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Invasive Insects, Pathogens and Plants in Western and Pacific Island Forests

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List of Acronyms and Abbreviations

ALB	Asian longhorned beetle
APHIS	Animal Plant Inspection Service (USDA)
ARS	Agriculture Research Service (USDA)
BLM	Bureau of Land Management (USDI)
BOR	Bureau of Reclamation
CAPS	Cooperative Agricultural Pest Survey Program
CLHB	Citrus longhorned beetle
CSREES	Cooperative State Research Education and Extension Service (USDA)
DED	Dutch elm disease
DOD	Department of Defense
EA	Environmental Analysis
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration (USDOC)
FHM	Forest Health Monitoring
FHWA	Federal Highway Administration (USDOT)
FICMNEW	Federal Interagency Committee for the Management of Noxious and Exotic Weeds
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FS	Forest Service (USDA)
FWS	Fish and Wildlife Service (USDI)
FY	Fiscal Year
GIS	Geographic Information System
GPS	Global Positioning System
HEAR	Hawaiian Ecosystems at Risk Project
IPM	Integrated Pest Management
IPPC	International Plant Protection Commission
MOU	Memorandum of Understanding
MMS	Minerals Management Service
NAPPO	North American Plant Protection Organization

NAWMA	North American Weed Management Association
NEPA	National Environmental Protection Act
NFS	National Forest System
NGO	Non-Government Organization
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service (USDI)
NRA	National Recreation Area
NSF	National Science Foundation
OMB	Office of Management and Budget
POC	Port-Orford cedar
USAID	United States Agency for International Development
USCS	United States Coast Guard
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USDOT	United States Department of Transportation
USGS	United States Geological Survey (USDI)
WFLC	Western Forestry Leadership Coalition
WSCLB	White spotted citrus longhorned beetle
WTO	World Trade Organization

Executive Summary

This report to the Western Forestry Leadership Coalition has three purposes:

- Review the status and impacts of invasive insects, pathogens, and plants in Western and Pacific Island Forests.
- Review the National, Federal, State and Territorial responsibilities.
- Identify opportunities for WFLC to address invasive species issues

America's forests are under invasion. Our rural and urban forests have fallen victim to introductions of exotic insects, diseases, and noxious weeds/invasive plants. The primary reasons for this invasion are human immigration, ease of travel, and global trade.

Invasive species are organisms that have been introduced into an environment in which they did not evolve and whose introduction causes or is likely to cause economic or environmental harm. Typically they have few or no natural enemies to limit their reproduction and spread.

Staggering Impacts of Invasive Species

Economic:

- The economic impact caused by all invasive species in the U.S. is estimated at over $137 billion per year. Forests that are damaged by invasive species will yield far fewer goods and services (e.g., timber, recreation, wildlife).
- The cost of managing invasive species is very high. For example, during 1990 – 2001, the Federal/State cost-share program for gypsy moth suppression in the eastern U.S. ranged between $4.8 and $22.5 million per year and totaled $123.3 million.

Ecological:

- Invasive insects and pathogens can rapidly establish in a forest, weaken or kill native plants, degrade wildlife habitat, alter nutrient cycles, and threaten basic ecosystem structure and functions. Pathogens of unknown origin such as sudden oak death and insects such as the Asian Longhorned beetle pose a new imminent threat to many urban and rural forests in the West.
- Invasive plants can cause great harm to forest ecosystems by altering basic ecological processes such as the role of fire.

Social:

- Societal impacts include the annoyances associated with the presence of large numbers of invasive species (e.g., insects) especially in urban or recreation areas.

- The larvae of some invasive insects have hairs that cause skin irritation and defoliation and other types of damage are unsightly.

- Invasives threaten extinction of native plants used for current and/or future medicinal purposes and traditional uses.

