over-wintering nymphs they would occur on freshly cut logs and on seasoned logs if the timing of the season were correct.

Summary of Natural History—Overwinters as young nymph on host plant. Adults develop in the spring. There is a probability that the species is parthenogenetic (Danzig, 7986) because no males or male pupae have yet been found. There is likely only a single generation per year. Young nymphs are found on undersides of new shoots and on buds. A related species, P. *piceae,* has been introduced into North America from Europe.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin —Yes. Danzig (3986) states that the scale is found abundantly in spruce plantations.

2) Entry Potential—Good transport via young nymphs (overwintering stage). Occurrence of Sitka spruce along Pacific Coast. Introduction of a closely related European species has occurred.

3) Colonization Potential—Good. See item #2 above.

4) Spread Potential-Good, based upon spread of p. *piceae,* introduced from Europe. There are many more conifers in Western North America than in Eastern North America. Spruce species are very important in Canada, where they form a belt across the entire country.

B. Consequences of Establishment

1) Economic Damage Potential-Documented damage caused by related species (Furniss and Carolin, 1977; Drooz, 1985). Danzig (1986) reports P. *jezoensis* from spruce plantations in Siberia.

2) Environmental Damage Potential-All species of spruce (including ornamental species) at risk.

3) Perceived Damage (Social and Political Influences) -Discoloration of foliage, death of lower branches, and possible weakening of tree allowing other organisms to attack.

Estimated Risk for Pest-High.

Spread Potential

1) Probable Rate of Spread-Moderate, but likely to be difficult to detect because of small size. Dispersed by wind via young nymphs. Dispersal is partially dependent upon available host material.

2) Estimated Range of Spread-There are historical records of establishment and spread of related *P. piceae* introduced into Eastern North America. First reported in 1906, it is now found in Alberta and the Northwest Territories (Furniss and Carolin, 1977).

3) Damage comes from nymphs feeding on the buds and needles. This results in premature needle drop and weakening of tree.

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Wooly Adelgids

Scientific Name of Pest—*Adelges laricis* (Vall.) and A. *tardoides* (Chol.)

Scientific Name of Host(s)—*Larix*

Specialty Team-Entomology
Assessors--John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

The various species of *Adelges* are very small, inconspicuous insects with sucking mouthparts. They often go unnoticed until the damage to the trees becomes evident, at which time the trees are likely to be killed (Mitchell, 1967). Species of *Adelges* occur on a wide variety of conifer species (Rozhkov, 1966; Mitchell, 1967; Carter, 1969; Bevan, 1987). While species occurring naturally on their native hosts may be of relatively little economic importance, when introduced into a new area on new hosts the results may be devastating. The balsam woolly aphid introduced into North America is a well-documented example (Mitchell, 1967). The insect may have several generations per year. While males are found with the females (at critical times of the year) in their native areas, when introduced, only the females are required for establishment because they can reproduce without fertilization (parthenogenesis). Specifically, the balsam woolly aphid (*Adelges picea*), introduced into North America from Western Europe in 1928, occurs only as females and has from two to four generations per year. The adult females. lay 30 to 100 eggs each. The eggs hatch in a few days, producing the crawler stage. This is the mobile stage, and they may be moved from tree to tree by the wind. Once a proper site has been found, the small insect inserts its beak into the tree and remains in place until maturity. Very large populations can build up on individual trees. The saliva injected by the insect into the tree is toxic, resulting in abnormal responses by the tree. The amount and type of damage to the tree depends upon the location and concentrations of the insect. According to Mitchell (1967), over a billion and a half board feet of commercial timber (true firs) was killed or weakened in a 400,000-acre area in Washington State between 1950 and 1957. Bevan (1987) considers *Adelges laricis* Vall. the most damaging species of *Adelges* on larch in the United Kingdom. *Adelges laricis* occurs on larch in Siberia (Rozhkov, 1966). Other species of *Adelges* are found on spruce (Bevan, 1987). Although small and not easily noticed, some very serious pest species are found in this group. The ability of the females to reproduce without the males and their ready dispersal makes them a high-risk group. Carter (1969) reports on the damage caused by the introduction of three species from the European continent.

These insects are very small and easily overlooked. They occur on the bark of the trunk and on the branches. They would be easily transported. Eggs are deposited on the trunk. Hibernating stage is the young larva under the bark of the tree and under the scales on the branches. There are from two to four generations per year, depending upon the species and the locale. Only the females are required to establish a colony because they can reproduce parthenogenetically. The saliva of the bug is toxic and causes a response from the cells of the host plant. When concentrations of the bug are high enough, trees are killed. These insects are well documented in the scientific literature, chiefly because many are pests. General data base is quite good. Very good documentation on the pest status of many species. The fact most colonization and establishment requires only females (e.g., balsam woolly aphid introduced into North America) greatly enhances the likelihood of establishment. The very small, hibernating nymphs would make detection extremely difficult.

Summary of Natural History-Overwinters as a young nymph under the bark of trunk or branch. Completes development to adult female (if males are absent). Female lays eggs that hatch in a few days producing a very small, active "crawler." The crawler may move a short distance and settle down or be dispersed by wind to another tree. When a suitable locale is found, the crawler molts and becomes a sedentary nymph, feeding on the host by means of a long beak. There may be from two to four generations per year. The female is able to reproduce without being fertilized, making it very easy to build up large numbers of individuals.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-Some species of *Adelges* are considered pests at origin (Bevan, 1987). That includes native tree species and North American species planted in Europe. *Adelges laricis* Vall. is not considered a pest of larch by Rozhkov (1966) in Siberia but is considered a serious pest of larch in the United Kingdom (Bevan, 1987).

2) Entry Potential-Excellent. Over-winter on the trees as extremely small nymphs (difficult to detect), able to reproduce without male, able to survive for extended periods.

3) Colonization Potential-Excellent. Seventy-two conifer species in Western North America. Ability of female to reproduce without male makes colonization very easy.

4) Spread Potential-Excellent. Spread of *Adelges picea* in North America is well documented.

B. Consequences of Establishment

1) Economic Damage Potential-High. This group of insects kills trees (Mitchell, 1966). Their toxic saliva causes damage to the cells in the trees.

2) Environmental Damage Potential-High. Documented examples (balsam woolly aphid) clearly demonstrate the potential damage (see above) of species of *Adelges in* both Old and New World.

3) Perceived Damage (Social and Political Influences)- Tree death, serious weakening of other trees not killed. High concentration of damage in restricted areas. Likely to attack trees in urban areas as well as forests.

Estimated Risk for Pest-High in all categories.

Spread Potential

1) Probable Rate of Spread-Example: balsam woolly aphid in Western North America (Mitchell, 1967). First detected on the West Coast in 1928. Spread to Willamette Valley in Oregon by 1930. Detected around Mt. St. Helens, Washington, in 1954. By 1957, 600,000 acres of forest in Oregon and Washington infested. By 1959, found on Vancouver Island and at Vancouver, British Columbia.

2) Estimated Range of Spread-Throughout ranges of host plants (72 species in Western North America).

3) Damage will be by killing trees and weakening remaining trees, making them more susceptible to damage by other organisms.

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Larch Aphid

Scientific Name of Pest—*Cinara laricis*

Scientific Name of Host(s)—*Larix sibirica, Larix* spp.

Specialty Team—Entomology
Assessors-John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest-

Cinara laricis is a small, gray insect with numerous dark brown spots on the upper surface of the abdomen. The species occurs on various species of larch from Western Europe to far-eastern Siberia and Japan (Shaposhnikov, 1967; Rozhkov, 3966). While not considered a pest of larch by Rozhkov (1966), the species is very widespread in the Old World and biotypes are likely. Members of this genus are confined to conifers throughout the northern hemisphere. Another species of *Cinara, C. pini,* occurs from England east into Siberia , and occurs on *Pinus sylvestris* throughout the range of this tree. Bevan (1987) reports this as a pest of *Pinus sylvestris* and the American *Pinus contorta* in England. According to Shaposhnikov (1987), the association of aphids with conifers is an ancient one. Further, he states that if a potential new host is closely related to the normal host, the transition to the new host may be fairly easy, although the range of hosts may be narrow (i.e., conifers). According to Eastop and Hille Ris Lambers (1976), there are over 215 species of *Cinara* known in the world, occurring on a wide variety of coniferous hosts. The presence of 72 species of conifers in Western North America provides many potential hosts for newly introduced aphid species. This is a colonial insect, often found living in groups on the host. The insect usually lives on the bark of the branches of older trees and on the trunk of younger trees. The populations are dynamic and often break up into smaller groups, sometimes in response to increased numbers. Adults may be winged or wingless. The females are normally parthenogenetic during the six or seven generations per year. The males only appear late in the season, mate with the female, and die. The females seem to overwinter in the fertilized state and lay eggs in the spring. This makes them excellent candidates for transport and colonization. The ability to reproduce without the male makes it possible for aphids to exploit an environment in the absence of the male. Crowded conditions often result in the production of winged individuals that are able to move to other plants.

This is a small, inconspicuous insect that is not easily detected by casual observation. During the cooler months, the over-wintering females are often under bark chips on the branches and trunk. While the species is found on the surface of branches and trunk in the summer, winter is spent as a fertilized female, often under bark. There are six to seven generations per year, all females except the final generation when the males are produced. They mate with the female and die. The female overwinters as a fertilized female. Many aphids are vectors of disease. The range of this species is documented by many publications. There are a number of aphid specialists who have described many species of *Cinara.* A catalog exists that lists all the species found in the world. While new localities are certain to be found, the general data base is good. The fact that the fertilized female overwinters under the bark of trunks and branches and deposits eggs on the surface of the trunks and branches in the spring provides a very long period for potential movement via logs. The proximity and abundance of potential conifer hosts also enhances the possibility of establishment.

Summary of Natural History—Overwinters as fertilized female on trunk, lays eggs in spring on trunk and branches. Eggs hatch into stem mothers (females) who reproduce parthenogenetically. If crowding occurs, winged individuals are produced that move to another tree and establish new colonies. There are six to seven generations per year. The young aphids move out onto the needles when they molt, returning to the branch or trunk after molting. At the end of the season, males are produced. These mate with the females and these mated females overwinter. Aphids feed by means of beak, sucking plant fluids from the trees. Many species of aphids are vectors of diseases.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin---Not considered a serious pest in Siberia but other species of *Cinara (e.g., Cinara pini* that occurs on *Pinus sylvestris*) are considered pests on some trees including *Pinus contorta* in England (Bevan, 1987). Abundant species in Siberia.

2) Entry Potential-Excellent. They overwinter as fertilized females under bark on branches and trunks.

3) Colonization Potential--Excellent. Able to reproduce without males, able to produce winged individuals if crowding occurs, abundant hosts very similar found in immediate region of contact.

4) Spread Potential-Excellent, aphids have shown a remarkable ability to spread once they reach North America (e.g., Russian wheat aphid-in 4 years it reached all of Western North America; Blue alfalfa aphid, essentially the same). The 72 species of native conifers in Western North America provide ample potential host material.

B. Consequences of Establishment

1) Economic Damage Potential--Potential pest causes yellowing of foliage of trees, smaller trees likely to be most vulnerable but will occur on all stages,

2) Environmental Damage Potential--Rather high, very likely to establish and spread widely. Likely to encounter favorable environments within the ranges of the potential hosts.

3) Perceived Damages (Social and Political Influences)--Alteration of appearance of trees, perceived change in quality of forests, potential loss of trees.

Estimated Risk for Pest---Moderate, but certain

Spread Potential

1) Probable Rate of Spread---High. Aphids have demonstrated unusually high spread rate—example: Russian Wheat Aphid-in the first 4 years in North America it reached the entire western portion of the United States and much of Canada.

2) Estimated Range of Spread-Entire range of host plants.

3) Damage will be to foliage of trees; younger trees likely to be most susceptible. Aphids are well-known vectors of plant diseases. Little known about this subject on conifers.

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Pine Flatbug

Scientific Name of Pest—*Aradus cinnamomeus* (Panzer)

Scientific Name of Host(s)—*Pinus sylvestris* and other pines; rarely on larch.

Specialty Team—Entomology
Assessors-John D. Lattin

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Aradus cinnamomeus is a small, flat bug that occurs chiefly on pines in the Old World. its favored host is *Pinus sylvestris,* but it is known to occur on other pines and on larch (Rozhkov, 1966). The natural range of *A. cinnamomeus* extends from the United Kingdom east across Europe at least as far as Barnaui, Siberia (Kirichenko, 1955). This species is a serious pest of young pine trees in many parts of its range including European U.S.S.R. (Rozhkov, 1966). That it is capable of movement is documented by its relatively recent recovery from England (Leston, 1951a), a country whose Hemiptera fauna is very well known (Southwood and Leston, 1959). Strawinski (1925) provides a very detailed study of the biology of this species. The damage is caused by the direct feeding upon the stem (chiefly) and the branches of the young trees. The individuals are found under the bark or scales of the tree. Their small size and inconspicuous appearance make their discovery difficult. The insects occur on mature trees as well as young trees. Damage is chiefly on young trees.

This species of Aradidae occurs in several different forms. Some individuals have fully developed wings and are able to disperse, while other individuals have reduced wings and are unable to fly. This creates a population able to respond to quite varying conditions, able to exploit a habitat without expending excess energy in dispersing, and at the same time having some individuals wit11 fully developed wings able to move to new environments. These facts, coupled with their small size and normal occurrence under the bark of the trunk and branches of the tree, make them very difficult to detect and likely to be transported on logs. Forty-six species of Pinaceae occur in Western North America, including *Pinus contorta* that occurs along the north Pacific Coast. This species of pine, along with its other subspecies, is the most widespread species of pine in North America. it occurs with other pines, including *Pinus ponderosa,* another very widespread species.

References under this name for North America should be referred to *Aradus kormilevi* Heiss (Heiss, 1980). The North American taxon is considered a distinct species.

This insect is difficult to detect by casual inspection because it is small, inconspicuous, and found under bark or bark chips, on the trunk, and on branches. The insect is found throughout the year as nymphs and adults. The adults would be the normal colonizing stage.

The documented range of this specie5 is based upon literature published in Europe and Russia. The general distributional information is reliable because it is based upon the work of highly regarded scientists. The range of this species in the eastern Soviet provinces is likely to be greater than reported simply because of the vast area involved. The insect is found on living trees but would be expected to occur on fresh cut logs as well. Seasoned logs might contain these insects, depending upon the season. They remain inactive during the colder parts of the year and thus could be transported with ease.

Summary of Natural History. Egg, spring; nymphs and adults overwinter; gradual metamorphosis with five nymphal instars, found under bark of conifers. Adults are either fully winged or brachypterous. it is a serious pest of young pine trees in Europe and parts of the U.S.S.R. While many Aradidae are fungus feeders, this species feeds upon the tree itself.

Specific Information Relating to Risk **Elements:**

A. Probability of Pest Establishment

1) Pest with Host at Origin-This insect is very widely distributed in the Old World, from Western Europe to Siberia. Its chief host is *Pinus sylvestris*, but it is known to occur on other conifers, including larch.

2) Entry Potential--Excellent. This is a very inconspicuous insect and is easily overlooked. All stages occur under bark and it hibernates as both nymphs and adults. It is inactive at low temperatures, thus able to he transported with ease.

3) Colonization Potential-Excellent. Leston (1951b) documents the colonization of this species in England. Shore pine (*Pinus contorta*) occurs along the Pacific Coast from north central California to the Yukon Territory. The other subspecies of *P. contorta* occur in the Sierra Nevada, Cascade, and Rocky Mountains.

4) Spread Potential-Excellent because of the many species of Pinaceae found in Western North America (46 species). This includes species of considerable economic value.

B. Consequences of Establishment

1) Economic Damage Potential--Strawinski (1925) provides detailed biological information. The damage would be to young trees rather than mature trees. This is considered a serious pest of pine in the Old World.

2) Environmental Damage Potential--Damage to young trees, reduction of generation of trees. Might be serious where even-aged stands are bring regenerated.

3) Perceived Damage (Social and Political Influences) -- Reduced generation of trees when mature forests are removed. Could slow the reforestation efforts in some areas.

Estimated Risk for Pest---High

Additional Remarks—Greatest risk would be to young regenerating stands or reforestation efforts. The many species of Pinaceae in Western North America make the possibility of damage to some of these tree species quite high.

Spread Potential

1) Probable Rate of Spread-Slow because most individuals are flightless, but a small percentage have functional wings. Estimated rate 1 to 5 miles/year.

2) Estimated Range of Spread-Most of Western North America because of the high number of species (46) of the Pinaceae found in that region. There is also a possibility of spread across Northern North America via *Pinus banksiana* to the pine regions of Eastern North America.

3) Damage will be to seedlings and young trees rather than to mature trees, especially in regenerating stands.

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Pathogens

Larch Needle Cast

Scientific Name of Pest—*Meria laricis* and other *Meria* spp.

Scientific Name of Host(s)—*Larix* spp., *Pseudotsuga menziesii*

Specialty Team- Pathology
Assessors-jeffrey Stone

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Teleomorph: Unknown for *M. laricis;* the teleomorph of the nearly identical species, *M. parkeri,* which occurs on Douglas-fir, is *Rhabdocline parkeri* (Sherwood-Pike, Stone, and Carroll, 19%). The genus *Rhabdocline* contains species that cause severe defoliation of Douglas-fir, R. *weirii* and R. *pseudotsugae,* although *R. parkeri is* not pathogenic. The two species of *Meria* are distinguished by their occurrence on different hosts. It is therefore likely that if a teleomorph is discovered for *M. laricis,* it will he a relative of *Rhabdocline,* either congeneric or at least in the family Hemiphacideaceae.

