Pathways to America

Forest Susceptibility

Forests cover approximately one-third of the land area in the United States: 1.15 million square miles (USDA APHIS and Forest Service, 2000). These forests are comprised of approximately 500 species of trees plus thousands of identified species of terrestrial and aquatic animals and non-woody plants (USDA APHIS and Forest Service 2000) and likely thousands of undescribed species (http://www.discoverlife.org). Representatives of almost every type of vegetation that occurs worldwide can be found within the United States or its protectorates (*cf.* USDA APHIS and Forest Service, 2000). Additionally, many exotic plant species are grown for horticulture, Christmas trees, and other uses. Approximately 4,000 exotic plants are established outside cultivation in the United States [Kartesz, 1999; United States Geological Survey (USDI USGS), 1998]. This combination of native and exotic species across the United States provides ample opportunities for imported pests to find suitable hosts (USDA APHIS and Forest Service, 2000; Niemala and Mattson, 1996). The more than 400 exotic insects and pathogens that are permanently established in North American forests and woodlands demonstrate the vulnerability of these forests to exotic organisms (Mattson *et al.*, 1994; Liebhold *et al.*, 1995; USDA APHIS, 2000).

Forest ecosystems vary in their susceptibility to exotic pests. Forests comprised of relatively few trees, *e.g.*, forests dominated by Douglas-fir in the Pacific Northwest, would be more easily damaged by a species-specific pest than eastern forests, which have more diversity. Conversely, eastern forests provide greater opportunities for exotic pests to find suitable hosts. Damage to host species may range from negligible to potential extinction. The impact of some exotic pests is noticeable in a relatively short period after introduction, *e.g.*, Asian longhorned beetle, or can be delayed as with Asiatic oak weevil (Triplehorn, 1955; Roling, 1979; Stanton, 1994). Changes in host preference also can occur. Pear thrips were introduced to the country in 1900 and were spread throughout the country by the orchard industry. Only in the latter portion of the 20th century was pear thrips damage noted in a variety of forest tree species. Although some generalizations can be made, there is an uncertainty about how an exotic species will react in a new environment, what impact it will have on host species, and when it will be recognized as a problem species (USDA APHIS and Forest Service, 2000).

International Trade and Exotic Pest Prevention

To date, 72 and 18 percent of the established exotic forest insects are from Europe and Asia, respectively (USDA APHIS and Forest Service, 2000), reflecting past trade patterns and ecological similarities. In the 16 years 1985-2000, APHIS intercepted 6,827 bark beetles that were of potential concern as forest pests. While the intercepted beetles came from 117 countries, more than 43 percent of the beetles were in shipments from Western Europe. Another 8 percent (500 beetles) were from Russia and China. Other major source countries were Mexico, Jamaica, and India (Haack 2002). International trade is increasing rapidly with importations from a greater variety of countries. United States' imports in 2001 were 28 times greater than in 1970; they rose 82 percent just since implementation of the World Trade Organization in 1994 (U.S. Trade Representative 2002). Budgets for APHIS, the first line of defense against exotic pests, have not grown correspondingly. Nor has the agency rapidly adopted new, more effective approaches to excluding exotic pests. Therefore, the probability for importing additional exotic pest species and genotypes from European and Asian ecosystems and new pest species from the ecosystems of our expanded trade partners has significantly risen.

Primary Pathways of Introduction

Beetle cartoon by Steve Greenberg, 1999. Reprinted by permission of the Seattle Post-Intelligencer

Exotic forest pests can travel to the United States in many ways, ranging from importation of logs with bark to smuggled budwood for grafting. With very few exceptions (European gypsy moth was purposely brought to this country), exotic forest pests are transported as unwanted "hitchhikers" on imports of live plants or minimally processed wood, including wood used as packing materials. We will focus our discussion on three modes of introduction or "pathways" that have been shown to have a high probability for introducing forest pests: 1) nursery-related materials, 2) unprocessed wood (logs, lumber, railroad ties, and chips), and 3) crates, pallets, and dunnage. During the 16-year period 1985 - 2000, 20 percent of APHIS' interceptions of exotic bark beetles (*Scolytidae*) occurred on imports of plants or food; 0.05 percent on imports of logs or lumber; and nearly 72 percent on wood packaging (Haack 2002).