Complex National, Federal, and State Responsibilities

Executive Order 13112, signed by President Clinton on February 3, 1999, established the National Invasive Species Council (NISC) to provide leadership and coordination regarding invasive species management and to prepare a National Invasive Species Management Plan (available online: http://www.invasivespecies.gov)

Much of the responsibility for invasive species management is assigned to USDA. Existing Federal laws give certain invasive species responsibilities and functions to the Environmental Protection Agency and to other agencies within the Departments of Commerce, Defense, Transportation, and Interior.

State agriculture departments, rather than State forestry agencies, are usually the lead for invasive species management.

Opportunities for WFLC to Address Invasive Species Issues

These opportunities include:

1. Increase awareness of invasive species and their impacts at all levels, including Congress and State legislatures. Make use of existing capabilities within the WFLC membership, the media, non-government organizations, and with other partners to publicize the invasive species issue.

2. Promote partnerships between Federal and State agencies and private landowners and NGO's (especially at the field level where pest management activities are conducted) to ensure that infestations are treated effectively.

3. Facilitate identification of gaps in authorities and responsibilities. If questionable authorities exist, encourage appropriate action (e.g., new legislation, MOUs) to enable full implementation by all partners.

4. Support Integrated Pest Management as the guiding framework for all WFLC member organizations.

5. Support the concept of cross-cut (multi-agency) budgets for management of invasive species as proposed by the National Invasive Species Council.

6. Support and utilize new research and technology/methods as part of a sound IPM program directed against invasive species.

7. Promote the use of national data and mapping standards to facilitate information sharing between WFLC members and other organizations on the status of invasive species and progress of pest management programs.

Introduction

America's forests are under invasion. Since the earliest days of European colonization, our forest and woodland ecosystems have fallen victim to introductions of exotic insects, disease causing agents, plants and animals.

The primary reasons for this invasion is human immigration and trade. Early settlers to this country brought with them seeds and plants from their native lands. They planted the seeds at their new homesites. The seeds of grains or other agricultural crops they brought with them were sometimes contaminated with seeds of other plants, pathogens or insects. Some of these became established and spread over large areas, displacing the native vegetation. Some introduced trees also escaped cultivation and displaced native trees. Insects and disease causing organisms arrived on plants, imported logs, packing materials and dunnage. They established themselves on native hosts that did not co-evolve with these agents. In the absence of natural enemies to regulate their numbers, they became widespread and damaging. Today, the rate of introduction of invasive species is higher than ever, due to a global community with increased world trade and a highly mobile human population capable of traveling to the far corners of the world in high-speed aircraft in a matter of hours.

Some invasive species have been with us for so many years that we have almost forgotten their origins. The tumbleweed, a plant that has become a symbol of the old West, was introduced by Russian immigrants who brought with them flaxseed contaminated with tumbleweed seeds (USDA Forest Service 1937) (Fig 1). Moreover, few people realize that the ubiquitous dandelion they painstakingly remove from their lawns each summer is a plant introduced by European colonists in the 1600s as a salad green (Westbrooks 1998).

What is an invasive species? Invasive species are referred to as non-natives, exotics, aliens, non-indigenous harmful species, weeds, and by a host of other names. All these definitions incorporate a basic concept: invasive species are organisms that have been introduced into an environment in which they did not evolve and whose introduction causes or is likely to cause economic or environmental harm (NISC 2001). Typically they have few or no natural enemies to limit their reproduction and/or spread. Moreover, the hosts (e.g., native trees) for invasive insects and diseases often have not co-evolved with the introduced pest. Consequently native hosts are often much more likely to be damaged or killed by the invasive pest.