Prior to 1986, the name *Meria laricis* was applied to taxa occurring on both *Larix* spp. and on *Pseudotsuga menziesii.* The discovery of the teleomorph of the taxon from Douglas-fir resulted in the separation of the taxa into two distinct species, *Meria laricis* on *Larix* spp. and *Meria parkeri* on Douglas-fir. It is possible that critical examination of *Meria laricis* will show that the. taxon is not monotypic and result in recognition of additional species. For example, the taxon from Eurasia may in fact represent a species or a species complex different from that of North America. For the purposes of this risk assessment, *Meria laricis* and *Meria parkeri* will he considered together as *Meria* species parasitic on conifers. A critical examination of Siberian collections of *Meria laricis* should be made to determine whether they are in fact the same taxon as North America *Meria laricis.*

Summary of Natural History: —*Meria laricis* conidia overwinter on dead foliage. Rain dispersed conidia infect newly emerging foliage in the spring; diseased needles abscise prematurely in summer. Moist conditions in spring favor the dispersal and infection process. M. *laricis* is already present in Western North America, distributed with the range of its natural host, *Larix occidentalis.* Damage from larch needle cast is sporadic, because *Larix* spp. are deciduous, defoliation is seldom fatal to mature trees.

Meria parkeri infests needles of Douglas-fir beginning in the fall of the first year after bud break and continuously thereafter. Incidence of infection increases with needle age, needles become multiply-infected as they age from repeated reinfection (Bernstein and Carroll, 1977; Stone, 1987a; Todd, 1988). 'The conidia are rain-dispersed and are produced either on abscised needles or on galls of the Douglas-fir gall midge, *Contarinia* spp. (Sherwood, Stone, and Carroll, 1986; Stone, 1987a). Ascospores of the *Rhabdocline* teleomorph are produced on abscised needles in the winter. Host genotype and degree of *Contarinia* infestation affect the level of infection (Todd, 1988).

Infection of Douglas-fir needles by *M. parkeri* does not ordinarily cause disease symptoms. Infections are restricted to single epidermal cells in healthy foliage. Colonization of the needles does not occur until thr onset of senescence or upon injury (Stone, 1987b). Disease has been reported in nurseries and orchards under wet spring conditions (Funk, 1985). *M. parkeri* should therefore be considered a t worst a weak parasite of Douglas-fir. The species is widespread in Douglas-fir in western Oregon, Washington, and northern California (Carroll and Carroll, 1978).

Given the taxonomic similarities between M. *laricis* and *M. parkeri* and their relationship to known pathogens of Douglas-fir, the possible existence of a more virulent Eurasian strain or species of *Meria* capable of infecting and damaging Douglas-fir should be considered before *Meria* is dismissed as an insignificant risk. The widespread distribution of *M. parkeri* in foliage of Douglas-fir in the Pacific Northwest suggests that native Douglas-fir would have little or no genetic resistance to infection by an introduced virulent strain.

Whereas the deciduous habit of *Larix* spp. mitigates the severity of damage from larch needle cast, Douglas-fir would be much more severely affected by a defoliating pathogen. In addition, because *Larix* is found primarily east of the Cascade range far from the proposed ports of entry, the probability of an introduction from Siberia finding a suitable *Larix* host is remote. However, the possibility of a strain capable of infecting Douglas-fir is not remote; if such a strain exists the potential for introduction is high; and the potential for damage resulting from such an introduction is very large.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-M. *laricis* is reported on larch from Siberia and the Soviet Far East (Rozhkov, 1966). See remarks above concerning whether this taxon is monotypic. The infective propagules (conidia) will be present in foliage even where disease is not apparent, symptoms would be apparent only during the summer when the diseased needles are being shed. The disease is probably very widespread in its distribution, but may be inapparent.

2) Entry Potential-The conidia overwinter and would presumably survive the transit from the U.S.S.R. to ports of entry in North America. Needles lodged in bark crevices and attached to small branches would be difficult to detect and remove completely. Any mitigation procedure designed to prevent entry of pests from bark (e.g., gypsy moth) would probably also effectively reduce the potential to introduce *Meria* spp.

3) Colonization Potential-The potential for colonization of North American *Larix* spp. is low. As discussed above, however, species of *Meria* can infect Douglas-fir and the potential for possible colonization of Douglas-fir by a Eurasian strain should also be considered. In this case, potential for colonization would be high, as virtually all the Douglas-fir foliage in western Oregon and Washington is infected with *Meria parkeri*. All life stages of these species are restricted to foliage.

4) Spread Potential-The potential for spread of the disease will depend on the proximity of a suitable host. If western larch is the only host, then spread potential is low. Ornamental larch grown in landscape settings might be infected and act as a bridge to native western larch stands. If Douglas-fir is a potential host, even if less favorable a host than western larch, spread potential is high. The conidia are rain dispersed and can apparently survive for long periods on foliar residues.

This is not an insect-vectored disease. Conidia, and ascospores if they are important in spread of the disease, are rain-dispersed. Spread will depend therefore on meteorological factors, the distribution and density of suitable hosts, and the efficiency of the pest in establishing on a host. I am unable to offer any specific quantitative estimate of rate of spread. The range of probable spread will coincide with the distribution of the host. If the host is western larch, *M. Laricis* is already established throughout its natural range. If Douglas-fir is the host, the range will coincide with that of Douglas-fir. Direction of spread will probably follow prevailing winter wind patterns in a northeasterly direction.

B. Consequences of Establishment

1) Economic Damage Potential-Probably low, unless a novel, more virulent strain is introduced, or a strain capable of infecting Douglas-fir.

2) Environmental Damage Potential-Unknown, severity of disease is impossible to predict.

3) Perceived Damage (Social and Political Influences)— Unknown.

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Melampsora Rust

Scientific Name of Pest—*Melampsora* spp.

Scientific Name of Host(s)—*Larix* spp., *Populus* spp., *Salix* spp., *Betula* spp.

Specialty Team—Pathology
Assessors—J.D. Rogers

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Melampsora Castagne is a rust genus with both heteroecious and autoecious species. Species of particular interest herein are heteroecious and macrocyclic, requiring conifers (*Abies, Larix, Tsuga,* or *Pseudotsuga*) and hardwoods (*Populus* or *Salix*) to complete the ordinary life cycle. It is noteworthy, however, that several *Melampsora* species, including *M. epitea* Thuem. can become perennial on the hardwood host and persist indefinitely in the absence of the coniferous host, spreading to additional hardwood via urediniospores. Moreover, there are subtaxa of *Melampsora* species that-though morphologically indistinguishable-have different host ranges. Additionally, some species (for example, *M. epitea*) in cold climates can do without the coniferous host, becoming perennial on two angiospermous hosts. Finally, at least *one Melampsora* has been found on an entirely unexpected coniferous host-M. *albertensis* Arth. was found on a pine host in British Columbia. *Melampsora medusae* Thuem has been found on six coniferous hosts.

Potential damage *by Melampsora* rusts is great. Heavy infection on *Larix* can cause severe premature defoliation and several successive years of defoliation stress could have a severe impact on growth.

Populus and *Salix* can be severely damaged by heavy leaf infections. Damage can be particularly significant on hosts with perennial infections.

Specific Information Relating to Risk Elements

Melampsora rusts of interest herein have five spore stages, as follows:

Spermatia (pycniospore) (O)—Fertilizing element. Noninfective. On conifer needle.

Aeciospore (I)—On conifer. Infects hardwood, but cannot reinfect conifer. Probably very resistant to desiccation and loss of viability. Can be carried hundreds of miles by wind.

Urediniospore (II)—On hardwood. Spreads fungus among hardwoods. Cannot infect conifer. Probably very resistant to desiccation and loss of viability. Can be carried hundreds of miles by wind.

Teliospore (III)- –On hardwood. Noninfective. Produces basidiospores.

Basidiospore (IV)—On hardwood. Infects conifer needle. Cannot infect hardwood. Fragile; loses viability rapidly after formation. Cannot be carried far in viable condition under ordinary circumstances.

Pest with Host of Origin--

Melampsora spp. reported to occur in Siberia and the Soviet Far East include:

M. betulinum (alternate hosts = *Betula* spp.)
M. larici - Capraearum (alternate hosts = *Salix* spp.)
M. larici - epitea (alternate hosts = *Salix* spp.)

M. larici - populina (alternate hosts = *Populus* spp.)
M. larici - temulae (alternate hosts = *Populus* spp.)
M. *populnea* (alternate hosts = *Populus* spp.)

There may be other species as well. There are reported to be 148 known species of Melampsoraceae in the U.S.S.R. as compared to only 90 in the United States and Canada.

Survival potential of spore states—

Stages 1, II, and 111 could very probably survive on conifer (I) or hardwood foliage (II, 111) that inadvertently was brought into the country. Stages I and II could potentially "hitchhike" on logs (debarked or barked) or other debris. Because these spores are microscopic, they would not be readily detectable.

Establishment potential of *Melampsora* spp.—

The most resistant spore stages, which are likely to survive the importation, infect the hardwood host. Thus, one might expect that *Populus* and/or *Salix* in the vicinity of ports would be infected first. There would be a high potential for perennial infection of these hosts; the alternate *Larix* host might not be required for **survival** and intensification.

Entry potential *of Melampsora* spp.—

Potential **would** be high if any foliage debris is present on the introduced logs.

In my opinion *Melampsora* spp. would eventually be introduced, given the cryptic nature and the number of chances.

Colonization Potential--Risk is high.

Rust spores are windborne and can be carried for great distances. There are large areas of native poplar throughout the Pacific Northwest and frequently adjacent to import sites and milling sites as well as along transport routes. Within 100 miles of the Columbia River on both the Washington and Oregon sides from the Pacific Ocean at Astoria to the Tri-cities area in Washington, there are large acreages of hybrid poplar being **grown** under a Short Rotation intensive Cultivation (SRIC) program. The hybrid poplar have been developed from clones throughout the United States, and their rust susceptibility is totally unknown. It is likely to be high.

Spread Potential of *Melampsora* spp.—

The potential spread from *Larix* to hardwood via stage I and hardwood to hardwood via stage II is great, perhaps for hundreds of miles. Spread from hardwood to *Larix* would be generally local owing to the fragility of stage IV.

A. Consequences of Establishment

1) Economic Damage Potential-There is potential for great damage to *Larix* and to *Populus* and *Salix*. The potential damage to the hardwood species is especially worrisome because of the great interest and investment in fast-growing and high-yielding *Populus* spp. in the Western United States. Unfortunately, the genetic potential for damage by *Melampsora* spp. is unknown. Even though **some** damaging *Melampsora* species are already in North America, we know nothing about the distribution of genotypes.

2) Environmental Damage Potential-

3) Perceived Damage (Social and Political Influences)—*Melampsora* spp. cause great aesthetic damage to foliage of both conifer and hardwood hosts. The public would not tolerate such damage from introduced pathogens.

Estimated Risk for Pest-Both in terms of likely introduction and potential damage, the risk is considered to be HIGH. It would be very difficult to monitor the cryptic spore states. Quarantine, in the restricted sense, would be virtually impossible.

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Conifer Shoot Blight

Scientific Name of Pest—*Sirococcus strobilinus* (J'reuss.) L.

Scientific Name of Host(s)—*Larix* spp., *Pinus contorta, Picea excelsa, P. sitchensis, Tsuga heterophylla, Pseudotsuga menziesii, Calocedrus* spp.

Specialty Team-Pathologists
Assessors—Mo-Mei Chen, Darroll Skilling, Fred McElroy

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Since its original description (see Sutton, 1980, for taxonomy), this pathogenic fungus has been reported on cones and needles of *Picea, Pinus, Tsuga,* and *Pseudotsuga* in the U.K., France, Switzerland, Canada, and the U.S.S.R. S. *strobilinus* already occurs in North America, but the Siberian biotype may be different. Needles are infected and the fungus spreads to the current year's shoot, resulting in shoot mortality. In general, the disease is identified by fruiting bodies of the casula fungus, which are found on the dead portions of infected needles and cones. Complete defoliation is usually fatal. Primary spread is by ascospores; secondary spread, by conidia. Infection occurs primarily in warm spring weather.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-Reported on shoots, cones, and needles of pines, but no records show this disease on a specific larch host in the U.S.S.R.

2) Entry Potential--If needle or cone bits stick in bark crevices or small twigs escape removal, there is a high entry potential. This pathogen could be a "hitchhiker" on logs of species other than its preferred host.

3) Colonization Potential-High. It is a hazard to forest trees, especially those in nurseries and young plantations (from seedlings to Xl-year-old trees). The pathogen survives saprophytically in dead needles and cones and can easily he transported.

4) Spread Potential--High potential for gradual spread from the point of entry to interior lands. Because there is an airborne ascospore stage, spread could be rapid and cover great distances, especially because highly susceptible young larch or pine plantations (to 30 years old) are common in eastern Oregon, Washington, Idaho, and Montana.

B. Consequences of Establishment

1) Economic Damage Potential-Low, unless a different, more virulent biotype enters and causes young plantation, nursery, and ornamental failures.

2) Environmental Damage Potential—Generally low, but composition of stands could change if reproduction of some species is restricted.

3) Perceived Damage (Social and Political Influences) -Estimated risk for pest low unless different biotype is introduced. Brown foliage could be unsightly in areas of high aesthetic value.

Additional Remarks-Mitigation would involve excluding foliage, cones, and twig contaminants on logs. This may be difficult. A similar situation in East Asian coniferous plantations involved introduction of brown-spot needle blight cases by *Lecanosticta acicola* from the Southern United States into slash pine plantations in the northern region of Fujian province in China. Another example, the larch needle blight (*Mycosphaerella lariciIeptopsis*) was introduced from Japan causing larch to defoliate 2 months earlier than normal, especially those on 10- to 30-year-old larch plantations.

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Siberian Forest Pests of Concern in Bark and Inner Bark

Insects

Engraver Beetles

Scientific Name of Pest—*Ips duplicatus*

Scientific Name of Host(s)—*Picea* primarily; *Pinus* sp.; *Abies* sp.; *Larix* sp.

Specialty Team-Entomology
Assessors--Roy Beckwith and David Wood

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

It is a Trans-Palearctic taiga species that occurs from the Nordic countries through Eastern Siberia. Generally prefers spruce but readily infests larch in pure stands and reported to prefer larch stands in Eastern Siberia. The insect prefers thin stands infesting weakened and dying trees, fresh windfall and timber with succulent phloem that have not been infested by other bark beetles.

Hibernate as adults or larvae in the host. In the Baykal area, the adults fly as early as mid-May. Larvae are found in galleries in June and July with young adults in late July or August. Varying with locality, there can be one to three generations per year.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-High -- Especially if larch originates in Eastern Siberia.

2) Entry Potential-High -- Survival should be excellent in logs.

3) Colonization Potential-High -- Especially because some entry ports will contain log decks of host species. Spruce may be relatively nearby.

4) Spread Potential-Moderate to high varying with location.

B. Consequences of Establishment

1) Economic Damage Potential-High -- Could spread throughout the range of susceptible hosts. Sitka spruce is an extremely valuable species in U.S. coastal forests.

2) Environmental Damage Potential-Possible adverse effect on the species composition and all the associated organisms that depend upon a particular stand composition.

3) Perceived Damage (Social and Political Influences)—Moderate to high.

Estimated Risk for Pest—High.

Additional Remarks—Suggest bark removal and/or fumigation as mentioned for *Ips subelongatus*

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Engraver Beetles

Scientific Name of Pest—*Ips sexdentatus*

Scientific Name of Host(s)—*Pinus* sp., *Larix* sp., *Picea* sp., *Abies* sp.

Specialty Team-Entomology
Assessors-Roy Beckwith and David Wood

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest —

Trans-Palearctic species that occurs throughout Europe and Siberia. This species prefers pines but predominates in pine-larch forests and is found in pure larch forests. Also found in Japan and Thailand.

This insect is the largest species of *Ips*. Attacks weakened and downed trees in stands of varying densities. Seems to prefer the exposed sunny-side of logs that are unbarked and contain fresh phloem.

The insect goes through one to three generations varying with geographical location. It usually has a l-year generation in Nordic countries. Hibernates under the bark and in the duff and soil. In the Baykal area, peak flight occurs at the end of May or early June. Second generation adults are active in August.

Summary of Natural History—

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin—High -- Especially if logged trees are present during adult activity or are already infested.

2) Entry Potential-High -- Could reinfest logs at deck sites or during transit if conditions of the host permit.

3) Colonization Potential-High -- Especially if pine or other host logs are available at or near port-of-entry.

4) Spread Potential-Moderate to high depending upon local area and conditions. Could spread throughout the western coniferous forests if they succeed in adapting to U.S. tree species.

B. Consequences of Establishment

1) Economic Damage potential---High -- Has the potential to come in on larch and spread to pine in log decks and eventual spread throughout our western coniferous forests.

2) Environmental Damage Potential—High -- Same as other *Ips* sp

3) Perceived Damage (Social and Political Influences)—Moderate to high

Estimated Risk for Pest-High.

Additional Remarks-Suggest bark removal and/or fumigation as mentioned for *Ips subelongatus*.