APHIS Interceptions of Bark Beetles on a Variety of Imported Goods

During the period 1985 - 2000, APHIS recorded 6,825 interceptions of exotic bark beetles (*Scolytidae*) from 117 countries (Haack 2002). The top 10 countries were

Italy	1,090	16%
Germany	756	11%
Spain	457	7%
Mexico	425	6%
Jamaica	398	6%
Belgium	352	5%
Russia	247	4%
France	261	4%
China	255	4%
India	224	3%

The most common vectors for these beetles were SWPM (72 percent of interceptions) and food or plants (20 percent of the interceptions).

crates	32% of the interceptions; from 57 countries
dunnage[1]	27% of the interceptions; from 57 countries
seed	11% of the interceptions; from 57 countries
unspecified wood	7.5% of the interceptions; from 50 countries
fruit	6% of the interceptions; from 51 countries
pallets	5% of the interceptions; from 31 countries

[1]Dunnage is defined by the UN Food and Agriculture Organization as "wood materials used in (*sic*) wedge or support cargo"; North American Plant Protection Organization, Draft International Standards for Phytosanitary Measures, Import Requirements for Non-Manufactured Wood Packing Material, April 1999.

(1) Nursery-Related Materials

Legal or illegal importation of nursery materials (*e.g.*, budwood, seeds, plants) from foreign countries has been repeatedly proven to transmit devastating pests (Kenney and Bagenski, 1998; National Plant Board, 1999). Since the late 1800s, several of the most damaging forest pests, *e.g.,* the chestnut blight fungus (Howard, 1898; Metcalf and Collins, 1909), as well as a wide variety of agricultural and horticultural pests (Haleamau, 1998; Regelbrugge, 1998; Office of Technology Assessment, 1993; Society of American Florists, 1998; Ostry, 2001) have been imported on nursery stock. Despite the early, specific warnings that importations of nursery stock are the most dangerous vector for transporting exotic pests (see, *e.g.*, Howard 1898) and the current best efforts of APHIS, this pathway remains very active. The citrus longhorned beetle, Japanese cedar longhorned beetle, and sudden oak death have probably entered the country on nursery stock during the 1990s.

Forest Pests Probably Introduced on Imported Horticultural Stock or Seeds

Pest	Host(s)
chestnut blight	American chestnut, Allegheny and Ozark chinkapins
Phytophthora cinnamomi	American chestnut, Allegheny and Ozark chinkapins, variety of other species in nursery and field situations
white pine blister rust	Five-needle pine species
Port-Orford-cedar root disease	Port-Orford-cedar
balsam woolly adelgid	Balsam and Fraser firs
larch casebearer	Eastern and western larches
beech scale	American beech
butternut canker	Butternut
dogwood anthracnose	Flowering and Pacific dogwoods
sudden oak death	Oaks and other hardwood trees and shrubs
Citrus longhorned beetle	Variety of hardwood species

United States plant imports are on the rise: from about 456 million plants in 1993 to more than 694 million plants in 1999 [APHIS Federal Register July 23, 2001 (Volume 66, Number 141)]. For example, imports of bonsai shrubs and trees have risen from fewer than 600 plants in 1993 to 54,749 plants in 1998 [Federal Register April 20, 2001 (Volume 66, Number 141)]. These growing imports represent a wide variety of plants; in 2000, the U.S. imported 863 genera of plants (Meghan Thomas, APHIS, personal communication). This growing variety shipped from a larger number of countries increases the variety of pests that could be introduced [Federal Register July 23, 2001 (Volume 66, Number 141)]. Even plants shipped from Canada, our largest supplier, can transport potentially damaging pests, since Canadian officials rely on their colder climate to control pests that can be harmful in warmer parts of the United States (National Plant Board, 1999).

Seed imports have also risen, from 8.7 million kilograms in fiscal year 1997 to 12 million kilograms in fiscal year 1999 [Federal Register July 23, 2001 (Volume 66, Number 141)]. Imported seeds also can transport invertebrate pests and pathogens (Roques, 2001), including such pathogens as pitch canker (Fraedrich, 2001).

During the ten-year period 1990-1999, 35-40 percent of all plant-feeding arthropods (that APHIS considers to pose a quarantine threat) intercepted by APHIS personnel at the ports were found on imports of plants, bulbs, roots, or stems or leaves used for propagation. Only some unspecified proportion of these arthropods were pests of trees or woody shrubs. These 14,878 intercepted pests were from 85 countries of origin (National Research Council, 2002a). A separate analysis of interceptions during the 16-year period 1985-2000 determined that APHIS

intercepted 1,979 bark beetles on imports of food or plants: 38 percent of these beetles were in shipments of seeds, 20 percent on fruit, and another 12 percent were on stems, leaves, roots, or flowers (Haack, 2002).