Today, invasive species cause millions of dollars worth of damage to croplands, rangelands, pastures, wetlands, waterways and forests. In addition, they have caused ecological and societal impacts. Invasive species do not recognize land ownership boundaries and invade Federal, State, and private lands with equal vigor wherever they find suitable habitats. Moreover, the U.S. is not the only victim of the exotic species invasion. This is a global problem. Invasive species such as cypress aphid in Africa, European wood wasp in Australia, New Zealand, South America and South Africa, cypress canker in Mediterranean Europe, the water mold, *Phytophthora cinnamomi* in

Australia and Portugal and prickly pear cactus in Australia are just a few examples. Species indigenous to the U.S., which are considered to be more or less innocuous in their native habitat, have become major pests in other parts of the world. The red turpentine beetle and loblolly pine scale are causing severe damage in China. Pinewood nematode is a major pest of pines in China and Japan. The California poppy is a common plant in portions of central Chile. While it is attractive, it is undoubtedly displacing native vegetation. The black locust tree, native to the Appalachian region, has escaped cultivation in Italy and other Mediterranean countries and is displacing native trees.

Figure 1 – The tumbleweed, introduced from Russia in contaminated flaxseed, has become so common in the western United States that few people realize that it is an introduced plant. Tumbleweed is also a serious pasture pest in Hawaii.

The purpose of this paper is to:

1. Provide a comprehensive review of the status of invasive species and their impacts on both rural and urban forest resources.
2. Review the roles, authorities and responsibilities of various government agencies at the Federal, State and local levels and their coordinating mechanisms.
3. Identify opportunities for the Western Forestry Leadership Coalition (WFLC) to call attention to the problem and encourage appropriate action to reduce the impacts of these damaging pests.

The scope of this paper focuses on three broad groups of invasive species:

1. Insects
2. Agents capable of causing plant diseases
3. Plants

The geographic area covered is the 17 western states and the 6 Pacific Islands.

This paper is organized into two parts. Part I is an overview of the invasive species issue and Part II summarizes technical information on important invasive species.

Part I
An Overview of Invasive Species

Impacts of Invasive Species

Invasive species have wide ranging impacts on forests and other plant ecosystems. The following sections address impacts under three broad categories: economic, ecological and societal.

Economic Impacts

A paper by Pimentel and others (2000) estimates that the sum total of economic impacts caused by *all* invasive species in the U.S. is over $137 billion per year. Forests that are damaged by invasive species will yield far fewer goods and services (e.g., timber, recreation, wildlife).

The cost of management of invasive species to reduce their impacts and reduce their rates of spread is extremely high. For example, during the period 1990 – 2001, the Federal/State cost share program for cost of gypsy moth suppression in the eastern U.S. ranged between $4.8 and $22.5 million per year and totaled $123.3 million[1]. While this insect is not yet established in the West, there have been a number of projects to eradicate the insect from localized areas. For example, since 1967, expenditures for eradication of gypsy moth have been $1,806,306[2] in Oregon:

Ecological Impacts

Invasive species have profound ecological effects. In forest ecosystems, invasive plants can alter basic ecological processes in invaded habitats, affect food supplies and nesting sites for native wildlife species, and alter nutrient cycles or fire frequency. Invasive insects and pathogens can change tree species composition and, in extreme cases, virtually eliminate susceptible species from forests.

Loss of Biodiversity

More aggressive invasive plants displace native vegetation. In the U.S., approximately 40% of the species listed as threatened or endangered are thought to have been imperiled by the effects of invasive species (Wilcove and others 1998). In other parts of the world, the situation is far worse. In some regions up to 80% of the species classified as endangered are due to the effects of invasive species. As many as 42% of the vertebrates whose causes of extinction are known are attributed to the effects of invasive species (Wiedenmann 2001). In Idaho's Snake River Canyon, for example, an endemic species of mariposa lily is threatened by the occurrence of yellow star thistle (FICMNEW 1998).

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[1] Source, Gypsy moth digest, USDA Forest Service, Morgantown, WV (http://fhpr8.srs.fs.fed.us/wv/gmdigest/acostyr1.cfm)

[2] Most of this was for eradication of gypsy moth from a large area of Lane country between 1984 and 1987.