References

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Lekander, B., Bejer-Petersen, B., Kangas, E. and A. Bakke, 1977. The distribution of bark beetles in Nordic countries. Acta Entomol. Fenn. 32.

Engraver Beetles

Scientific Name of Pest—*Ips subelongatus*

Scientific Name of Host(s)—*Larix* sp. primarily (probably attack all conifers in mixed larch conifer forests)

Specialty Team-Entomology
Assessors-Roy Beckwith and David Wood

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Distributed throughout the entire conifer zone of North Asia. Occurs primarily in larch forests; rarely in stands of pine and "dark" conifers. Most numerous in larch stands with a large number of weakened and dying trees, felling areas, and timber yards of fresh logs. During mass increase in these materials, this species can infest living trees in all age classes. Infestation on standing trees mainly on the median and apical parts of the trunk; on recently felled trees, infests the entire trunk with possible exception of the very thick bark on the butt.

Adults hibernate partly in pupal cells, feeding tunnels, and forest litter. Goes through one to two generations per year. In the Baykal area, mass adult flight occurs in Bate May or early June. The second generation starts in July.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin—High -- Especially if log decks of fresh logs have been allowed to remain during adult flight or the trees have been infested before or during cutting.

2) Entry Potential—High -- Survival in the phloem should be excellent.

3) Colonization Potential-High -- Especially if unloaded in areas that have local log decks of susceptible hosts and/or if logs are transported through areas containing host stands.

4) Spread Potential-High -- If colonization is successful, the species has the potential to spread throughout the range of larch in the Western United States and Canada.

B. Consequences of Establishment

1) Economic Damage Potential-High -- Potential to spread throughout the range of its host(s) in North America. Larch is an extremely important species in the ecosystem.

2) Environmental Damage Potential—High -- Could change species composition within the area now occupied by larch.

3) Perceived Damage (Social and Political Influences)-High.

Estimated Risk for Pest-High.

Additional Remarks—
Suggest mitigating practice of fumigation or bark removal at the point of origin. The fumigation should be done before off-loading of logs at destination.

Most Scolytids can be carriers of fungi and other organisms that may be detrimental to the host species.

References

Payne, T., 1991., Siberian insects of pine, spruce, larch and fir. List compiled for the Siberian Log Workshop.

Rozkov, AS., 1966. Pests of Siberian larch, (vrediteli listvennitsy sibirskoi). Academy of Sciences of the U.S.S.R., Siberian Department, East Siberian Biological Institute, Izdatel'stvo "Nauka," Moscow.

Engraver Beetles

Scientific Name of Pest—*Dendroctonus micans*

Scientific Name of Host(s)—*Larix* spp., *Picea abies* spp., *Pinus* spp., occasionally *Abies* spp., *Pseudotsuga* spp.

Specialty Team-Entomology
Assessors-George Ferrell (USFS)

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

This Eurasian bark beetle (family Scolytidae) attacks trunks of living, mature trees in either vigorous or weakened condition. Emerging adults frequently attack the same, or a neighboring, tree but can fly considerable distance to attack distant trees. In contrast to most bark beetles, this species usually mates before emerging, attacks singly instead of *en* masse, and thus kills a small patch of the cambial zone but seldom the entire tree. Over time, however, the tree can be weakened and predisposed to other bark beetles.

Except for dispersal and host-finding by emerged adults, all stages occur beneath the bark in the cambial zone. The entire life cycle requires 1 to 3 years, depending on variations in ambient temperatures and other factors. Because of these variations, adults can be present at any season, and under controlled lab conditions, are ready to emerge after 44 days at 20 "C. This pest is present in live trees, fresh-cut logs, and in older, still-seasoning logs.

During sporadic outbreaks occurring in response to tree stress, trees are frequently mass-attacked, and many are killed. Spruces are the primary hosts, with North American Sitka and white spruces actually more susceptible than Eurasian spruces in some instances. Also, host-switching to pines is reported in some locales. Larch, true fir, and Douglas-fir are occasional hosts.

There is presently little evidence implicating this beetle as a vector of those fungi or other biological agents causing tree diseases.

This pest has spread west from Siberia into Europe in relatively recent times, in 3982 reaching the British Isles. Detailed range records are lacking, but generally, this beetle ranges across Eurasia from the southern limit of its Norway spruce host to the northern limit of coniferous forests. In locales scattered throughout Eurasia, silvicultural and biological control have shown some success, provided they were applied once outbreaks have subsided.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin -Pines, spruces, and larches are hosts, and these conifers are common and widespread throughout most of Siberia.

2) Entry Potential-Very high because many, if not most, host trees have been attacked at some time in the past, and a considerable proportion are probably currently infested because of the 1 to 3 year longevity beneath bark.

3) Colonization Potential-Very high because females mate before emergence and need not be present in large numbers to successfully attack and reproduce and because susceptible hosts are common as ornamentals and forest trees in North America,

especially Sitka spruce growing along the coast of **Oregon,** Washington, British Columbia, and Alaska.

4) Spread Potential-Very high because it attacks **healthy as well as low vigor hosts that** are widespread and common, particularly in coastal Pacific Northwest and Alaska and the continuous belt of spruce forests in Northern North America.

B. Consequences of Establishment

1) Economic Damage Potential -Very high because it attacks, weakens, and **sometimes** kills mature trees of commercially important conifer species. This pest has successfully attacked Sitka, white, black, and blue spruces where these North American species have been planted in Europe, and Sitka spruce has repeatedly **shown** to be even **more** susceptible than Norway spruce, its primary European host.

2) Environmental Damage Potential—Very high as Alaskan and Pacific Northwest forests are largely composed of susceptible hosts and these forests are often on steep watersheds important for spawning of valuable stocks of anadromous fish.

3) Perceived Damage (Social and Political Influences)-Very high, because remnant, ancient forests with high aesthetic and biological values could be affected.

Estimated Risk for Pest-Very high because of its attack habits and longevity beneath bark. Its frequent single attacks and cryptic subcortical infestation sites make discovery difficult. Because females emerge from brood chambers already mated, **each** can cause a reproductively successful infestation. Proximity of susceptible forests to arrival ports, storage areas, and manufacturing facilities increases risk. Ability to successfully attack healthy hosts suggests this pest could be most damaging as a predisposer of such trees to North American bark beetles.

Additional Remarks- Successful establishment of **this** bark beetle **in** North America would seriously hamper efforts to reduce damage caused by bark beetles by improved forest management practices.

Reference

Gregoire, J.-C., 1988. The Greater European Spruce beetle, p. 455-478. In A.A. Berryman (ed.), Dynamics of forest insect populations. Plenum Press, New York.

Weevils

Scientific Name of Pest—*Pissodes piniphilus* and Pissodes *harcyniae*

Scientific Name of Host(s)--

Specialty Team-Robert Gara
Assessors—Entomology

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Pissodes piniphilus (Hrbst.) breed in stems and branches of weakened pines and *Pissodes harcyniae* (Hbst.) infest spruces.

P. *Piniphilus* is distributed throughout Central and Northern Europe up to northern Lapland. It is frequently found in Siberia especially around the Amur River. This species mainly attacks pines at the age of 30 to 40 years. A fertilized female deposits up to four eggs in an ovipositional puncture made in the bark of host stems. Larvae then make irregular feeding galleries-in the phloem and pupate within a chip cocoon dug in the sapwood. Adult weevils overwinter in litter. The weevils attack weakened pines, but when populations are high they attack healthy trees. Spring-emerging adults are sexually immature and have to feed on pine branches for sexual maturation. The main damage produced by this species is introduction of blue staining fungi into the sapwood.

P. harcyniae is found throughout the range of European and Siberian spruces. In Siberia adults over-winter in the duff and litter at the base of trees. In May to June, when ambient temperatures reach about 10 "C, these sexually immature adults make their first appearance from their overwintering sites. They crawl up spruce trees and make feeding punctures in the upper stems, Upon reaching maturity, the insects mate, and gravid females fly off in search of suitable hosts. These females excavate egg-laying cavities into the phloem of weakened trees and oviposit one to five eggs per cavity. As the eggs hatch, the larvae feed in the succulent tissues and, in this manner, construct star-like gallery patterns. These galleries end in a chip cocoon dug into the sapwood. There is one generation a year.

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-Both weevil species will attack weakened host material as well as log decks.

2) Entry Potential-If only larch were imported, the entry potential of these insects would be low. The weevils could be passively included in shipments if a significant amount of litter also accompanied the logs. However, if pine and/or spruce were imported, the likelihood of introducing these weevils would be high because a small part of the over-wintering population is left within the logs.

3) Colonization Potential—*Pissodes harcyniae* and *P. piniphilus* if accidentally introduced could probably locate pine and spruce log decks located near seaports. Accordingly, the colonization potential of these weevils is high. *Pinus contorta and Picea sitkensis* will be in the vicinity of ports in northern California, Oregon, Washington, and British Columbia.

4) Spread Potential-Pissodcs are not known as strong fliers. On the other hand, they are K-selected insects and as such have well-developed host selection behaviors. This propensity means that their spread would be slow and deliberate, but eventually their populations would be well installed in North American pine and spruce growing sites.

B. Consequences of Establishment

1) Economic Damage Potential—*Pissodes harcyniae* is well known for its capacity to infest medium-aged spruce stands that have been weakened by root diseases or industrial pollution. It is reasonable to assume these stands would also be available in North America. *P. piniphilus* is the more aggressive of the two weevils. Large populations of these weevils can produce primary attacks and kill living trees. Their most important damage would be the log degrade they would produce by infesting stored logs.

2) Environmental Damage Potential-Environmental damage would not be expected from introductions of these weevils. The only conceivable damage, might come from spraying particularly valuable decked logs with an insecticide. This event is unlikely as stacked logs can be protected by installing water sprinkler systems.

3) Perceived Damage (Social and Political Influences)—It is not likely that the general public would perceive these insects as being major pests. The blue stain produced by P. *piniphilus,* however, would be looked upon as a major problem by the timber industry--especially those involved in log exporting.

4) Overall Risk-If only larch logs are imported, the risk of introducing these weevils is small. If pine and/or spruce logs are imported, introduction of these weevils is probable, and the risk of economic damage is high.

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Siberian Forest Pests of Concern in Wood

Insects

Wood Boring Insects

Scientific Name of Pest—*Monochamus sutor, M. urussovi*

Scientific Name of Host(s)—*Picea* spp., *Abies* spp., *Larix* spp., *Pinus* spp., *M. urussovi.* Adults have also been reported to infest *Salix, Quercus, Acer, Populus,* and *Betula.*

Specialty Team—Entomology
Assessors-Darrel Ross, Kathleen Johnson, Dan Hilburn

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Monochamus sutor and M. *urussovi* have a 2-year life cycle in Siberia. Adults of both species are active from June to September in this region. The adults feed primarily on bark and phloem of twigs in the crowns of conifers, including spruce, fir, larch, and pine. *Monochamus urussovi* may apparently also feed on some hardwoods, also, including birch, willow, oak, maple, and aspen. Adults feeding on twigs can kill the distal portions of the stems and significantly reduce the foliage area in the canopy of heavily infested trees. 'Typically *Monochamus* adults become sexually mature 7 to 10 days after emergence. The sexually mature beetles are attracted by volatile compounds to weakened, dying, or recently dead trees or logs to mate and oviposit. Trees weakened by fire, defoliation, or other disturbances are particularly susceptible to attack. Windthrown trees and logs are also highly attractive to breeding adult beetles. *Monochamus sutor* females can lay at least 50 eggs. Eggs are laid in the phloem at the base of niches excavated by the females in the bark of tree boles and logs. From one to six eggs may be found in individual niches and thousands of eggs may be laid in a single log or tree.

The neonate larvae feed on the phloem and sapwood throughout their first year. The larvae overwinter primarily as second instars and resume feeding the following spring. During the second year, the larvae continue feeding and bore deeper into the wood. There are five larval instars. The mature larvae form pupal cells in the wood near the surface where they spend the second winter. Pupation and adult emergence occurs the following spring.

Apparently *Ceratocystis* spp. are associated with M. *urussovi* in the U.S.S.R., but the relationship between the fungi and beetles are unclear.

Specific Information Relating to Risk Elements—

A. Probability of Pest Establishment

1) Pest with Host at Origin—There is a high probability that logs cut in Siberia will become infested during storage and transport to port cities or during storage at port cities. Because only 50 percent of the annual harvest is removed from the forests between December and March because of poor road conditions at other times, logs are likely to be stored in the forest at the time when adult beetles are actively breeding. The longer the storage period for logs at the upper and lower landings between the months of June and September, the higher will be the probability of infestation by

Monochamus spp. These insects are also very likely to be in some standing trees before harvest. Both *Monochamus* species are found throughout the forest zone of the Palearctic region from Europe to the Pacific Ocean. In the mountains of the Baykal region, *M. sutor* occurs all the way to timberline; *M. urussovi* up to 1,600 m.

2) Entry Potential-There is a high probability that untreated Siberian logs entering the United States would harbor living *Monochamus* (all life stages, but especially larvae in the wood). *Monochamus sufor* is frequently found in timber imported into Great Britain from Europe. In the past, timber delivered to Bulgaria during the months of July and August from the Komi ASSR was heavily infested by *M. sutor, M. urussovi*, and M. *galloprovincialis*. The first test shipment of Siberian logs imported into California was found to contain' live cerambycid larvae and adults (adults were identified as *Tetropium gabrieli*), proving that cerambycids are easily capable of surviving the logging/transport process. Older larvae and pupae could be transported in debarked logs and green or air-dried lumber.

3) Colonization Potential-There is a high probability of colonization by these insects because of the presence of abundant susceptible host tree genera (living and down trees and cut Jogs) near port cities, along transportation routes, near milling sites, and where lumber would be used. Segregating Siberian logs at the mill would do little to prevent colonization by these insects. Based on the flight capabilities of other *Monochamus* spp. (Kobayashi et al., 1984), adults are probably able to fly up to several kilometers. Consequently, if suitable breeding material is available within that distance of the imported logs or certain wood products, then there will be no impediment to colonization by emerging adults. The larval stage may be extended in green or air-dried lumber if *Monochamus* larvae react like other ceramhycid larvae to milling. This would lengthen the time over which *Monochamus* could emerge and colonize a new area. An infestation could go undetected for several years.

4) Spread Potential--Susceptible host tree genera range from Central America north through Canada and from the J'acific to Atlantic Oceans. Rate of natural spread may be slow (probably only a few miles/year), but spread would be greatly enhanced by transport of logs, firewood, and lumber (non-kiln dried). Thus, the spread potential of these pests would be high.

B. Consequences of Establishment

1) Economic Damage Potential--*Monochamus urussovi* and *M. sutor* represent a serious economic threat to Pacific Northwest forests and the forest industry. Larval feeding can significantly degrade the value of salvageable timber or logs in storage. Current outbreaks of western spruce budworm, Douglas-fir tussock moth, and numerous bark beetle species are creating abundant breeding sites for these cerambycids if they were to be introduced into the United States. These *Monochamus* spp. could drastically reduce the potential for salvaging timber damaged or killed by native pests or wildfires. in the Eastern United States, *Monochamus* spp. "often cause heavy losses in windthrown or fire-killed timber, in sawlogs left too long in the woods before milling, and in improperly handled pulpwood" (USDA, Forest Service, 1985). In the Baykal region of the U.S.S.R., *M.* sufor is an important pest of harvested logs. The U.S.S.R. forest industry suffers large annual losses in timber yards where wood is stored. In one study in the Baykal area, from 10 to 80 percent of larch wood in a timber yard was found to be infested by *M. sutor*. Because oviposition can occur only when bark is present, sawn lumber is usually immune from attack, though larvae already present in the wood at the time of milling can continue to develop. Rozhkov (1966) states that the economic importance is ". . . very great for M. *sutor* in larch forests. For example,

in the Baykal area the species destroyed a very great quantity of larch building timber logged in the preparation for the Bratsk Sea [Bratsk Reservoir] bed. . . *M. sufor* is, also, a serious physiological pest of forests in a large part of its range."

Monochamus urussovi has caused significant economic damage in the U.S.S.R., particularly following defoliator outbreaks and fires. In the Krasnodar region, a severe outbreak of M. *urussovi* affected more than 1 million hectares in the 1950's. At high population densities, adult feeding by this insect can weaken trees and increase their susceptibility to other pests such as bark beetles.

Monochamus spp. are vectors of the pine wood nematode species complex (*Bursaphelenchus* spp.). Direct damage by these beetles could be less important than their role in introducing or vectoring nematode-induced pine wilt disease. *Monochamus* adults typically move pine wood nematodes to healthy trees during feeding and to dead and dying trees or logs during oviposition. Pine wood nematodes move into newly emerging *Monochamus* adults as they leave the infected wood. Siberian logs are highly likely to contain *Monochamus* life stages capable of moving pine wood nematodes to U.S. trees. Because the logs may have been stored in extremely cold temperatures since harvest or have been transported to the United States in a timely manner, the nematodes can also arrive in logs still suitable for oviposition and larval development by native Monochamus. Introduced pine wood nematodes from Siberia may show greater pathogenicity in the United States than do native nematode populations because native trees would not have developed resistance to the introduced nematodes. Introduction and spread of a virulent pine wood nematode species/pathotype into the United States would likely cause tree species composition shifts (as in Japan) and tremendous economic and other damage (see pest risk assessment and economic analysis for pine wood nematode).