(2) Minimally Processed Wood

A second high-risk vector for exotic pests is imports of minimally processed logs, lumber, and wood, including wood chips. Among the types of pests likely to be introduced via this pathway are larval and adult phases of wood borers and bark beetles, and deep-wood pathogens. The wood borers and deep-wood pathogens are especially hard to detect, as they reside within the imported wood. Bark beetles and some plant pathogens, *e.g.*, Dutch elm disease, are frequently transported on wood with some portion of bark attached. Once imported, bark beetles typically have a high capacity for dispersal, colonization, population increase, and spread (USDA APHIS, and Forest Service 2000).

Transport of pests has also been documented in shipments of wood chips. More than 100 species of fungi in 82 genera have been identified from piles of chips (Dwinell, 2001b). The pinewood nematode from North America has been repeatedly intercepted in shipments of North American wood chips to Nordic countries (Dwinell and Lehman In press; Magnusson *et al.*, 2001). There is dispute, however, as to whether large insects can survive chipping and transport; documentation of insects in wood chips is incomplete (Magnusson *et al.*, 2001).

Increased importation of logs, lumber, railroad ties, and wood chips.

Despite its extensive natural forests and plantations, the United States is the world's largest importer of forest products.[1] Most imports are of softwood (conifers): 96 percent of lumber, 86 percent of logs, and 99 percent of chips (Howard, 2001). Between 1989 and 2000, imports of softwood logs rose 17-fold, from 104,000 m^3 to 1,732,000 m^3; and imports of hardwood (usually deciduous) logs almost tripled, from 83,000 m^3 to 240,000 m^3. Imports of softwood lumber increased by 29 percent, from more than 35 million m^3 to more than 45 million m^3; and imports of hardwood lumber more than doubled, from 824,600 m^3 to 1,682,000 m^3.

Records of wood chip imports began in 1991. Imports of softwood chips were at 605,157 dry metric tons in 1991, peaked at 747,518 dry metric tons in 1996, then declined to only 85,837 dry metric tons in 2001. Imports of hardwood (usually deciduous species) chips increased by a factor of 25, from 3,500 metric tons in 1991 to 72,000 dry metric tons in 2001 [www.fas.usda.gov/ustrade]. While shipments of chips from Canada and Chile usually enter the country at Pacific ports, chips from tropical countries arrive at Gulf Coast ports (USDA APHIS, 1998b; Magnusson *et al.*, 2001), thereby facilitating exotic pests' access to the region of greatest commercial forestry in the United States.

The vast majority of these wood imports were from Canada: in 2000, Canada supplied 94-99 percent of imported logs (hardwood and softwood), softwood lumber, railroad ties, and wood chips. Canada also supplied more than 70 percent of the imported hardwood lumber. Wood imported from Canada carries little risk of introducing exotic pests, since U.S. and Canadian forests are largely contiguous.

Imports of minimally processed wood products from countries other than Canada constitute a significant pest risk. The risk to the continental United States is primarily from other temperate countries, although pests from high elevations in tropical countries could pose a risk to temperate countries. Imports from lower elevations in tropical countries pose a threat to forests in Hawaii and Puerto Rico.

Suppliers shift rapidly due to market conditions. These shifts make it difficult to predict either the quantities of wood that will be imported or, more importantly, the countries which will supply the wood. However,

[1]Unless otherwise specified, trade data cited in this chapter are from USDA Foreign Agricultural Service, www.fas.usda.gov/ustrade.

both New Zealand ["Hodgson Speaks to Forestry Conference" ForestPacRim: NZ Forest Minister addresses Forestry conference Date: 10/5/2000] and South American countries (USDA Forest Service, 2001) expect to greatly increase wood exports from existing plantations in coming decades. As long as APHIS continues to rely on country- or region-specific risk assessments to develop regulations, it must prepare such studies more quickly on the full range of suppliers, both those now shipping to the United States and those which might in future.

Softwood and hardwood logs. Imports of softwood logs from principal temperate trading partners other than Canada rose five-fold between 1989 and 1994 (from 21,600 m^3 to 111,000 m^3), then fell to 38,000 m^3 in 2001. The principal non-Canadian supplier is New Zealand: imports peaked at 102,542 m^3 in 1994, then fell steadily to less than a quarter of that volume. The lesser volumes imported from Chile peaked in 1989 and 1997. Even smaller-volume imports from Mexico peaked in 1995. Mexico had almost disappeared from the market by 2001. In contrast, imports from Europe spiked in 2000 to levels exceeding New Zealand's.

Imports of hardwood logs from temperate trading partners other than Canada grew from 3,444 m^3 in 1989 to 6,433 m^3 in 2001. Europe (including Russia) has been the principal supplier after Canada; Chile and, recently China, have supplied small quantities.