Altered Species Composition

Species composition in forest ecosystems can be significantly altered because of invasive species. The introduction of the fungus that causes chestnut blight has virtually eliminated American chestnut from the broadleaf forests of the eastern U.S. Dutch elm disease has eliminated native elms from many forest ecosystems in the eastern U.S. and has reduced the viability of American elm as an ornamental and shade tree. Repeated defoliation by gypsy moth has resulted in loss of oaks in eastern forests, which are being replaced by red maple and other less desirable species.

Changes in Fire Regimes

One of the most significant effects of invasive plants is to alter fire regimes in forest ecosystems. Some invasive species, such as cheatgrass, have increased fire frequency while others such as diffuse knapweed, have the potential to decrease fire frequency (Harrod and Reichard 2001). In the insular ecosystems typical of Hawaii and the Pacific Islands, indigenous forests have not co-evolved with fire. Introduction of plants such as fountain grass has increased the incidence of wildfire with devastating ecological effects.

Fire exclusion in dry forest ecosystems has led to catastrophic, stand replacement wildfires. Disturbances created by these fires increase the potential for invasion by exotic plants, further altering ecosystems by displacing the native vegetation that would otherwise occupy these areas. Examples of invasive species favored by catastrophic wildfires include leafy spurge, diffuse knapweed, Scotch broom and dalmation toadflax. (Harrod and Richard 2001).

Societal Impacts

The presence of large numbers of insects can be extremely annoying, especially in urban forests or recreation areas. The larvae of some insects (e.g., gypsy moth) have hairs that cause skin irritation. Defoliation and other insect caused damage is unsightly. A study in New Jersey showed that residents forfeited almost 200 days of recreational use of their properties during a gypsy moth outbreak (Stein and Ravlin 2001). Some people are allergic to the pollen of invasive plants (e.g., Scotch broom). The coqui frog, introduced into Hawaii, makes a piercing call that disrupts sleep and discourages visits by tourists.[3]

[3] Personal communication, Duane Nelson, USDA Forest Service, Hilo, HI.

Some Case Histories

Gypsy Moth

The gypsy moth, *Lymantria dispar*, is undoubtedly the most serious insect pest of broadleaf trees in the eastern U.S. This insect was introduced into Massachusetts from Europe in 1869 and is now distributed throughout most of the Northeast and is rapidly spreading south into Virginia and west into Ohio, Michigan and Wisconsin.

Gypsy moth can feed on at least 500 species of trees, shrubs and vines. In the eastern U.S., its favorite hosts include oaks, apple, alder, basswood birch, poplar and willow. Older larvae are also capable of feeding on conifers.

Since it has become established in this country, gypsy moth has had a number of societal impacts. Extensive defoliation of forests is unsightly (Fig 3). In forested urban communities, it is regarded as intolerable. Gypsy moth larvae are a major nuisance when they defoliate shade and ornamental trees, crawl on and around houses and leave debris from their feeding in swimming pools and patios. In forested areas, repeated defoliations will cause reductions in growth, cause top dieback and kill oaks and other trees (McManus 1980).

Gypsy moth females lay eggs virtually anywhere, including lawn furniture, hubcaps of motor vehicles, trailers, etc. Consequently, they are easily transported, resulting in infestations in new locations. Recently, introductions have occurred in several western states, resulting in the need for extensive and expensive eradication programs. Moreover, increased international trade with China and Russia has increased the hazard of introduction of the Asian form of the gypsy moth. The Asian form has a female moth that is capable of flight (females of the European form of gypsy moth do not fly) and would be more easily dispersed should it become established.