2) Environmental Damage Potential-If M. *urussovi* or *M. sutor* populations reach high densities by breeding in damaged or dead trees, they could exacerbate problems associated with outbreaks of indigenous pests and wildfires. Feeding by adults could weaken healthy trees predisposing them to attack by indigenous insects. This could lead to more frequent or prolonged pest outbreaks. The larvae could also impact the natural community of organisms decomposing logs. Because these beetles feed on living trees, there is also the possibility that they could become important vectors of native or introduced pathogens *(e.g., Bursaphelenchus* spp. or *Ceratocystis* spp.). If adults introduce and vector an exotic pathogenic species/pathotype of pine wood nematode, for example, to healthy trees, great environmental damage resulting from tree mortality and tree species composition shifts could occur.

3) Perceived Damage (Social and Political Influences)--Public interest in the health of forests throughout the United States, including the Pacific Northwest, is currently very high. Defoliators, bark beetles, pathogens, and wildfires are causing a great deal of visible damage to our forests, particularly east of the Cascade Range. Public concern has led to increasing pressure by many groups and individuals on government to take actions to improve forest health. Introduction of *these Monochamus* spp. has a high potential to increase the incidence, severity, and impact of the pest outbreaks that are already causing significant problems.

Estimated Risk for Pest-The risk of introduction, establishment, and spread is high. The risk of significant economic or environmental damage directly attributable to these beetles alone is moderate to high. The risk of them vectoring exotic pine wood nematodes is high. The overall estimated risk for *M. sutor* and *M. urussovi* is high.

Additional Remarks--Debarking, milling, and air drying are not reliable control measures for insects boring deep in the wood such as these *Monochamus* spp. Fumigation and kiln-drying are the standard methods for dealing with cerambycid wood borers. Because of a lack of effective detection and control techniques for *Monochamus* spp., it is unrealistic to hope that an established infestation of an exotic species could be eradicated.

Significant literature exists in Russian on *M. sutor* and M. *urussovi;* much remains untranslated, however. Computer models generated for *M. urussovi* populations in the U.S.S.R. are reported in the Russian literature.

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Wood Boring Insects

Scientific Name of Pest—*Xylotrechus altaicus*

Scientific Name of Host(s)—*Larix* spp.

Specialty Team-Entomology
Assessors-Dan Hilburn, Dave Schultz

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

X. alfaicus is a longhorned beetle. The larval stage is a wood borer. This species is common in Siberia where it infests larch. Spruce, fir, pine, and hardwoods are not attacked by this insect. Adult beetles are active in June, July, and August. Females fly to potential host trees and lay their eggs singly in bark crevices. Each lays 50 to 145 eggs. In Siberia, X. *altaicus* has a 2-year life cycle. During the first summer, larvae feed in the phloem under the bark. After hibernating through the first winter, they resume feeding and excavate long transverse galleries in the phloem, then they bore into the sapwood (1 to 10 cm deep) where they again overwinter. The following spring they move closer to the surface and construct a pupal cell.

X. alfaicus infests mainly previously stressed trees, such as those affected by fire, insect defoliators, or overmaturity. In Siberia, there is an alternation of years of relative scarcity and years of mass abundance. This insect is a secondary pest except during outbreaks when they will attack healthy larch. During outbreaks, trees damaged by the larvae die and timber loses its marketable value. Stands of valuable timber can be turned into fuel wood in 3 to 5 years.

Rozhkov (1966) summarizes the economic importance of *X. alfaicus* with these words: Very great. This species is one of the most serious physiological and technical pests of larch forests which have been weakened by primary pests, fire, or other causes. The damage is increased by this species' ability to multiply in large numbers over large areas. Foci of mass multiplication of this species may last for decades.

Specific Information Relating to Risk Elements —

A. Probability of Pest Establishment

1) Pest with Host at Origin—*Xylotrechus alticus* infests larch in Siberia. It is found from the Urals (Sverdlovsk) to the Pacific coast, from Yakutia to Altay, Amur, Sakhalin, and northern Mongolia; especially common in the foothills of Altay, Tuva, and southern Trans-Baykal. There is a very high probability that this insect will be found in larch timber from Siberia.

2) Entry Potential-All life stages could survive transport and storage of logs. Older larvae and pupae would be present even in debarked logs. There would be no visible evidence of infestation by this insect detectable by inspection of raw logs. Round "grubholes," somewhat smaller than the diameter of a pencil, would be visible on debarked logs and lumber. In one study of 40 damaged trees, an average of 36 to 37 penetrating larval galleries were found per meter length of trunk.

3) Colonization Potential-The potential for successful colonization by X. *alfaicus* depends on the proximity of *Larix* spp. to the ports and mills where Siberian logs would be unloaded and processed. Adult beetles could emerge and fly from infested wood anytime from when the ship arrives in port to after the lumber is milled. If logs or

green lumber are transported or stored in the vicinity of native or ornamental larch trees, the potential for colonization is high. If not, the potential is low. In the Pacific Northwest, natural stands of western larch (*Larix occidentalis*) are found east of the Cascades. The closest natural stand of larch to the port of Portland, OR, (Larch Mountain), is about 35 miles away; the port of Coos Bay, OR, is at least 150 miles from any native larch stands.

Larch, however, is also planted as an ornamental tree in residential areas. Although larch is not common in western Oregon, sixteen nurseries in Oregon produce ornamental larch varieties for shipment all over the country. This scattered distribution of ornamental larches and nurseries growing and selling larches significantly increases the potential for X. *altaicus* colonization.

The eucalyptus borer, *Phoracantha semipunctata*, provides an example of a cerambycid wood borer that has become a tree pest in this country after being introduced. This beetle is native to Australia, but it has been spread by commerce to all areas of the world where eucalyptus trees are grown, including California. The initial introductions are thought to have occurred from crates or pallets manufactured from infested wood.

4) Spread Potential-Once established on native or ornamental trees, spread potential would depend on the distribution and abundance of larch in the newly infested area. Initially, build up would be rather slow due to the insect's Z-year life cycle. If this insect established first in ornamental trees in a residential area, its presence could go unnoticed for years. Eventually, however, if stands of native larch became infested, an outbreak could build up rapidly (within a few years). Western larch forests cover approximately 2.7 million acres in mountainous regions of eastern Oregon, Washington, and British Columbia, northern Idaho, and western Montana. There are several other *Larix* species in North America; the most common and widespread is *Larix Juricinu* known as the American larch, tamarack, or hackmatack. Human transport of infested logs, lumber, and firewood would increase the rate of spread significantly.

Using the eucalyptus borer as an example, we can estimate how fast a new cerambycid wood borer could spread. The borer was first discovered in 1984 infesting eucalyptus trees in Orange County, California. By 1986, the borer was found in six counties in southern California. By 1989, all southern California counties were infested, as well as three counties in the San Francisco Bay area. The beetle spread a distance of 375 air miles in 6 years. Although the beetle is a strong flier, most of the long-distance spread is thought to be because of the transport of infested firewood. Eventually, it is expected to spread throughout California wherever eucalyptus is grown.

B. Consequences of Establishment

1) Economic Damage Potential-Western larch is an important timber tree in this country. It is used for construction lumber, plywood, poles, and paneling. Production has averaged over 500 million board feet per year during the past few decades. Larch is also used as an ornamental tree in residential areas. *Xylotrechus altaicus* has the potential to cause considerable larch mortality if it becomes established in North America. The quality of larch lumber could also be lessened by the presence of more "grubholes." It is difficult to predict the economic damage potential of this insect, but we know it is of "very great" economic importance in Siberia and in a new environment, without its complex of natural enemies, its impact could be worse.

In Australia, the eucalyptus borer occurs throughout the eucalyptus forests, but is usually restricted to dead or dying trees, broken branches, or logging residue. During droughts it will attack standing trees that are under severe moisture stress but seldom kills them. Numerous natural enemies are associated with the beetle in Australia but are absent from most beetle populations outside its area of origin. In California, South Africa, and the Mediterranean region, where it has been introduced, the beetle will kill living trees. The greatest economic impact in California has been the cost to remove dead eucalyptus from residential or recreational areas. Some plans to grow eucalyptus on short rotations to produce paper or fuel for electric generating plants have been made uneconomical because extensive thinning or irrigation would be necessary to avoid losses from the eucalyptus borer.

2) Environmental Damage Potential-Larch is an important component of some forest ecosystems. In the Pacific Northwest, it commonly occurs in mixed stands with Douglas-fir. *Xylofrechus alfaicus* has the potential to suppress or even eliminate larch from these ecosystems, thus reducing species diversity and impacting other organisms which are associated with these trees. Bears, moose, elk, deer, squirrels, porcupines, and a variety of other wildlife find food and protection in larch forests.

3) Perceived Damage (Social and Political Influences)—Larch foliage turns yellow in the fall before dropping. It contributes to the aesthetics of fall foliage in areas where larch is found. Any mortality to native and ornamental larches would reduce the aesthetic value of this species.

Estimated Risk for Pest-Low to High. Accidental introduction of this insect could prove almost harmless or nearly disastrous. It is very likely to arrive alive and undetected in larch logs (with or without bark) or green lumber from Siberia. Establishment could occur easily if infested wood is transported or stored in the vicinity of native or ornamental larch. Once established, its impact could be minor or extremely serious. Probably the safest assumption is that, as in Siberia, X. *alfaicus* could become a secondary pest of larch with periodic outbreaks that affect healthy trees. If, however, in the absence of natural constraints *X. alfaicus* became a primary tree killer in North America, it could have serious economic and environmental repercussions. Douglas-fir, *Pseudotsuga,* is not native to Siberia, but it is a very close relative of *Larix.* A host shift by this insect to Douglas-fir could have disastrous consequences for the timber industry in the Pacific Northwest.

Additional Remarks-Cerambycids are difficult to control because of life stages that are found deep in the wood. Fumigation or kiln-drying are the standard methods of dealing with wood infested with wood borers. In most cases, there are no practical treatments for infested standing trees. An established infestation of an exotic species like X. *altaicus* would be virtually impossible to eradicate because of our lack of good detection and control tools.

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Wood Boring Hymenoptera

Scientific Name of Pest-Siricidae: *Sirex, Parurus, Xrris* (family, general)

Scientific Name of Host(s)—*Larix* spp., *Abics* spp., *Pinus* spp., *Pseudotsuga*, spp.

Specialty Team-Entomology
Assessors-Boyd Wickman

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest —

Wood boring hymenoptera of the siricid family are important insects associated with coniferous trees world-wide. In a strictly ecological context, they are beneficial organisms because they decompose and recycle dead trees providing mulch and nutrients for forest soils. A symbiotic association exists between several hasidiomycete fungi and various siricids that hastens the decomposition process.

This group becomes a pest in two ways-first, when introduced fungi and larval galleries degrade wood products sawn from infested trees, and second, when attacks on live trees cause the trees to die. According to Rozhkov (1966) this is one of the principal pests of Siberian larch. It is a trans-Siberian species occurring everywhere up to timberline in the Baykal area. it prefers warm, well-illuminated forests; it has been found in large numbers in stands defoliated by *Dendrolimus sibiricus*. It can make mass attacks in trees weakened by defoliators and cause tree mortality. This family flies and makes attacks from the end of July through September.

The taxonomy of this family is not well worked out. For instance, Benson (1962) reduced to subspecies five forms of S. *juvencus* previously treated as species. S. *juvencus monglorum*, S. juvencus *ermak*, and S. juvencus *carinthiacus* occur in the U.S.S.R.; and S. *juvencus californicus* occurs in the Pacific Northwest. It could be argued that if Benson's subspecies taxonomy is correct, then cross introductions of subspecies may be insignificant biologically. This may be tenuous reasoning because of the long-term evolved adaptation to geographically specific environments and hosts of each subspecies. The damage caused by S. *noctilio* to *Pinus radiata* when introduced to New Zealand and Australia demonstrates the non-adaptive parasite/host relationships that often result from introductions.

The following notes summarize the biology, ecology, and life history of the family in a general fashion.

Typical Life History - Average 2 to 3 ears

Eggs - Female oviposit deeply (6 to 20 mm) into the wood. Number of eggs varies from 1 to 7, average 3 to 4 per tunnel. 1.5 mm long, incubation period 3 to 4 weeks.

Larvae - Approximately 21 months spent in larval stage. The young larva starts boring at right angles to the horizontal oviposition tunnel and remains in the sapwood for 6 to 8 months before moving into the heartwood. The larva usually makes a loop from the sapwood to the heartwood and back to the sapwood before it pupates. The larval tunnels may vary from 6 to 30 inches in length for various species and are tightly packed with grass. The larvae molt 3 to 4 times. Cutting infested trees for lumber may prolong the length of life of the larval stage for a year or more. Wood-destroying fungi are associated with larvae.

Pupae - Larva pupates about ½ inch from the surface of the wood and remains in the pupal stage from 5 to 6 weeks. If pupation takes place too far below the surface of the wood, the adult may die when it emerges from the pupal case.

Adults - Emerge in the summer, are present from early summer to early fall. Some have been found flying as late as November. Adults fly mostly in bright sunshine, and females usually outnumber the males. Males are reported to resort in tree tops or high ground where pairing takes place. The genitalia are of slight significance for purposes of taxonomic distinction.

"These insects are widely disseminated by shipments of infested lumber or timber, and the adults may not emerge until several years have elapsed." (Middlekauff, 1960)

"Female *Sirex areolatus* have even been reported as attacking recently sawed redwood lumber." (Essig from Middlekauff, 1960, and Keen, 1952. All probably citing Essig.)

Females usually oviposit in weakened trees, occasionally selecting a healthy tree. "Members of the family are attracted to forest fires and it is not unusual to find them oviposit& in smoking logs, material too hot for the bare hand to touch, whether or not eggs deposited in such situations hatch is not known." (Chamberlin, 1949)

"Horntails are of additional interest to biologists because of the symbiotic relationship of *Sircx, Urocerus,* and *Tremex* with certain wood-destroying fungi. No fungi or fungal sacs have been found in adult males. The egg becomes infected as it is laid and the wood-destroying fungus penetrates the wood surrounding the larvae as it feeds. Experiments have demonstrated that larvae can live for at least 3 months on a pure culture of the fungi." (Middlekauff, 1960)

"A number of natural enemies prey upon the horntails; of these, various Hymenoptera are most important. Members of the cynipid genus *Ibalia* and the ichneumonid genera *Rhyssa* and *Megarhyssa* parasitize the larvae of Siricidae." (Middlekauff, 1960)

"Prompt utilization of unseasoned wood exposed to attack by these insects is the best means of avoiding damage. Logs placed in mill ponds and frequently rolled will not suffer from attacks. Kilndrying gives complete control, destroying the infesting larvae, and there is little danger of these insects attacking dry, finished lumber products." (Keen, 1952)

"Horntail wasps, or wood wasps, settle on freshly felled trees, sometimes before the woodsmen have finished cutting them into logs, and on fire-killed trees before the fire is out . . . ." (Keen, 1952)

The above material was cited from Middlekauff, 1960, and Chamberlin, 1949.

One interesting quote from Middlekauff, 1960, on life histories follows:

"According to Hanson (1939), the life cycle of *Sirex cyaneus* normally extends for a period of three years from egg to adult, but development may be retarded and the adult insects may not emerge from the timber until several additional years have elapsed. A number of generations may be present in a single log at any one time, and this greatly complicates understanding the composition of the population."

Specific Information Relating to Risk Elements:

A. Probability of Pest Establishment

1) Pest with Host at Origin-Weakened and dead trees (fire killed, defoliated, windthrown, drought stressed) and log decks left in the woods can be expected to contain eggs, larvae, and/or pupae. Their common occurrence in coniferous forests of

the world mean that there is a high probability that some trees being harvested will contain siricids. Log decks left in the woods during female flight periods are also susceptible to infestation.

2) Entry Potential-Because eggs, larvae, and pupae are deep in the sapwood of logs, there is a high probability that siricid brood would survive storage and shipment to the United States and emerge from logs after arrival.

3) Colonization Potential-The family has the capacity to attack most coniferous species and some hardwoods. Given the colonization experience of S. *noctilio* into New Zealand and Australia, they must be considered serious threats to colonize after introduction.

4) Spread Potential-Males and females are strong fliers and known to fly long distances to forest fires. Adults have also commonly emerged from finished lumber in homes, pallets, boxes, and so forth. So, spread could also take place over very long distances (transcontinental) in finished products, unless all lumber is kiln treated immediately after milling.

B. Consequences of Establishment

1) Economic Damage Potential-The attacks can result in wood degrade and can cause structural damage. Adult emergence in new dwellings and furniture is disconcerting and often results in lawsuits by homeowners.

2) Environmental Damage Potential-It is possible that attacks will occur in live stressed trees in plantations causing mortality. The family can be considered a serious pest even when it does not kill trees outright. The fungi introduced by female oviposition increases the rate and severity of decay. In the U.S.S.R., heavy attacks can result in blue stain and decay and the complete economic loss of wood products according to Rozhkov (1966).

3) Perceived Damage (Social and Political Influences)— If members of this family become established and duplicate the experience of S. *noctilio* in New Zealand and Australia, there could be large expenditures needed for research and control activities. The economic loss to the resource could be large, especially if they become tree killing pests in plantations. There could be quarantine measures applied against States processing Siberian lumber.

Estimated Risk for Pest-High, based on known introduction of S. *noctilio* into Australia and the problems that occurred as a result.