Softwood and hardwood lumber. The United States imported 3.6 million m^3 of softwood lumber from countries other than Canada in 1989; in the mid-1990s this volume fell to about 1 million m^3, then rose to 2.9 million m^3 in 2001. Europe has steadily supplied about one-third of the imports. Imports from New Zealand, Argentina, and Brazil grew rapidly during the period, while imports from Chile and Mexico fell.

The United States imported over 118,000 m^3 of hardwood lumber from Europe and Chile in 1989. These imports collapsed to just 4,600 m^3 in 1992, then rose to somewhat less than 20,000 m^3. By 2000, imports had reached 44,000 m^3, with Europe usually supplying about two-thirds of the total. Imports of hardwood lumber from non-Canadian sources in 2001 exceeded imports of softwood logs from non-Canadian sources in that year: this pathway deserves greater scrutiny.

Railroad ties. Railroad ties are large-dimension lumber and thus provide a haven for a variety of forest pests. Imports of railroad ties fluctuate from year to year. Peak imports—in excess of 70,000 m^3—occurred in 1993, 1996, and 1998; lows of 28,000 - 29,000 m^3 were observed in 1994 and 1995. Imports in 2000, 57,300 m^3, were in the middle of this range. Imports fell further to 38,703 m^3 in 2001. While most railroad ties are imported from Canada, other countries enter the market in years of relatively high demand. Most of the non-Canadian ties came from West Africa, but Mexico exported ties from 1994 to 1998; the peak was 30,000 m^3 in 1996.

Wood chips. While Canada dominates U.S. chip imports in most years, other countries provided significant quantities of softwood chips in the middle 1990s. Thus, Mexico supplied approximately half of U.S. imports of softwood chips in 1993 and 1994; Chile supplied more than 40 percent of imports in 1995 and 1996 and 28 percent in 1997. Brazil supplied 21,600 metric tons in 1995 and 10 percent of U.S. imports in 1998. Europe is a distant second to Canada in supplying hardwood chips, shipping between 2,000 and 4,000 metric tons each year.

Minimizing the pest risk

In the early 1990s, concerns about the risks associated with wood imports prompted APHIS to ask the USDA Forest Service to carry out several risk assessments with the goal of determining that risk and the appropriate phytosanitary measures to meet it. These studies analyzed the potential threat of pest introductions from Siberia (USDA Forest Service, 1991), New Zealand (USDA Forest Service, 1992b), and Chile (USDA Forest Service, 1993). Later risk assessments examined imports of pine and fir from Mexico (USDA Forest Service, 1998a) and plantation-grown *Eucalyptus* from South America (USDA Forest Service, 2001). Contrary to expectations, however, these countries have not become the dominant non-Canadian source of imported wood. Europe, Brazil, and Argentina have become increasingly important sources of softwood lumber, but APHIS has never conducted risk assessments on logs or lumber from Europe or pine from Argentina or Brazil. As noted above, rapid shifts in suppliers spurred by market forces have undercut the value of country-specific risk assessments.

Pests on softwood logs and lumber. North American forests have been demonstrated to be vulnerable to pests from Europe. Although many European pests have already been introduced to the United States, additional potentially troublesome organisms could be introduced from that continent. Among the damaging pests that could be introduced on softwood logs imported from Europe, including Russia, are the European spruce bark beetle and the associated fungi, and the Mediterranean pine engraver beetle. Imports of lumber from Russia might include lumber originating in Siberia that could transport Asian gypsy moth, nun moth, large pine weevil, and various Asian wood-boring beetles in the *Monochamus* and *Hesperophanes* genera.

New Zealand was the most important non-Canadian supplier during the decade, and it might become more important in the future, as New Zealand expects production to double over the next 20 years ["Hodgson Speaks to Forestry Conference," ForestPacRim: NZ Forest Minister addresses Forestry conference Date: October 5, 2000]. The most damaging pest associated with plantation-grown pines in New Zealand is the *Sirex* woodwasp and its associated *Amylostereum* fungus. A second potential introduction is the red-haired pine bark beetle, which has already been introduced into New York (Haack *et al.*, 2002). The *Sirex* woodwasp and associated fungus also could be introduced on coniferous logs or lumber imported from South America. Thirteen other pests of pines or firs posing a "moderate" or "high" risk to forests throughout the "lower 48" states have been identified as possible hitchhikers on logs from Mexico (USDA Forest Service, 1998a).