Figure 2 – Defoliation of oaks and other broadleaf trees by gypsy moth, South Mountain, Pennsylvania

White Pine Blister Rust

Undoubtedly the invasive disease with the most severe impacts to date on western U.S. forests is white pine blister rust, caused by the fungus, *Cronartium ribicola*. This fungus is native to Asia and has life stages that attack both five needled pines and wild and cultivated species of currants and gooseberries, *Ribes* spp. Prior to the arrival of this fungus in the U.S., it was causing severe damage in Europe, where the American eastern white pine was widely planted and virtually every rural family cultivated a few European black current bushes in their garden. The disease eventually caused European foresters to abandon eastern white pines in their plantation programs.

When white pine blister rust arrived in the U.S. ca 1906, the fungus found an excellent habitat in which to survive. Five needle pines were important components of both northeastern and western forests and several (eastern white pine, western white pine and sugar pine) were keystone species for a rapidly growing American lumber industry. When white pine blister rust was first discovered in the U.S., the lumber industry was just getting established in the Pacific and Inland Empire forests of western white and sugar pines. In the northeastern and north central states, extensive planting programs were underway using inexpensive and plentiful white pine nursery stock imported from Europe. By the time the disease was discovered in the U.S., it was widely established.

The first attack on white pine blister rust in the U.S. consisted of a quarantine designed to prevent its introduction into the West. This was followed by an attempt to eradicate *Ribes* plants, the alternate hosts of the fungus from white pine areas. White pine blister rust resulted in the passage of the first quarantine and weed laws and regulations and the first organization of agencies and cooperative federal state programs dealing with forest pests. Many laborers were employed in *Ribes* eradication programs. The white pine blister rust control program was an economic boon, especially during the Great Depression when eradication programs reached their peak in terms of employment and expenditure.

Ribes eradication effectively protected white pine plantations in many parts of the East. However, in the West, wild *Ribes* were excellent sources of rust inoculum and were large and abundant in white pine forests. Despite efforts to eradicate the plants using chemicals, heavy machinery and explosives, the program was ineffective and abandoned in the 1960s. Moreover, an attempt to treat blister rust cankers with antibiotics failed.

The loss of white pines from many western forests resulted in significant changes in species composition and set the stage for several indigenous pests (bark beetles, defoliators and root disease) to become more abundant. The disease continues to spread in the West and is currently threatening high elevation forests of whitebark and limber pines. These species are important sources of food for birds and other wildlife and are critical for maintaining soil stability at high elevations.

Today, several approaches are being used to manage white pine blister rust with moderate levels of success. These include use of genetically resistant planting stock, silviculure treatments to reduce regeneration of *Ribes*, and thinning and pruning. Despite these pest management tools, white pine blister rust has been an ecological disaster for the West and continues to threaten new areas (Geils 2001).

Cheatgrass

Cheatgrass, *Bromus tectorum*, is a winter annual grass native to the Mediterranean Region that was introduced to North America in the mid 19th century. It is now widely distributed throughout North America and is found in every state in the U.S. Cheatgrass has a profound effect on sagebrush-grass ecosystems by replacing the perennial native grasses. Once established, cheatgrass is favored by wildfire. Cheatgrass allows hot fire to occur early in the spring when perennial grasses are especially susceptible to burning. The extended fire season creates conditions for cheatgrass to dominate these sites.

While cheatgrass is primarily an invader of rangelands, it also has detrimental effects on the extensive piñon-juniper woodlands that dominate much of the Southwest and Great Basin. In conjunction with fire, cheatgrass can create a threshold that prevents re-establishment of these woodlands following wildfire (Mitchell 2000).

Miconia

Miconia, a tree native to Central America, was introduced into Tahiti as a biological curiosity in 1937 where its seeds were dispersed by birds. By the 1980s, dense thickets of this seemingly innocent ornamental plant replaced over 70% of the native forest of the island. Tahitians now refer to this tree as the "green cancer." French Polynesian scientists estimate that one-fourth of Tahiti's indigenous species are threatened by extinction due to habitat loss (Westbrooks 1998).