Additional Remarks-These are the most difficult wood borers to control because eggs are inserted into the wood and larvae more deeply into the wood as they develop. Kiln treatment of lumber is the only certain method of killing the insects in the wood. Tree mortality caused by attacks of *Sirex ermak* has been reported in weakened Siberian larch. The most renowned example of tree mortality has occurred in New Zealand and Australia after *Sirex noctilio* was introduced from Europe. *Sirex noctilio* is considered a secondary pest in Europe, but when it was introduced along with its fungi into New Zealand at around the turn of the century, it developed into a primary tree killer in *Pinus radiata* plantations. Most of the damage occurred in trees stressed by drought or overcrowding nevertheless, hundreds of thousands of crop trees were killed in the 1940's and 1950's in New Zealand; by 1952, the insect was introduced into Australia with similar consequences. The economic impact was severe in terms of lost fiber resources and costs of developing control and preventive measures.

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Pathogens

Wood Ring Rot

Scientific Name of Pest—*Phellinus pini*

Scientific Name of Host(s)—*Larix, Pinus, Abies, Calocedrus, Picea, Chamaecyparis, Tsuga, Pseudotsuga,* and *Thuja* spp.

Specialty Team-Forest Pathologists
Assessors-Robert L. Gilbertson

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—

Phellinus pini is a cosmopolitan species, distributed throughout the coniferous forest ecosystems of the Northern Hemisphere. It decays heartwood in living trees and has been reported in virtually all North American species in the Pinaceae. It is especially important in Douglas-fir, larch, pine, and spruce. Infection of living trees occurs by wind borne basidiospores germinating on branch stubs to produce mycelium that grows through the branch stub into the heartwood. After a period of several years of growth in the heartwood, P. *pini* forms basidiocarps (conks) under branch stubs 4 to 20 feet behind the farthest extent of decay in heartwood above and below conks. Basidiospores liberated from these conks may be transported long distances in the air and are the propagules that cause more infections. The conks are perennial and grow and sporulate on the living tree for years.

In Douglas-fir in the Pacific Northwest, the dominant, fast-growing trees that begin self- pruning early are the first infected in a stand at about 50 years. The fungus has a pathogenic effect on these trees, eventually slowing the growth rate, resulting in the release of other trees which then become the dominants. These are in turn infected, and the cycle is repeated until all the Douglas-fir is infected and deteriorates and is replaced by tolerant climax species. There seems to be no information on variation in pathogenicity among different genotypes of P. *pini*. The decay is a white pocket rot with little change in strength properties into the intermediate stages. In the incipient stages the wood undergoes a red discoloration, the basis for the common names red ring rot, red rot, or red heart. The fungus is not a primary invader of dead wood and quickly dies out in cut lumber. The decay does not continue in wood in service.

Specific Information Relating to Risk Elements—

A. Probability of Pest Establishment

1) Pest with Host at Origin—*Phellinus pini* is described in the literature as the most widely distributed and damaging heart rot fungus on larch species in Siberia and the Soviet Far East. It definitely should be expected to be one of the organisms that will inevitably be present in conifer logs imported from that region.

2) Entry Potential-High for vegetative stages of the fungus. Incipient decay may be difficult to detect, and decay pockets in logs may not show on cut ends. Conks are generally apparent and easily detected but very small; viable and sporulating conks cou ld escape a casual inspection.

3) Colonization Potential-If logs with conks are imported, the conks could still be viable if the time between harvesting and importation is short. If sporulation occurred, infection of native hosts is possible. The likelihood of this taking place is highly

unlikely because the conks must be positioned with the tubes containing basidia in a perfectly vertical alignment as on the standing tree for any spore release to occur. For this reason colonization by spores from conks on imported logs is not a serious potential problem. The potential for colonization from infected wood is even more remote, especially if logs are processed in the mill soon after importation. The fungus dies out quickly in cut lumber and other wood products, and dissemination of the vegetative mycelium by vectors is not known to occur.

4) Spread Potential-If native hosts are colonized by *P. pini,* the probability of eventual spread is high. However, there would be a substantial time lag before development of conks and production of basidiospores on native hosts. The potential long range dispersal of these spores presents the possibility of infections by introduced genotypes being established at localities far from the source. Spread potential from vegetative mycelium or decayed wood is low because the fungus does not produce any asexual spores and the mycelium in wood dies out quickly after the logs are processed. In all probability, East Asian genotypes have already been introduced into North America countless times by basidiospores airborne from conifer forests in Kamchatka and other coastal localities to hosts in Alaska conifer forest ecosystems.

B. Consequences of Establishment

1) Economic Damage Potential—*Phellinus pini* is already a major cause of volume loss in the United States and Canada, particularly in old-growth stands. However, *P. pini* is not likely to cause significant volume **losses** in second-growth stands managed on short rotations. The main concern would be that Asian genotypes might act differently, have different host preferences, and be more pathogenic than native American strains of the fungus. This is only a possibility, and there is no evidence that any greater economic loss would be probable.

2) Environmental Damage Potential—*Phellinus pini* is already one of the major factors in decline and deterioration of old-growth conifer stands preserved in wilderness and natural areas. From an ecological standpoint, this is a natural function **and an** essential role in the cyclic nature of stand succession that characterizes dynamic forest ecosystems. The potential for environmental damage is very low.

3) Perceived Damage (Social and Political Influences)-The effects of P. *pini* are cryptic and not readily perceived by the lay public or politicians. Therefore, the potential for it causing any problems in this region is extremely remote.

Estimated Risk for Pest-There is a high probability that P. *pini* would be introduced as vegetative mycelium in decay in larch or other conifer logs from Siberia and Eastern Asia. There is a low probability that viable conks could also be present on imported logs. The probability that any of these would release spores on horizontal logs is virtually nonexistent. Because P. *pini* does not produce any asexual spores, there would be no readily disseminated propagules, and the colonization and spread potential would be extremely low. Also the fungus dies out quickly in lumber and other wood products, and decay and damage essentially does not continue after harvest and processing. Because of the biological characteristics of *P. pini,* it will almost certainly be introduced, but the probability of colonization of native hosts and spread from the point of introduction is very low. The fact that it is a native pathogen and has apparently been widely distributed in all North American conifer forest ecosystems for millions of years also mitigates any potential risk from introduction of this organism.

Additional Remarks—Rigorous inspection procedures to remove basidiocarps from logs prior to importation, and especially debarking of imported logs, would virtually eliminate *any* potential introduction of alien genotypes.

In the past, records on geographic distribution and host relationships of *P. pini* have been combined with those of *Phellinus chrysoloma,* a similar, sympatric species. The biology of P. *chrysoloma* is similar to that of *P. pini,* but it is associated more with *Abies* and *Picea.* It was commonly considered a variety of P. *pini* until about 20 years ago.

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Scientific Name of Pest—*Ophiostoma* spp. / *Leptographium* spp.

Scientific Name of Host(s)—*Larix* spp., *Pinus* spp., *Picea* spp., *Abies* spp., *Tsuga* spp., and *Pseudotsuga menziesii*

Assessor-Donald J. Goheen
Specialty Team-Pathology

Pest Risk Assessment (Including References)

Summary of Natural History and Basic Biology of the Pest—
Fungi in the genus *Ophiostoma* belong in the Division Eumycota, Subdivision Ascomycotina, Class Pyrenomycetes, Order Sphaeriales, and Family Ophiostomataceae. There are over 100 known species with anamorphs in the genera *Leptographium*, *Verticicladiella*, and *Phialocephala* (Harrington, 1988). They are characterized by having a unique cell-wall chemistry, a high tolerance to cycloheximide, and vector relationships with subcortical insects. Virtually all bark beetles (family Scolytidae) as well as some Cerambycids, Curculionids, Diptera, predatory beetles, mites, and nematodes have one or more *Ophiostoma* spp. associates (Francke-Grossman, 1963; Whitney, 1982; Harrington, 1988). *Ophiostoma* spp. form fruiting bodies (both perfect and imperfect types) in insect galleries under bark or in wood. Spores are produced in sticky masses, and these adhere to emerging insects. The insects carry the spores with them and inoculate the fungi into new hosts when feeding or constructing galleries. Some bark beetle species have specialized fungus-carrying structures (mycangia) while others carry spores passively on their exoskeletons or in their digestive tracts. Spores may be carried long distances by the vectors.

Effect of Pest on Host--
Some *Ophiostoma* spp. are saprophytes, but many are pathogenic to varying degrees. Most of those that are associated with Scolytids are involved with their vectors in tree killing. When introduced into a host by the bark beetles, these fungi invade the sapwood, occlude water conducting vessels, and contribute to killing the tree. They assist their vectors in a mutualistic fashion by stopping host defense reactions and creating conditions conducive to brood production (Graham, 1967; Dowding, 1984). A few species, notably *O. polonicam* and *O. dryocoetidis*, have been shown to be highly pathogenic, capable of forming rapidly expanding lesions that can girdle and kill a tree with extreme rapidity (Molnar, 1965; Horntvedt, 1983; Christiansrn, 1985). In addition to contributing to tree death, bark beetle-associated *Ophiostoma* spp. usually cause additional economic loss by staining the sapwood of affected trees and substantially reducing their salvage value.

A few *Ophiostoma* spp. with *Leptographium* anamorphs are root pathogens (Alexander et al., 1988; Wingfield et al., 1988). One pathogen, *L. wageneri* in particular, causes a damaging disease of several conifers in Western North America (Cobb, 1988; Hansen et al., 1988; Morrison and Hunt, 1988). The fungus is vectored by root-feeding bark beetles and weevils but also spreads readily from tree to tree via root contacts and by growing a short distance through soil. It causes rapid tree decline and death in radially expanding disease centers primarily in *Pinus* spp. and *Pseudotsuga menziesii.*

Specific Information Relating to Risk Elements—

A. Probability of Pest Establishment

1) <u>Pest with Host at Origin</u>-There is an extremely high probability that several *Ophiostoma* spp. occur with bark beetles, weevils, and other invertebrates on all of the genera of trees being considered for importation from Siberia and the Soviet Far East. From the lack of references in the literature, it is apparent that *Ophiostoma* spp. have not received much attention to date from scientific investigators in the Eastern Soviet Union. However, numerous *Ophiostoma* spp. have been reported in the Western Soviet

Union (Vanin, 1932; Miller and Cernzow, 4934; Mejer, 1953) and the Scandinavian countries (Lagerberg et al., 1928; Mathiesen-Kaarik, 1953; Kaarik, 1975). In fact, wherever studies have been done, almost all bark beetles have been found to have one or more *Ophiostoma* spp. associates: it is virtually certain that **some** if not most of the numerous Scolytid species reported on larch, pine, fir, and spruce in Siberia and the Soviet Far East do as well. 'The probability is also great that *Ophiostoma* species from the Eastern Soviet Union will be different from those currently found in Western North America. Logs from previously healthy trees that are decked in the woods have a high likelihood of being colonized by insects and associated *Ophiostoma* spp. Logs from trees that were infested by bark beetles before felling have an even higher probability of having been colonized.

2) Entry Potential-Entry potential for *Ophiostoma* spp. is very high. These fungi survive well for some time in cut logs {more than a year with favorable temperatures and moisture regimes). They would be favored by the conditions that could be expected to prevail during transport of the logs (many logs packed close together in an enclosed, moist environment). Bark removal would not prevent survival in transit, and, in fact, mitigation of these fungi would require a type of treatment that would kill hypae occupying the entire sapwood cylinder of the logs. *Ophiostoma* spp. fruit prolifically in insect galleries, bark or wood cavities, and on the undersides of logs, bark, or wood scraps, especially in moist situations. The likelihood of spores being produced in or on untreated colonized logs once they have been delivered to ports in Oregon, Washington, or northern California is extremely high.

3) Colonization Potential—Colonization potential would depend on the ability of Siberian *Ophiostoma* spp. to infect North American conifers and the efficacy of vectors in spreading the fungi here. While some *Ophiostoma* spp. do appear to be quite host specific, many are known to affect a number of tree species, especially if they are in the same or closely related genera (Harrington, 1988). Given the similarity of conifer genera in the Eastern Soviet Union and Western North America, the probability that host cross-over could occur seems great. The probability of effective vectoring also seems substantially high. Even if exotic vectors are prevented from accompanying the *Ophiostoma* spp., it is very likely that native insects would fill the vector role. An example in which this has already occurred in North America with a closely related fungus involves the native bark beetle *Hylurgopinus rufipes* and the introduced fungus *Ceratocystis ulmi*.

4) Spread Potential—If established, *Ophiostoma* spp. have great potential to spread rapidly and far. Fungi associated with insect vectors are not limited in their spread by their own growth rates. Rather, the distances travelled by their insect associates are the critical factors. Bark beetles and Cerambycids are capable of flying distances of several miles and can be carried even further by winds. Some of these insects have two or more generations per year, so it is possible that there could be two or more increments of vector spread annually. Also, spread of *Ophiostoma* spp. and associated insects can be increased substantially by human transport of harvested logs and firewood.

B. Consequences of Establishment

1) Economic Damage Potential-Economic damage could take several forms: (a) If a Siberian *Ophiostoma* spp. and its exotic vector are introduced together, there could be a new kind of tree-killing beetle-fungus association established. In addition to tree **killing,** there would also be sapwood staining caused by the fungus. The amount of damage would depend on the host affected, the aggressiveness of the vector insect, and the virulence of the fungus. It is believed that most bark beetles require their

fungal associates to successfully infest and kill trees, so introduction of the fungi is as important as introduction of the insects, and, indeed, the two cannot usually be separated (For economic importance ascribed to introduction of Scolytid and Cerambycid beetles from the Eastern Soviet Union, see entomological sections of this evaluation); (b) If a Siberian *Ophiostoma* spp. is introduced without its exotic vector and a native insect develops a vector relationship with the fungus, the new association could contribute to increased amounts of tree killing by that native insect. This would happen if the introduced *Ophiostoma* sp. was more pathogenic than any fungal associate that the North American vector insect had previously carried; (c) Although it is much less likely than either of the scenarios in (a) and (b) above, it is also possible that a virulent *Ophiostoma*-caused root disease similar to the black stain root disease incited by *L. wageneri* could be introduced on imported logs. We do not know if any such pathogen occurs in the Soviet Far East, but it is certainly possible. Such a disease would be vectored into new areas by insects but once establish4 could cause substantial tree killing by itself.

Precise economic damage potential figures are impossible to provide with our current knowledge of *Ophiostoma* spp. in the Soviet Far East. Damage would certainly involve timber loss through mortality and degrade because of wood staining. One thing to remember when considering risk associated with *Ophiostoma* spp. is that introduction of a *number* of different species with different vector potentials and host ranges is very likely if effective mitigating measures are not employed.

2) Environmental Damage Potential-Because bark beetles and associated *Ophiosfoma* spp. as well as *Ophiostoma*-caused root diseases tend to kill trees of one or several closely related species in groups, they could be responsible for tree species shifts. Type or magnitude of any such shift cannot be predicted without additional information on specific fungi and insects that might be involved.

3) Perceived Damage (Social and Political Influences)-Tree mortality caused by a bark beetle-*Ophiostoma* spp. association has the potential to be rather spectacular and thus evident to the public and interest groups. If a new tree-killing beetle-fungus association were established in the Pacific Northwest, there would certainly be political implications. Damage by some *Ophiostoma* spp. and associated bark beetles tends to be especially great on offsite plantings. Thus, ornamental plantings and Christmas tree plantations might be at higher risk to damage from some of these beetle-fungus associations than forest stands.

Estimated Risk for Pest—High.

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APPENDIX J
Assessment of Timber Economic Impacts of Potential Defoliators Associated With Siberian Logs

Summary of Workshop Data

Potential l'ests-Nun Moth and Asian Gypsy Moth (Hitchhikers)

Growth loss	15 to 25 percent decade growth loss over the 77.1 million acres of susceptible host type in the West.
Mortality	GO percent for conifers (other than Douglas-fir and larch) every 10 years. 30 percent for hardwoods, Douglas-fir, and larch every JO years.
Defect	The nature of defoliation does not impart defects per se.
Premature cutting	There will be losses due to premature cutting that involve early harvest to preclude major economic impacts. However, no estimate of the economics of such actions can be made.
Species	The colonization, establishment, and spread of the introduced gypsy moth in oak-hickory and hardwood forests of the Eastern United States over the long term will cause species shifts.

Assumptions Developed in Workshop for Assessment of Impacts on Timber Resources in the West

Growth Loss

As a defoliator of mostly spruce, fir, and larch (see table J-1 for the area and volume of unreserved forest in the Western United States with the potential for defoliator loss), the nun moth represents a potential threat to approximately 77.8 million acres of forest in the American West. The gypsy moth type is more restricted to larch and hardwoods for all larval instars; a mixture of these species with fir and spruce is essential for early larval establishment—later instar larvae then move to fir and spruce. Experts predict that pine would be the only conifer not at risk, because neither the nun moth nor the gypsy moth uses pine as a primary host. Some 50 percent of Douglas-fir, 100 percent of spruce fir, 100 percent of hemlock-Sitka spruce, 50 percent of other softwoods, and 100 percent of hardwoods could serve as acceptable hosts. Conifers will exhibit 15 to 25 percent growth loss and hardwoods 10 to 20 percent growth loss. We assumed no time frame for colonization. Although both defoliators could potentially spread east, this scenario was not analyzed because of the difficulty of predicting such a spread and distinguishing the effect from that of the existing gypsy moth infestation in the East.