Pests on hardwood logs and lumber. Imports of hardwood lumber from China (*ca.* 6,000 m^3 of lumber in 1999) could transport various wood-boring beetles, including the Asian longhorned beetle. Fortunately, the volume of wood imported from China has since fallen, constituting only 1,109 m^3 in 2001 [www.fas.usda.gov/ustrade]. China also supplies a variety of smaller wooden articles. Pests have been found in baskets, bamboo garden stakes, and artificial Christmas trees shipped from China. Examples of damaging pests that could be introduced on wood articles imported from China include (*cf.*, USDA Forest Service, 1991b) Asian gypsy moth and nun moth, Siberian silk moth, large pine weevil, wood boring wasps in the *Siricidae* family, and (USDA APHIS 1998c) wood-boring beetles in the *Ceresium*, *Monochamus*, and *Hesperophanes* genera, including the Asian longhorned beetle.

(3) Solid Wood Packing Materials

Raw wood used as packaging material (called solid wood packing material, or SWPM), including pallets, crates, wooden spools for cable, and dunnage, is an especially dangerous vector for importing pests (USDA APHIS and Forest Service, 2000). No agency has attempted to quantify how much wood packaging comes into the country in any given year. Estimates of the proportion of U.S. imports contained in solid wood packaging vary from 15 percent (Berven, 1999) to 90 percent (Peters, 1999), although most official data suggest that approximately 50 percent of maritime shipments and 9 percent of air shipments use SWPM (USDA APHIS and Forest Service, 2000). The United States imports between 14 million ("William Booth, "Where Sea Meets Shore, Scenarios for Terrorists." *The Washington Post,* January 3, 2002; Bill Miller, "Customs Chief Seeks Checks Overseas of U.S.-Bound Cargo," *The Washington Post*, January 18, 2002) and 30 million (Robert Kanter, Port of Long Beach, personal communication) shipping containers; if only one-half contained SWPM, that represents 7 to 15 million loads of SWPM.

Exotic pest introductions via solid wood packaging are a serious threat due in part to the rising volume of imports, and in part to distribution patterns within the United States. Since the 1970s, SWPM has been the vector for 85 percent to 97 percent of the forest pests detected by APHIS during inspections (Williams and La Fage, 1979; Haack and Cavey, 1997; USDA APHIS and Forest Service, 2000). Over the 16-year period 1985-2000, 72 percent of the 6,825 bark beetles (*Scolytidae*) intercepted by APHIS were hitchhiking on SWPM (Haack 2002).

SWPM is imported from nearly every trade partner to every part of the United States. As international trade increases, there is a corresponding increase in the amount of wood packaging entering the country (USDA APHIS and Forest Service, 2000). The risk is highest for crates, intermediate for dunnage, and lowest for pallets. Haack and Cavey's 1997 reviews of APHIS interception data for all potential forest pests found that 45 percent of 6,952 insect interceptions were on crates; 33 percent on dunnage; and only 6 percent on pallets. Considering only

bark beetles, but over the longer period 1985-2000, Haack (2002) found 32 percent in crates, 27 percent in dunnage, and 6 percent in pallets.

Construction of SWPM can occur in any country, and pieces with attached bark may be included. Unfortunately, some exporters have purposely constructed SWPM so as to conceal wood with attached bark from inspectors, *e.g.*, on the inside of spools (Dawson *et al.*, 1997). Durable SWPM products, *e.g.*, pallets, are often recycled after initial use. For example, a pallet built in China would be loaded with goods, enclosed within a shipping container, arrive in a United States port, and be transported to a factory in an interior city. After the pallet was unloaded, it would be stored with other pallets until collected by a pallet recycling company and eventually used in a shipment to another country. During these months, exotic pests can emerge.

Proper inspection of SWPM by APHIS is virtually impossible for a variety of reasons that are listed below (*cf.* USDA APHIS and Forest Service, 2000):

- The sheer volume of imports using SWPM prevents APHIS from inspecting individual pallets, crates etc.
- Containerization of shipments limits access to SWPM by inspectors.
- SWPM is not identified on the shipping manifest, so APHIS does not know if it is present, in what form, *e.g.*, pallets, crates etc., and if it has been sterilized.
- SWPM can accompany a wide variety of goods; one survey found SWPM with more than 250 different commodities.
- SWPM can be made from virtually any species of woody plant, and without sterilization information, an accurate assessment of risk is impossible.
- Solid wood can conceal deep-wood pests.
- Since SWPM often accompanies imported goods to their final destination, any associated pests can be taken to virtually any location within the United States.
- The practice of reconditioning and reusing damaged SWPM results in further distribution and opportunity for pests to mature and escape.