Over the past 60 years, Miconia has been introduced to other islands including Hawaii in the 1960s. The tree was found growing in the wild on east Maui in 1990, about 20 years after its introduction at a botanical garden near Hana. Since then, Miconia has been found in several sites in east Maui as well as other islands of the Hawaiian chain.

Miconia forms dense thickets that keep sunlight from reaching the forest floor. Few plants can survive beneath this canopy. It destroys natural habitat, deprives native plants of sunlight, takes nutrients from the soil and deprives native birds of the plants they need to survive. Without soil stabilizing native ground cover, infested sites tend to erode.

A major program has been launched in Hawaii to control these infestations. The Maui Invasive Species Committee estimates that the potential range for Miconia to exceed 180,000 acres on Maui. The Big Island Invasive Species Committee estimates that over 500,000 acres on Hawaii are potentially suitable. Due to the scale of the current infestation, the long-lived seed bank, and the immense production of bird disseminated seeds, it is highly unlikely that Miconia will ever be eradicated from Maui and Hawaii. Containment and control efforts will have to continue for several decades, even with the assistance of a yet undiscovered effective biological control. Control programs on these two islands alone exceed $1.5 million per year

Smaller, but widely distributed populations of Miconia have been found on Oahu and Kauai. If these populations are not eradicated immediately, thousands of acres on each island will soon be contaminated with highly viable seed, setting the stage for an explosive invasion.

Dealing With Invasive Species[4]

How can we deal with the large number of invasive species that are affecting rural and urban forest ecosystems in the West, Hawaii and the Pacific Islands Territories? A number of pest management tools are available and others are being developed. The overall approach to managing both indigenous and exotic pests is known as Integrated Pest Management (IPM).

Healthy Ecosystems – The Objective

The objective for managing both indigenous and exotic pests in forests should be to keep these lands in a healthy, productive condition. What is a healthy ecosystem? The concepts of "healthy forests" and "healthy ecosystems" evolved during the mid to late 1980s. In economic terms, a healthy ecosystem is one in which pests and diseases remain at low levels and do not interfere with management objectives. In ecological terms, a healthy ecosystem is fully functional, one in which all of its components are intact and has its full capacity for renewal and recovery from a wide range of disturbances.

The healthy ecosystem concept directs resource managers to focus on the ecosystem rather than its pests and diseases and takes into account the natural role of insects, fungi, fire and other so called "damaging agents" and their interactions in the dynamics of ecosystems. Under an overall policy of ecosystem health protection, pests and diseases are seen as symptoms of an unhealthy system rather than as the problem. This directs resource managers and specialists engaged in ecosystem protection to address the underlying causes of the pest or disease – factors such as overstocking, overgrazing, poor site/species matching, excessive fuels and low diversity. Striving for healthy ecosystems also involves anticipating pests and diseases based on historical records of their occurrence and the knowledge of conditions that favor their abundance. This allows time to implement management practices that will make ecosystems less hospitable to damaging pests and diseases.

The healthy ecosystem concept may seem like an idyllic approach in cases where invasive species have caused profound ecological effects on forest ecosystems that have not co-evolved with the invasive. In many cases, invasive species lack the natural control mechanisms present in their native habitats or their new hosts are extremely sensitive to attack, so the invasive species negatively affect ecosystem health and are having severe impacts. However, in other cases damaging invasive species respond to site conditions, and evidence indicates that they tend to flourish in unhealthy ecosystems. Invasive plants often establish themselves on recently disturbed sites or overgrazed rangelands. Some exotic insects, at least in their initial stages, invade weakened or stressed trees (e.g., the European wood wasp) or cause severe damage on poor sites (e.g., the propensity for gypsy moth to cause heavy defoliation on ridgetops). An understanding of the ecology of

[4] This section is revised from Ciesla, W.M., 2001. Protecting plantations from pests and diseases. FAO, Forestry Department, Rome, Italy, Forest Plantations Thematic Papers, Working paper FP/10, 18 pp.

invasive species is essential in the development of appropriate pest management approaches.