Table J-1. **Area and Volume of Unreserved Forest in the Western United States and Potential Losses From** Attack **Due** to Soviet Defoliator Insects, All Ownerships"

	Forest Type					
Forest type	Douglas-fir	Fir/ Spruce	Hemlock Sitka Spruce	Larch	Other Softwoods	Western Hardwoods
M acres	35,487	23,083	5,520	2,633	4,287	**25,973**
% acres attack	50%	100%	100%	7 00%	50%	**100%**
Acres attacked	17,743	23,083	5,520	2,633	2,143	25,973
Net vol MMBF	510,030	279,339	134,905	34,388	17,290	74,336
Annual growth MMBF	10,200	5,587	2,698	688	346	1,487
Annual growth attacked MMBF	5,100	5,587	2,698	688	173	1,487
Annual growth loss %	2%	2%	**2%**	**1.5%**	2%	1.5%
Annual growth loss MMBF @ t=10	102	172	54	10	3.5	22
Annual mortality %	3%	**6%**	6%	3%	**6%**	3%
Annual Mortality MMBF @ t=10	7,650	16,760	**8,094**	1,032	1,037	2,230

[a] USDA, 1987.

Notes:

(1) Decade Outbreaks-Evidence shows that outbreaks for similar defoliators occur approximately every 10 years in the United States. 'Therefore, an outbreak could be expected to occur 10 years after introduction of defoliators (t = 10). Evidence shows that the spread rate of similar pests is approximately 20 kilometers per year.

(2) Annual Growth---Annual growth rates are estimated to be 2 percent by volume. This was figured by using tables 7, 8, and 28 of *Forest Statistics of the United States, 1987,* Net Volume of Hardwood and Softwood Growing Stock, and Net Annual Growth of Growing Stock.

(3) Annual Growth Losses-Predicted to be 15 to 20 percent per decade and calculated on an annual basis by volume, depending on species.

(4) Annual Mortality-Mortality primarily occurs during decade outbreaks. Losses are spread out on an annual basis. Mortality was predicted to be between 30 and 60 percent per decade by volume, depending on species for the worst case scenario, and 5 percent per decade for the best case scenario.

Mortality

It was assumed that outbreaks of defoliators would occur every 10 years, last for 2 years, and that tree, stand, and economic impacts would be similar to those from native pests such as the western spruce budworm and Douglas-fir tussock moth. Outbreaks of the native Douglas-fir tussock moth in Oregon grand fir and Douglas-fir stands have resulted in mortality rates ranging from 5 percent in moderately defoliated areas to 72 percent in heavily defoliated areas (Wickman, 1978). The proportions of total infested area suffering from heavy defoliation in tussock moth outbreaks in Oregon and California range from 14 to 25 percent (Wickman et al., 1973). Mortality to spruce and fir could be greater when defoliated by nun moths or gypsy moths since they would be introduced pests and may not be affected by the natural controls of native pests. The mortality estimates for each 10-year outbreak period are reflected as loss in volume in the infested region by reduction in stand basal area. Mortality rates of 60 percent for conifers (except Douglas-fir and larch) and 30 percent for Douglas-fir, larch, and hardwoods would occur if the introduced defoliators were more damaging than the native defoliators.

Defect

Not applicable to the damage produced by these two defoliators.

Premature Cutting

Due to the major effect of defoliation to conifer mortality and past historical investment in management practices in the Pacific Northwest forests, premature harvesting would be expected to exceed comparable gypsy moth defoliation (management) in hardwood forests of the Eastern United States.

Species Conversion

Based upon more than 100 years of defoliating episodes in the hardwood forests of the Eastern United States, significant changes in species composition have occurred. Because the trees most susceptible to defoliation tend to suffer the highest mortality, the oaks tend to be eliminated, while the numbers of other less preferred species, such as red maple, have increased. There is no scientific reason to expect anything different for the long-term defoliation effects on Pacific Northwest coniferous forests by these defoliators. Depending upon the tree species and site, three scenarios are possible.

(1) Worst Case -- Complete loss of a forest type (for example, high-elevation spruce and fir could be converted to no forest cover).

(2) Reversion of Type -- Tree defoliation and subsequent mortality will revert to a more pioneer species (for example, conifer to aspen and alder).

(3) Accelerated Succession -- Elimination of most preferred conifers will speed up to if late successional stage (western hemlock and Sitka spruce to pure western hemlock).

Appendix K
Potential Economic Impact of Larch Canker in the Western United States

Background

European larch canker (*Lachnellula willkommii*) is common in Europe and the Eastern United States. It attacks only members of the larch (*Larix*) genus, including western larch (*Larix occidentalis*) and several species commonly planted as omamentals (Smerlis, 1973). Larch canker has never been reported in the Western United States, but it is widely distributed in Siberia and the Soviet Far East. Because the pathogen survives in dead wood and bark, it could be introduced into the Western U.S. forests via shipments of imported logs. However, it is not known whether the disease could gain a foothold in forests containing western larch.

Lachnellula willkommii causes permanent cankers on branches and main stems up to 10 cm (3.9 inches diameter at breast height [d.b.h]), often resulting in girdling of the tree or tree branches. Damage is most prevalent on IO- to 25-year-old trees (Sinclair et al., 1987). Killing infections have been observed on trees up to 25 cm (9.6 inches d.b.h). Infection can be thorough; surveys in New Brunswick have shown 60 percent of eastern larch in a large sample to be infected, affecting up to 100 percent of the trees in individual stands (Magasi and Pond, 1982). Indeed, in some areas of Europe, larch has been almost completely eliminated. The pathogen spreads on windblown spores, but can also be spread on trucks and ships, as on shipments of ornamental larches or raw logs. Experience in New Brunswick (Ostaff, 1985) with eastern larch (*Larix laricina*) has shown that the disease can spread about 4 miles per year.

Control of *Lachnellula willkommii* consists of killing and disposing of all infected trees, including larger trees that harbor the pathogen but are not killed or even substantially damaged by it. But even with such radical measures, the disease is difficult to control. The disease was thought to be eradicated in Eastern North America in 1965, but it reappeared in 1980 and now occurs throughout New Brunswick, Nova Scotia, and coastal Maine. Infected stands are converted to nonsusceptible species either through deliberate silvicultural activity or natural succession. With the potential to eliminate larch in future rotations, this disease could seriously alter the species composition of western forest ecosystems.

Western larch (*Larix occidentalis*) is an important commercial forest tree and plays a significant part in the functioning of forest ecosystems in the intermountain region of the United States. Larch is a deciduous conifer and a subclimax species maintained by periodic fire. There are almost 2 million acres of commercial forest land in larch type (more than 50 percent larch) in the West (table K-l). In addition, larch is found on a variety of range sites and is often associated with ponderosa pine (*Pinus ponderosa*); grand fir (*Abies grandis*); western hemlock (*Tsuga heterophylla*); western white pine (*Pinus monticola*); and at higher elevations, Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Most western larch occur in Idaho, Montana, eastern Washington, and Oregon. Most (1.8 million acres) of the larch type is available for commercial harvesting in the timber management (table K-I) that is not in reserved or deferred status. About 44 percent of the total acreage is in the seedling/sapling and pole timber size classes, which are presumably at the greatest risk from attack by larch canker (table K-2). Most of the pure larch type (1.5 million acres) is in the National Forest System. The largest concentration of private ownership (165,000 acres) is in Montana (table K-3).

There are 6 billion cubic feet of larch growing stock in pure larch and other forest types (table K-4). Seventy-seven percent of this volume is publicly owned. About 90 percent is in unreserved land class. About 26 percent is in trees 10 inches or less in diameter, which would be susceptible to loss from larch canker (table K-5). The portion of this volume that is in pure larch stands is most vulnerable.

Table K-l. Area of Commercial Timberland in Western Larch Forest Type by Land Class

State	Area (thousand acres)		
	Unreserved	Reserved and Deferred	Total
Montana	577.40	95.7	673.1
Idaho	656.60	66.0	722.6
Washington	467.00	44.0	511 .0
Oregon	92.0	0.0	92.0
Total	1,793.00	205.7	1,998.7

Sources: Green et al., 1985; Benson et al., 1985; Bassett and Oswald, 1981; Gedney, 1982; Farrenkopf, 1982.

Table K-2. Area of Commercial Timberland in Western Larch Forest Type by Stand-Size Class and State

State	Area (thousand acres)				
	Sawtimber	Poletimber	Sapling! Seedling	Non-stocked	Total
Montana	404.7	106.0	152.4	10.0	673.1
Idaho	375.8	166.2	173.4	7.2	722.6
Washington”	265.7	117.5	122.6	5.1	511.0
Oregon[a]	47.8	21.2	22.1	0.9	92.0
Total	1,094 .0	410.9	470.5	23.2	1,998.7

[a] Estimated from percentage distribution by size class in Montana and Idaho.

Sources: Green et al., 1985; Benson et al., 1985; Bassett and Oswald, 1981; Gedney, 1982; Farrenkopf, 1982.

Table K-3. Area of Commercial Timberland in Western Larch Forest Type by Ownership Class and State

state	Area (thousand acres)				
	National Forest System	Other Public	Forest Industry	Other Private	Total
Montana	468.8	38.4	115.1	50.8	673.10
Idaho	594.5	46.1	36.0	46.0	722.60
Washington	396.0	53.0	43.0	19.0	511.00
Oregon	74.0	4.0	11.0	4.0	92.00
Total	1533.3	141.5	205.1	119.8	1,998.70

Sources: Green et al., 1985; Benson et al., 1985; Bassett and Oswald, 1981; Gedney, 1982; Fnrrenkopf, 1982.

Table K-4. Net Volume of Growing Stock of Western Larch on Commercial Timberland by Ownership Class and State

State	Net Volume (million cubic feet)				
	National Forest System	Other Public	Forest Industry	Other Private	Total
Montana	1303.8	J3X.h	394.8	141.5	2,J 78.7
Idaho	778.8	221.1	191.2	231.7	1,422.8
Washington	701 .0	483.0	177.0	146.0	1,507.0
Oregon[a]	**771 .o**	22.0	65.0	40.0	898.0
Total	3,754.6	864.7	828.0	559.2	6,006.5

[a] Includes 34 MMCF in western Oregon.

Sources: Green et al., 1985; Benson et al., 1985; Bassett and Oswald, 1981; Gedney, 1982; Farrenkopf, 198'2.

Larch sawtimber volume is 27.7 billion board feet (table K-6), 78 percent of which is in public ownership (table K-7). The biggest concentration of larch sawtimber in pure larch types is in Montana and Idaho; eastern Washington and Oregon have 42 percent of the sawtimber volume, where larch occurs more frequently in other forest types.

Table K-5. Net Volume of Growing Stock of Western Larch by Diameter Class (Inches at Breast Height) and State

State	Volume (million cubic feet)					
	5.0–10.9	11.0–16.9	17.0–22.9	23.0–28.9	29+	Total
Montana	547.2	601.6	506.0	320.0	203.9	2,178.7
Idaho	416.1	451.4	290.3	142.3	122.7	1,422.8
Washington	406.0	487.0	233.0	264.0	115.0	1,507.0
Oregon[a]	119.0	265.0	157.0	184.0	93.0	898.0
Total	1,488.3	1,805.0	1,186.3	910.3	534.6	6,006.5

[a] Includes 34 MMCF in western Oregon.

Sources: Green et al., 1985; Benson et al., 1985; Bassett and Oswald, 1981; Gedney, 1982; Farrenkopf, 1982.

Table K-6. Volume of Western Larch Sawtimber on Commercial Timberland by Diameter Class (Inches at Breast Height) and State

State	Volume (million board feet, international ¼ inch)					
	<10.9	11.0–16.9	17.0–22.9	23.0–28.9	29+	Total
Montana	925.1	3,235.30	2,722.6	1,792.8	1,156.2	9,832.0
Idaho	757.8	2,560.10	1,529.0	753.6	622.9	6,223.4
Washington	731.0	2,623.00	1,339.0	1,555.0	622.0	6,870.0
Oregon	400.0	1,503.00	1,027.0	1,220.0	617.0	4,767.0
Total	2,813.9	9,921.40	6,617.6	5,321.4	3,018.1	27,692.4

Sources: Green et al., 1985; Benson et al., 1985; Bassett and Oswald, 1981; Gedney, 1982; Farrenkopf, 1982.

Table K-7. Volume of Sawtimber, International ¼-Inch Rule of Western Larch by Ownership Class and State

State	Volume (million board feet)				
	National Forest System	Other Public	Forest Industry	Other Private	Total
Montana	6,534	740	2,025	533	9,832
Idaho	3,401	906	954	962	6,223
Washington	3,274	2,366	756	525	6,921
Oregon[a]	4,283	115	239	130	4,767
Total	17,492	4,127	3,974	2,150	27,743

[a] Includes 188 million board feet in western Oregon.

Sources: Green et al., 1985; Benson et al., 1985; Bassett and Oswald, 1981; Gedney, 1982; Farrenkopf, 1982.

Impacts of Larch Canker

Larch canker could have several impacts:

1. Loss in financial value of timber stands now containing western larch (see Timber Impact section below). In the long run the elimination of larch would severely reduce silvicultural options in the intermountain region.

2. Loss of a species that is relatively resistant to the insects and diseases that currently plague western forests. Conversion to other tree species could predispose the forest to greater damage from pine beetles, spruce budworm, root rot, and other problems. Larch is also quite fire resistant relative to these other species.

3. Loss in aesthetic quality of western forests. Larch's contribution to forest beauty and tourism stems from its unique form and dazzling fall coloration.

4. Reduction in the biodiversity of western forests. Possible impacts could involve:

   a. disruption of nutrient cycling patterns;
   b. long-term reduction in snag recruitment for cavity-nesting birds, especially the pileated woodpecker;.
   c. loss in habitat for other endangered species associated with larch;
   d. imbalances in hydrologic processes.

5. Loss in value of ornamental larches in urban forests, residential areas, and commercial nurseries plus direct removal costs in urban areas, might encourage replacement with other less preferred species. Loss in commercial nursery production for a number of larch species could cause dislocation, as nurseries reduce production and shift to other species. Customers close to infected areas would shift to nurseries in uninfected regions.

6. Costs of direct control in forest and urban areas. Forest disease control would involve removing and disposing of infected trees of all sizes. Some of this volume would have salvage value, but the rest would represent a direct control outlay. Intensified logging and disposal via mechanical methods or burning

could have negative environmental effects. Eradication programs in urban or rural/urban interface areas could be costly and politically difficult to implement. Even then eradication may not be entirely effective in reducing the disease's spread, as was shown in the Eastern United States and Europe.

7. Increased fire hazard from many acres of dead and dying larch.

8. Uncertain political ramifications, including possible losses in credibility for allowing the introduction of a known pest and international tension with Canada that could arise from exposing its substantial larch forests.

Most of the impacts described above could not be quantified in the time allowed for this assessment. The analysis below addresses only the potential financial impacts on the timber resource. Estimates are based on a number of assumptions about the biological interactions between canker and host, economic relationships, silvicultural regimes, and managerial responses of various levels of infection. The team treated the introduction and spread of larch canker as certain. The probability dish-ibutions of introduction and level of severity of an outbreak are under study by other teams.

Financial Impacts on Timber

Timber impacts can be described as (a) direct losses, (b) indirect losses, and (c) control costs.

Direct losses include:

(a) Unsalvageable **mortality**—The larch canker can infect merchantable timber, even though it does not usually kill sawtimber trees. Mortality can result from 'predisposition to insects and other diseases or from attempts to eradicate the disease through sanitation logging.

(b) Reduction in **stumpage** prices-Prices for salvaged logs would decrease because of reduced wood quality. Although we assumed that cankers on branches would be removed in a normal bucking and limbing process, the wood quality of young trees infected by the canker could be diminished in the future. However, no references to such a reduction in quality were evident, and there were no quantitative estimates of this.

(c) Reduced yield in the present rotation-Even if larch in the present stands survives the infection, final harvest yields would probably be reduced. In mixed stands the larch component could be lost, thereby reducing the yield to what the remaining species, e.g., ponderosa pine, Douglas-fir, lodgepole pine, or white pine, could provide. In many stands a conversion (either natural or artificial) to another species might occur (see indirect effect, below):

Faced with a larch canker infection, the manager's choices are two: allow the remnants of the damaged stand to finish the rotation or replace the stand with another species. Keeping the stand could involve a loss in yield, an increase in the length of rotation, or both, representing a loss in value in any case. The choice would depend on the degree of infection, the age of the stand, response by the undamaged portion, and the prognosis for other pest damage on the remaining species.

Indirect losses include:

(a) **Premature conversion** (assuming conversion to a species similar in yield and value)—Replacing a canker-infected stand requires an immediate brush disposal, site preparation, and reforestation cost. In addition, the yield of the damaged stand would be foregone; any harvest would be delayed by the length of the new rotation. The discounted present value of this converted stand is almost always less than the present value of finishing out a healthy stand already 30 to 60 years along. The difference in the present values between the healthy and converted stands is an estimate of the conversion impact. Note: A financial benefit could be attributed to the disease if it forced conversion of stands that are older than a financially optimum rotation age. This represents a forced divestiture of society's "opportunity costs" in preferring long rotation forestry and can complicate the financial impact. However, this impact did not prove to be important in our analysis of larch canker because the disease attacks young stands. This benefit could be a factor in control efforts that remove older trees.

(b) Species conversion-In a stand conversion, the "new" species could adversely affect yields, rotations, or stand maintenance costs. The new species can also present greater risk of losses due to insects and disease. In larch, the problem could be quite serious, since conversion species have broad arrays of serious insect and disease problems.

(c) Disruptions in the harvest schedule-Stand-level losses can be partially mitigated at the forest level in the harvest rescheduling process. The present value of the entire harvest schedule incorporates the fact that trees harvested in the salvage and sanitation program are substituted in the allowable cut. At the same time, however, the schedule can be affected by yield reductions caused by removal of larch in the growing stock. These effects change the allowable cut calculations or may stimulate managerial modifications in the harvest scheduling goals.

(d) Reductions in market stumpage prices-Local excess supplies of salvage logs could depress prices for larch and larch substitute species such as Douglas-fir. Under some control strategies, infected logs may be quarantined, which would aggravate oversupply problems. On a more aggregate level, however, the loss of larch would represent a reduction in timber supply, and hence overall increases in timber prices.

Control costs include:

(a) Removal of infected trees-Some larger trees could be salvaged, but many others would have to be cut and left, because their low per acre volumes would not allow economically feasible logging. Some of the growing stock would be premerchantable. Some on-site chipping to help defray control costs might be feasible but we did not have information on costs and returns for chipping on larch stands.

(b) Premature conversion and/or species conversion in control stands-Stands that would be infected but not killed would be subject to control measures.

(c) Administrative costs of implementing the control program-Additional staff, contracting, and supervisory costs would be necessary.

Methods

We limited our analysis to three financial impacts:

1. Reduced yields in present larch stands
2. Premature conversion of larch to other tree species
3. Direct control costs, consisting of
   a. Stumpage value lost in unsalvageable mortality in salvage and sanitation operations.
   b. Direct costs of further disposal, including piling, burning, or activities in excess of normal silvicultural treatment.

Time and resources did not permit us to address:

1. Wood quality
2. Harvest scheduling and allowable cut effects

3. Species conversion
4. Stumpage market adjustments (local or aggregate)
5. Control stand conversion impacts
6. Administrative control costs

To complete this analysis, the following estimates were developed.

1. Develop three alternative scenarios composed of different levels of infection and extent of control.

2. Estimate the acres of susceptible larch (host) type (see table K-2 and assumptions below) for each scenario. Larch in this area is completely killed in each scenario. Its base is the acreage in seed/sap and poletimber size classes. Acres that are reserved or deferred are not included.

3. Estimate the sawtimber volume of nonsusceptible larch that'is affected in a direct control program (see table K-6 and assumptions below) for the scenario. Part of this volume is salvageable at current market prices for stumpage; the rest is unsalvageable mortality. The volume that occurs as reserved or deferred timberland is not included.

4. Estimate a combined yield reduction/conversion impact for the host acreage.
   a. Estimate a per acre yield reduction impact for infected stands that are assumed to finish the rotation.
   b. Estimate a per acre stand conversion impact for infected stands that are converted immediately after infection.
   c. From a. and b., calculate a weighted average per acre impact based on an estimated relative frequencies of the two situations.
   d. Multiply the average loss c. by the number of host acres infected in the scenario, adjusting for unreserved acres.

5. Estimate the direct control cost-plus-loss.
   a. Estimate the value of the merchantable-size larch that are cut during control but are not sold, multiplying stumpage prices by the portion of the standing sawtimber volume. That portion is specified by each scenario. (See table K-6 and assumptions below.)
   b. Estimate the disposal costs not included in a., above, by multiplying some assumed net cost per MBF by the unsalvaged volume.
   c. Add 5a. and 4b., and adjust to the unreserved volume.

6. Add 4d. and 5c. for an estimate of the total impact for the estimated duration of the disease epidemic

7. Calculate the discounted present value of the impact in 6.
   a. Divide the total impact by the number of years in the epidemic (see assumptions below.)
   b. Apply formula for the present value of an annuity to the annual impacts calculated in 6.

Scenarios

7. High infection level. No control program.
   -- 100 percent of the susceptible host acreage is affected.

2. Medium infection level. Medium control intensity.
   -- 50 percent of the host acreage is affected.
   -- 25 percent of the sawtimber volume in nonsusceptible larch is cut.

3. Light infection. High control intensity.
   -- 25 percent of the host acreage is affected.
   -- 50 percent of the volume in nonsusceptible larch is salvaged and sanitation cut.

Assumptions

Biological Assumptions

1. Larch canker disease will spread completely through the larch resource in 25 years. The area occupied by larch is fairly contiguous. We assumed conditions favorable for rapid development of the fungus, including spread assisted by vehicular traffic and lofting winds.

2. Larch forest types in the seedling/sapling and poletimber size (up to 9 inches mean diameter) are susceptible. Montana and Idaho resource inventories showed that 47 percent of the commercial larch acreage falls in this group. Accurate estimates of the area exposed in Washington and Oregon were not available. We applied the Idaho and Montana proportion to the Washington and Oregon larch acreage. We subtracted IO percent of the acreage as reserved. Our final estimate was 793,000 acres at risk.

3. The average age of the susceptible larch stand is 30 years. For calculation simplicity we assumed that all stands are exactly 30 years old.

4. The larch component of other forest types (less than 50 percent larch stocking) will be killed by the disease, but the stands will undergo no yield reduction. Our estimates of the acreage distribution of larch in these stands, not to mention their relative predisposition to attack, was so uncertain that we chose the conservative assumption described here, recognizing that larch is prevalent in mixed stands, especially in eastern Oregon and Washington. This assumption, however, does not rule out unsalvageable mortality in forced control programs, because those estimates are based on total larch volume, not acreage by forest type class.

Silvicultural Assumptions

1. Larch stands will be replaced with Douglas-fir, which will be grown under a management regime with costs, rotation length, yields, and values identical to the larch regime. No significant increase in insect and disease damage will be experienced in the new stands. Actually, larch would be naturally replaced by, or converted to, a number of species, including ponderosa pine, white pine, lodgepole pine, and in some cases, grand fir. All have serious health problems. More extensive analysis could explore the tradeoffs implied in these possibilities.

2. The basic management regime is as follows:

Activity	Age	(Cost)/Revenue
(a) Site Preparation	1	($1.50)
(b) Planting	1	($100)
(c) Precommercial thinning	20	($100)
(d) Commercial thinning	50	$150 (3 MBF/acre @ $50/MBF)
(e) Final harvest	I 00	$2,100 (30 MBF/acre @ $70/MBF)

Note: The higher final harvest stumpage value is based on higher quality and lower cost togging. See financial assumptions.

3. In two-thirds of the infected host acreage, there will be enough residual growing stock in conversion species to finish out the rotation. In the other third, immediate conversion will be necessary.

4. In infected host acreage, all of the merchantable sawtimber volume will be sold at current (projected) stumpage prices identical to those of green larch. Furthermore, the volume salvaged is identical to what would have been harvested in planned commercial thinnings. Therefore, the kill of any merchantable volume does not contribute to any value loss.

5. In stands that are allowed to finish the rotation, yields will be reduced by 1/3 from 30 MBF per acre to 0 MBF/acre at 100 years.

Control Program Assumptions

1. The larger larch (above 11" d.b.h.) in all forest types will be removed. No control will be needed in the infected seedling and sapling larch stands, because 100 percent mortality was assumed.

2. The only value loss from the control program is the unsalvageable mortality, which is 25 percent of the current sawtimber volume, international ¼-inch of the > 11" d.b.h. trees. We calculated no loss from premature conversion or reduction in yield in stands containing this volume, because we had no estimate of their acreage and species composition. Further analysis could use data from resource inventories to better quantify this effect.

3. Control costs, net of the logging costs included in the unsalvaged mortality, are $10 per MBF of unsalvageable volume cut in the control program.

4. Stumpage values for larch removed in the control program are identical to prices for green uninfected larch.

5. The control program cost-plus-loss is only applicable for the volume in unreserved status. We assumed that the proportion of volume that was unreserved in a State was equal to the general proportion of commercial forest land unreserved for that State.

Financial Analysis Assumptions

1. Current stumpage prices for green larch are assumed to be $70/MBF. This represents the average stumpage price paid for larch on National Forest System sales in the Northern and Pacific Northwest Regions for the years 1985-89 (Warren, 1990a, b). The range of larch prices was $32.90 to $132 with prices being generally higher in the PNW Region. We assumed that with Douglas-fir, our conversion species sold for the same stumpage price. Actual averages are PNW: $71.77 larch/$71.36 Douglas-fir, and Northern region: $60.22 larch/$56.37 Douglas-fir.

2. Real discount rate is 4 percent. All funds during the cash flow will be reinvested at the same rate.

3. Rate of inflation for all costs is 3 percent per year

4. Real timber price increase is 1 percent per year.

5. Present rotations are financially optimum. None of the stands in the susceptible size is financially overmature.

6. The total financial impact from premature conversion and yield reduction is the sum of the stand-level estimates for the assumed acreage infected. We estimated no allowable cut adjustments.

7. The premature conversion effect is calculated with the formula:

$$\text{Value Change} = PNW^{wo} - PNW^{w}$$

where PNW^{wo} is the discounted present value of the present rotation and all future rotations without larch canker and PNW" is the discounted present value of the present and future rotations with the larch canker.

8. The form of PNW used in this analysis combines the present value of the remaining rotation with the soil expectation value (SEV) of an infinite series of rotations after the stand is converted. The SEV component is discounted to the present from its starting point, which is 70 years hence for stands in which the current rotation is allowed to finish.

9. The annual control cost-plus-loss is the total control impact divided by 25 years. Because the disease spreads uniformly over the acreage during the period, the impact is the discounted present value of a stream of 25 equal annuity payments, using the $-percent rate. (We assumed no real net of inflation increase in stumpage prices in the control impacts.}

10. Income and distribution effects are not estimated, with the exception of the distribution of financial impacts according to the relative proportions of the western larch resource in each state. Distributional impacts by income and other categories are not calculated.

11. Secondary economic and employment effects were not estimated

12. Financial losses were not calculated for acres and volumes that were in reserved or deferred status, because they have no market value as timber.

Results

The impact of larch canker will be a loss of $129 million in timber and forestland value (table K-8). This figure represents the net present value of a stream of impact over the 25-year period of spread. It is the average impact of the three infection/control scenarios, which ranged from $99 million to $166 million.

Half of this impact would come from yield reduction and conversion in present stands, and half from control costs and unsalvageable control mortality. These estimates are conservative in that they do not include the ecological impacts described in Chapter 6 and do not estimate the secondary economic impact of eliminating larch as a commercial timber species.

Under the high infection scenario, 100 percent of the impact would come from yield reduction and stand conversion. By contrast, under the low infection/high control scenario, 81 percent of the impact would come from control cost-plus-loss. A worst case scenario would include a high infection level in spite of an intensive control program, producing a value reduction of $99 + $141 = $240 million.

The impact would be greatest in Montana and Idaho ($75 million) (table K-9). Under the high infection scenario, Idaho would suffer the largest loss ($38.7 million) because of its relatively large acreage of susceptible forest type. Under the low infection/high control scenario, Montana would suffer the greatest loss ($55 million) because of its high volume of larch in the target control sizes.

Table K-8. Financial Loss From Larch Canker on Western Larch Under Three Scenarios, Four Western States

Scenario	Financial Loss (present value in millions of dollars for 25-year period)		
	Yield Reduction/ Stand Conversion	Control Cost/ Loss	Total Impact
1. High infection/No control	99.2	0	99.2
2. Medium infection/Medium control	49.7	70.6	120.3
3. Low infection/High control	24.9	141.4	166.3'
Average Impact	57.9	70.7	128.6

Table K-9. Financial Loss From Larch Canker on Western Larch for Three Scenarios, by State

State	Financial Loss (present value in millions of dollars of impact over a 25-year period)			
	High Infection/ No Control	Medium Infection/ Medium Control	Low Infection/ High Control	Average Impact
Montana	27.8	33.9	54.9	38.2
Idaho	38.7	31.1	40.8	36.9
Washington	27.3	26.8	41.7	31.9
Oregon	5.4	13.0	28.8	15.7
Total Impact	99.2	102.8	166.2	122.7

Tables K-10, K-II, and K-12 show the distribution of impacts by impact component. These results raise questions about the tradeoffs between infection and control that are assumed in the calculations. That is, why would a control program costing $48 million in Montana (table K-12) be implemented to hold the yield/stand conversion losses at $7 million? One answer is that the additional benefit from containing the infection (assuming it was biologically effective) would be in foregone negative economic and ecological effects not measured in this rough analysis. Further research using a range of assumptions, better information on the canker, growth-yield models, and more highly resolved economic data could help answer many of the questions raised in this analysis.

Table K-10. Financial Loss From Larch Canker on Western Larch for High Infection/No Control Scenario by Impact Component and State

State	Financial Loss (present value in millions of dollars for 25-year period)		
	Yield Reduction/ Stand Conversion	Control Cost/ Loss	Total
Montana	27.8	0	27.8
Idaho	38.7	0	38.7
Washington	27.3	0	27.3
Oregon	5.4	0	5.4
Total	99.2	0	99.2

Table K-11. Financial Loss From Larch Canker for Medium Infection/Medium Control Scenario, by Impact Component and State

state	Financial Loss (present value in millions of dollars for 25-year period)		
	Yield Reduction/ Stand Conversion	Control Cost/ Loss	Total
Montana	13.9	23.9	37.8
Idaho	19.4	15.6	35.0
Washington	13.7	17.4	31.1
Oregon	2.7	13.7	16.4
Total	49.7	70.6	120.3

Table K-12. Financial Loss From Larch Canker on Western Larch for Low Infection/High Control Scenario, by Impact Component and State

	Financial Loss (present value in millions of dollars for 25-year period)		
state	Yield Reduction / Stand Conversion	Control Cost / LOSS	Total
Montana	7.0	47.9	54.9
Idaho	9.7	31.1	40.8
Washington	6.X	34.9	41.7
Oregon	1.4	27.4	28.8
Total	24.9	141.3	166.2

Calculations

1. Estimated acreage in host type (seedling/sapling and poletimber) = 881,000 acres from table K-2 for 100 percent infection level, 793,000 of which is in unreserved status.

2. Estimated volume (< 11" d.b.h.) subject to control = 24.9 billion boardfeet from table K-6 for 100 percent control level.

3. Yield Reduction/Conversion Impacts
   PNW of susceptible stands without larch canker (average age = 30 years), per acre.
   (a) PNW of present stand at 100 years = $292.72
   (b) SEV of future rotations (discounted 70 years) = ($8.68)
   (c) Total of a) minus b) = $284.04

4. PNW of susceptible stands with larch canker that are allowed to finish the rotation, per acre.
   (a) PNW of present stand (age = 30) at 100 years = $195.15
   (yield reduction of 1/3)
   (b) SEV of future rotations = ($8.68)
   (discounted 70 years)
   (c) Total of a) minus b) = $186.47

5. PNW of susceptible stands with larch canker that are converted immediately, per acre.
   (a) SEV of future rotations = ($124.95)

6. Yield reduction effect, per acre
   3c -4c = $97.57

7. Stand conversion effect, per acre
   3c + 5a = $408.99

8. Weighted average impact, per acre
   2/3 ($98) + 1/3 ($409) = $200.63 $200/acre

9. Present = $200 (# unreserved acres in scenario) * (annuity factor for 25 years @ 4% or 15.622) value 25 years

Control Cost Plus Loss

1. Unsalvageable mortality (U.M.) lost in sanitation cutting $70 * .25 (U.M.%) * (unreserved sawtimber volume removed in the scenario)

2. Disposal cost
   $10/MBF * .25 (unreserved sawtimber volume removed in the scenario)

3. Total cost-plus-loss
   Sum of 1 and 2 above for the scenario

4. Present value = #3 above * (annuity factor for 25 years @ 4% or 15.622) 25 years

Appendix L
Report on the Site Visit to the Soviet Union
June 28 to July 16, 3991

Introduction

On June 28, 1991, a team of specialists from the U.S. Department of Agriculture (USDA) traveled to the U.S.S.R. The objective of the site visit was to ensure that the information developed for the pest risk assessment on the importation of larch from Siberia and the Soviet Far East was current and valid. The USDA team included specialists from the Forest Service (FS) and the Animal and Plant Health Inspection Service (AJ'HIS):

- Borys M. Tkacz, Team Leader, Pest Risk Assessment Team, FS
- James F. Fons, Team Leader, Management Practices Team, APHIS
- William E. Wallner, Entomologist, Pest Risk Assessment Team, FS
- Donald J. Goheen, Plant Pathologist, Pest Risk Assessment Team, FS
- Robert D. Housley, Forester/Economist, Pest Risk Assessment Team, FS

From June 28 to July 16, 1991, the USDA team met with Soviet scientists and foresters to discuss the pest risk assessment and viewed forest pests, forest harvesting practices, and log handling procedures in the Soviet Far East and Siberia. Along with hosts from the U.S.S.R. State Forestry Committee and the Siberian Branch of the Academy of Sciences, the USDA team visited export facilities at the ports of Nakhodka and Vostochniy in the Soviet Far East, and specific cutting, upper landing, lower landing, processing, and shipping areas near Lesosibirsk, Shira, and Krasnoyarsk in Siberia. The USDA team also met with forest entomologists and pathologists at the V.N. Sukachev Institute of Forestry and Wood, the Siberian Technological Institute in Krasnoyarsk, and the Far Eastern Forestry Research Institute in Khabarovsk. The following trip report summarizes the findings of the USDA team about the pest risks associated with the importation of logs from the Soviet Far East and Siberia to the Western United States.

Consultations With Soviet Scientists

Soviet scientists were provided in advance with a list of the pests assigned priorities according to whether they would be hitchhikers on the bark, in the bark, or in the wood. Dr. Vladimir Ynnovsky (V.N. Sukachev Institute of Forestry and Wood, Krasnoyarsk) and Dr. Galina Urchenko (Far Eastern Forestry Research Institute, Khabarovsk) both indicated that there were no major gaps in the insect species selected. Dr. Yanovsky indicated that there are exceptionally few monophagous insects of larch. The one exception is *Xylotrechus altaicus*. Therefore, many of the insect pest species considered principally for larch could also be considered under other coniferous species. This underscores the validity of the approach taken by the Pest Risk Assessment Team, because similar pest problems would likely occur on pine, spruce, and fir. Dr. Yanovsky also indicated that of the 82 species of Scolytidae noted to infest conifers, 50 occur on larch. Of those that he considers technical pests, that is, those that destroy the quality of the wood, *Monochamus* spp. and Siricidae are the most important. Dying or dead trees are hosts for various *Ips* spp., *Tetropium* spp., and Buprestidae, such as *Phaenops guttatata*. On recently cut trees and seedlings, *Hylobius* and *Pissodes* spp. are expected to be the greatest problem. In his experience, during the growing season (late April to September) one can expect to find Siricidae and Cerambycidae attacking the tree within 1 hour after trees have been felled and yarded. This infestation starts principally in the upper yarding area, but proceeds after the trees have been moved to the lower yard. Members of the team consistently encountered adult Cerambycidae, as well as *Ips* spp., in both upper and lower landings and milling areas. Dr. Yanovksy also indicated that, because of the similarity in the climates of the Soviet Far East and the Pacific Northwest, several insect species in the Soviet Far East would be particularly dangerous if inadvertently introduced into the United States. He speculated that in addition to the known pest species identified by the Pest Risk Assessment Team and reaffirmed by his observations, several other species could also be important. Uncommon pest species in Siberia and the Soviet Far East that could become potential problems if they were inadvertently introduced and became established in North America would include *Dryocoetes* spp., *Tetropium* spp., *Pissodes* spp., and some Siricidac. According to Dr. Yanovsky, there are no reports of nematode-insect relationships on larch in Siberia and the Far East. Attempts have been made to determine whether *Monochamus urussovi* vectored nematodes, but this relationship could not be established. However, Dr. Yanovsky stated that this borer was capable of vectoring *Ceratocystis* fungi. This commonly occurs when maturating adults feed on twigs in the upper crown, where the pathogen is introduced and kills the small branches.

Dr. Galina Urchenko had an opportunity to review the list of major pests and indicated no major gaps in the species identified. She did, however, suggest that the coneworm (*Lasiomma* spp.) be added, because part of its fife cycle is spent under bark scales as pupae. This species had been eliminated from detailed consideration in the pest risk assessment process because it was concluded that it would be eliminated by surface treatments used for other hitchhikers.

Dr. Urchenko reported that the Soviet Far East has recently had a major outbreak of a budworm (*Choristoneura murianna*) on spruce. North America has at feast two species of spruce budworms, but this is indeed a different species. But, like *Lasiomma* spp., any fife stages present on the bark would be effectively controlled by proposed mitigation procedures for hitchhikers.

Dr. Yuriy Baranchikov from the V.N. Sukachev Institute of Forestry and Wood discussed problems associated with the larch bud gaff midge (*Dasineura laricis*). This insect is very common in the forest-steppe zone of Southern Siberia and causes gaffs to grow on larch shoots. The midge overwinters in gaffs of the previous year and could be transported with logs that have attached branches. Trees that have been pruned for cone collection will have gall midge on epicormic branches. Dr. Baranchikov mentioned that the North American tamarack (*Larix laricina*) planted in provenance plantings near Shira was heavily infested with the gaff midge, but that the gaffs did not produce midges.

Dr. Baranchikov also showed the team stands infested with Siberian silk moth (*Dendrolimus sibericus*) and larch casebearers (*Coleophora* spp.). Although mortality of larch due to *D. sibericus* is rare, attack by secondary insects can occur after repented heavy defoliation. The group observed a larch tree killed by *Ips subelongatus* following several years of heavy defoliation by the Siberian silk moth. Some of the trees infested with the moth exhibited pupal cases on the main bole, but Dr. Baranchikov said this was not common. According to him, the probability of transporting larch casebearers on fogs would be greater than that of the Siberian silk moth because the adult casebearers overwinter in cases on fhe main stem at branches. The species of casebearers in Siberia are different from the European one that was previously introduced into North America.

The Pest Risk Assessment Team's impression from examining Soviet forest pathology literature before the trip was that very few tree pathologists have done or are doing work in the Eastern U.S.S.R. Unfortunately, this proved to be true. The team was able to consult with forest pathologists from only two organizations and learned of one additional location where work on tree nematodes is being done (in Vladivostok). The Soviet pathologists the team consulted with believed that (1) knowledge of tree diseases of the Eastern Soviet Union is incomplete and much remains to be discovered; (2) literature on these tree diseases is sparse and difficult to access; (3) tree diseases are nevertheless numerous, widespread, and damaging in Eastern Soviet forests; and (4) many tree diseases could potentially be transferred on untreated fogs exported from Siberia and the Soviet Far East to North America.

The first Soviet pathologist visited was Dr. Pavel Aminev, head of the Department of Forest Protection in the Siberian Technological Institute, Krasnoyarsk. Dr. Aminev teaches and does research on forest pathology, entomology, and wildlife biology, though pathology is his principal area of expertise. He is very knowledgeable and has considerable experience in the field of forest pathology and would be an excellent person to involve in cooperative research programs with the aim of filling critical data gaps on Siberian pathogens. After examining the fist of pathogens that the team had already prepared for larch species, Dr. Aminev indicated that the list was quite complete. He suggested that the following listed pathogens were especially likely to be encountered in Siberia: *Meria laricis, Melampsoridium betulinum, Melampsora larici-populina, Melampsora larici-tremulae, Lachnellula willkommii, Fomitopsis officinalis, Fomitopsis pinicola, Ganoderma lucidum, Laetiporus sulphreus, Phellinus pini, Armillaria* spp., *Heterobasidion annosum,* and *Phaeolus schweinitzii.*

Dr. Aminev suggested adding *Cytospora abietis, Leptostroma laricinum,* and *Pholiota adiposa* to the list. I Jr also provided information on what he believes are the most significant diseases of pine, spruce, and true fir in Siberia. The team questioned him about various aspects of the biologies of what we considered to be especially significant larch pathogens in Siberia, and his answers revealed several important points: (1) the root disease pathogens *H. annosum* and *Armillaria* spp., in addition to being widespread and often damaging in Siberia, frequently act very differently there than in North America, suggesting that different biotypes or strains of the fungi may be involved; (2) though little studied and not referred to in the literature, staining fungi (probably *Ceratocystis* spp., *Leptographium* spp., and/or *Ophiostoma* spp.) are common associates of insects on Siberian conifers, including larch; (3) *Fomitopsis pinicola* is commonly encountered on living larch in Siberia; and (I) in Siberia, *Lachnellula willkommii* is rarely encountered on trees more than 20 years old.

At the Far Eastern Forestry Research lnstitute in Khabarovsk, the team consulted with Dr. Lyudmila Chelysheva and her son Dimitri, forest pathologists working mainly in a seedling and nursery pathology project. They examined the team's list of larch pathogens and, although they believed that it was mainly complete with respect to pathogens of older trees, they suggested adding some seedling pathogens that might be transported in soil on logs. 'J-heir list included, on larch, *Phasidium infestens* and, on all conifers, *Fusurium solani, F. culmorum, F. javanicu m, F. aquaeductum, F. gibbosum, F. avenaceum* var. *herbarum, F. oxysporum, F. oxysporum* var. *orthoceras, Cylindrocarpon magnusianum, C. destructans, C. tenue, C. didinum, Alternaria alternaria, Ulocladium atum, U. chartanum, Rhizoctonia solani, Pestalotiopsis quepinii, Phoma pomorum, P. herbarum, Microsphaeropsis olivacea, Torula herbarum, Cladosporium cladosporioides, C. herbarum, Aureobasidium* sp., and *Acrcmonium roseum*. They further indicated that *Lachnellula willkommii* occurs on trees of all ages in the Soviet Far East, especially in association with scars, and that root diseases are much more common in old stands than plantations in the Far East. Also at the Far Eastern Forestry Research Institute, the team was able to examine an extensive collection of decay fungus sporophores made by the institute's founder. The collection also confirmed the occurrence of many of the team's listed pathogens in the Soviet Far East.

Entomologists at the V.N. Sukachev Institute of Forestry and Wood in Krasnoyarsk reported finding associations between staining fungi and tree-attacking beetles in the Eastern lJ.S.S.R. As mentioned above, a *Ceratocystis*-like fungus was associated with *Monochamus* sp. in causing significant branch mortality of true firs. Entomologists also suggested that the risk of spread of the staining fungi associated with forest insects in the Soviet Far East might be great but was difficult to assess because of the current poor state of knowledge on the subject. Entomologists further suggested that there was a lack of pathology knowledge and research in the Eastern U.S.S.R. and that this was an arm where more emphasis should be placed.

Foresters at virtually all locations visited believed that some d iseases, especially wood decays, were important in causing losses in the Eastern Soviet Union. They reported losses in all tree species, with the greatest damage in spruce and true fir.

Pests of Concern

During site visits to forest stands and observations of timber harvesting and transport in Siberia and the Soviet Far East, the team obtained considerable information about pests that potentially could be imported on logs from the Soviet Far East and Siberia. Field observations confirmed that the forest pests of concern identified during the pest risk assessment process were accurate.

Forest Conditions

Although the team had the opportunity to visit many diverse forest stands, these represented only a small fraction of the vast forested area of Siberia and the Soviet Far East. The most spectacular pest-caused damage observed by the team during travels in Siberia and the Soviet Far East was the defoliation caused by the Asian gypsy moth (*Lymantria dispar*) between Khabarovsk and Nakhodka. Population levels of this moth were exceptionally high near the ports of Nakhodka and Vostochniy. Extensive mortality of Scots pine caused by an undetermined bark beetle was observed near Krasnoyarsk. As mentioned above, the team also visited larch stands infested with the Siberian silk moth and larch casebearer near Shira in Siberia.

The team visited mature forests and plantations in several areas, especially near Black Lake and Shira in Siberia. Mature stands were, in the team's opinion, being seriously affected by several pathogens. Root diseases caused by *Heterobasidion annosum* and *Armillaria* spp. were widespread. In the stands visited, *H. annosum* was causing substantial mortality in true firs. Examination of cut stumps showed that it also was causing significant amounts of butt and stem decay in true fir, spruce, pine, and larch. *Armillaria* sp. was observed killing true fir, spruce, and Scots pine. Cut stumps of true fir and spruce also showed substantial amounts of *Armillaria*-caused butt and stem decay. As reported in the literature and indicated by Dr. Aminev, both root disease organisms appeared to be acting differently in the Siberian stands than their counterparts in Western North-America. Indicators (such as fruiting bodies) of heartrot decays were not common on tree trunks in examined stands, but some conks of F. *pinicola* and one of *F. officinalis* were observed. Stem and branch killing caused by a rust fungus (probably *Cronartium flaccidum*) was observed on Scots pine, and fir broom rust (caused by *Melampsorella* sp.) was very common on true fir. A branch flagging that might be caused by a *Cytospora* sp. was also common and widespread on true fir. Foliage pathogens were common but did not appear to be particularly damaging in the stands examined.

Plantations that the tram visited appeared to be remarkably healthy. This may be in part the result of the emphasis on stump removal and machine planting in the areas examined. Such procedures could greatly reduce root pathogen inoculum. Dr. Aminev indicated that he had observed plantations in Siberia with considerable root-disease-caused damage. These may have been established in a different fashion. The team did not have an opportunity to examine either very young plantations or plantations over about 25 years of age. Foresters who met with the team reported that in the Eastern U.S.S.R., between 20 and 30 percent of areas harvested are replanted. Other areas are allowed to regenerate naturally (and are often regenerated first with hardwoods). Planning regarding regeneration of units is done in Moscow.

Pests in Logs

The team had ample opportunities to examine fogs at upper and lower landings, at mills, in fog rafts, and on railroad cars. The most commonly encountered insects on fogs were two bark beetles, *lps subelongatus* and *lps sexdentatus,* and two Cerambycids, *Monochamus urussovi* and M. *sutor*. These insects were active as adults and larvae under the bark of fogs. These species are considered to be very aggressive in attacking recently yarded or cut timber and are extremely strong flyers, which enables them to infest yarded timber from distances in excess of several kilometers. All of these species were observed in tfte Krasnoyarsk region infesting principally larch, pine, and spruce fogs at the upper landing and lower landing, as well as in stored logs at mills destined for processing. These same species were considered by the pest risk assessment to be among the most important potential pests associated with the bark or in the wood.

The tram noted several points about tree diseases:

(1) Many fogs (about 10 percent of those examined) exhibited some amount of heartrot decay, which was frequently extensive.

(2) The most commonly observed decay was red ring rot (caused by *Phellinus pini*), which was observed on all conifer species and was not associated with fruiting bodies, although punk knots were observed.

(3) White rot decays caused by *Heterobasidion annosum* and *Armillaria sp.* were also common; the former in logs of true fir, spruce, pine, and larch, and the ratter mainly on spruce and true fir logs. The team did not see fruiting bodies of these fungi on logs.

(4) Brown cubical rot that could have been caused by any of several fungi (especially *Phaeolus schweinitzii, Fomitopsis officinalis,* and *F. pinicola*) was also encountered with some frequency. Fruiting bodies of *F. pinicola* were observed on decked logs (orientation of conks indicated that they had been formed after logs were decked).

(5) Fruiting bodies of *Pholiota* sp. and *Pleurotus* sp. were observed on some decked logs.

(6) Staining fungi were extremely common on pine logs and processed lumber as well; they were also seen on logs of true fir, spruce, and larch but were not as dramatic (probably because the fungi affecting these species cause brownish rather than blue stains); staining was associated with beetle infestation of logs.

(7) Though there was considerable variation from place to place, many decked and transported logs had substantial amounts of soil adhering to them and many also had foliage still attached (this was especially true of larch logs-the common formation of very short epicormic shoots on Siberian larch makes removal of all foliage particularly difficult with this species); therefore, a special effort would have to be required to eliminate soil and foliage from logs to be exported to the United States.

Timber Harvesting and Transport

The timber harvesting procedures utilized by the Soviets are limited by weather conditions. Harvesting during May through August is difficult in many areas because of wet soil conditions. Therefore, much of the harvesting and skidding to upper landings is done from November through April, when soils are frozen. In the case of logging operations some distance from transportation routes, the logs are skidded, with their crowns still attached, and yarded at upper landing areas that may be 500 to 1,000 meters from the cutting unit. Logs can remain at the upper landings all summer and may not be transported down to the lower landing until October or November. Where summer logging is feasible, logs can arrive at the lower landing as soon as several days following cutting. Typical operations will store logs at the lower landing for 2 to 4 months before further processing. Logs are delimbed, scaled, bucked, graded, and sorted at the lower landings.

In the case of operations close to rivers where log rafting is conducted, logs are yarded on the banks of the river and are floated once the ice on the river breaks up. During the winter, some of the timber may be transported on trucks driven down the frozen river for processing.

The Soviet logging and transportation system allows many logs to spend considerable time in deck; in the woods, in trains or log rafts in transit, or in log piles at the mill. In many instances, logs will be in the vicinities of many other logs and often close to forests for long time periods. This allows previously uninfested logs to become attacked by insects or diseases during transport and storage. Pests that could infest these logs include hark beetles, borers, and associated staining fungi. Major shipping areas that the team visited in the Nakhodka area are located close to forested areas. Although the logs are sorted by quality before shipment, the team noticed that a great deal of cull material was shipped over long distances for chipping and fuel use. Unfortunately, much of this cull material was sent to areas very close (less than a mile) to the shipping centers. Thus, logs at the seaports still have a high exposure to insects and pathogens. Though the Soviets have their own plant health quarantine service, consultation with their representatives indicated that workload was very high, training level regarding forest pests was low, and emphasis was on keeping pests out of the U.S.S.R. rather than detecting pests on export material. Quality control varies greatly in the Eastern U.S.S.R. The team saw some excellent logs that had been very well handled, as well as logs that were in very poor condition, dirty, and with foliage still attached. No assumptions should be made about the general condition or cleanliness of logs from Siberia and the Far East.

Conclusions

During the site visit to the U.S.S.R., the USDA team gathered information on the pests associated with logs by consulting with Soviet specialists and foresters as well as by actually visiting forests, landings, mills, and transportation and shipping facilities. Observations and consultations strongly supported the findings and conclusions of the pest risk assessment on the importation of logs from Siberia and the Soviet Far East. The team's findings during the site visit consistently indicated that importing untreated logs from the Eastern U.S.S.R. to the Western United States could indeed pose a substantial risk to the forests of North America because of the probability of introduction and establishment of new or different forest tree insects and pathogens.

☆U.S. Government Printing Office : 1991 282-960/40574