Island biota represent a special and perhaps extreme case, where the indigenous species evolved without grazing and browsing pressure from ungulates and therefore did not develop mechanisms to protect themselves. In this case, the introduction of large ungulates and smaller seed predators had a profound and devastating impact on what had been intact and healthy ecosystems.

Integrated Pest Management (IPM) – The Tools

The healthy ecosystem concept provides an umbrella or objective for managing all forest pests including invasive species. IPM, on the other hand, provides the tools to accomplish this objective.

The concept or philosophy of IPM as a "rational approach to pest control" was formalized during the 1960s. Crop protection specialists had become aware of the adverse side effects of dependence on chemical pesticides (e.g., resistance, occurrence of secondary pests, environmental damage, and human health risks). This led to the realization that alternative approaches (e.g., cultural, biological and genetic tactics) used either alone or in combination were also needed to provide long-term protection against damaging pests.

Many definitions of IPM appear in the literature. Smith and others (1976) refer to IPM as "a process based on ecological principles that integrates multi-disciplinary methodologies in developing agro-ecosystem management strategies that are practical and effective and protect both public health and the environment." Pimentel (1986) describes IPM as a "pest control method that includes judicious use of pesticide and non-chemical technologies – all of which are based on sound ecological principles."

IPM consists of two elements: a decision process and an action process. The decision process establishes the basis for any subsequent actions to be undertaken, including no action. The action program may consist of one or more ecologically, economically and socially acceptable tactics designed to reduce pest populations to non-damaging levels.

The Decision Process

The decision process is often the most time consuming and complex aspect of IPM. It requires careful consideration of the pest, its host(s), resource management objectives and the ecological, economic and social consequences of various available tactics. Estimates are made of population levels of the target pest, and projections are made of anticipated losses and the costs of treatment and its anticipated benefits. If treatment costs exceed losses, a rational decision may be not to treat and accept the loss. Other questions to address include: will natural controls take over within a short time frame so that artificial controls may not be necessary, or will the effects of proposed treatments be so adverse that they would outweigh the benefits of treatment?

A critical input into the IPM decision process comes from monitoring of forest pests and diseases (indigenous or exotic) and their resultant damage. Pest monitoring is becoming a sophisticated process and uses many technologies. Chemical attractants (pheromones) are used to monitor insect populations including such invasive species as gypsy moth and Asian longhorned beetle. Remote sensing tools are available to map and assess damage. Global Positioning Systems (GPS) can be used to pinpoint the locations of infestations, especially in remote areas. Geographic information systems (GIS) can be used to relate the location of infested areas to key resource values, terrain features, land ownerships and environmentally sensitive areas. Mathematical models can predict resultant damage caused by certain levels of pest numbers and their consequences. In some cases, growth and yield models and economic models are linked to make projections of pest and disease impacts. Data visualization techniques can display the expected results of alternative actions. These technologies must, of course, be continuously updated in order to be capable of detecting and monitoring new invasive species.

The Action Process

IPM action programs consist of two overall strategies: prevention or direct control (suppression). Specific pest management tactics exist under each of these strategies.

Prevention – Prevention consists of tactics designed to either reduce the probability of the occurrence of a pest or disease or to create environmental conditions inhospitable for its buildup into damaging numbers. Regulatory, cultural, genetic and mechanical tactics are examples of prevention strategies.

Regulatory tactics are designed specifically to prevent the introduction of invasive species and to prevent or reduce their rate of spread once they become established. Examples of regulatory tactics include:

1. Inspection of imports at ports of entry to intercept invasive species.

2. Conduct of pest risk analyses when new trade agreements are made to identify those species that have the potential for establishing themselves and becoming pests should they be introduced.

3. Establishment of quarantine zones when an invasive species is first discovered to reduce its rate of spread.

4. Requiring use of certified weed free hay to feed pack animals in remote areas and weed free seed when re-vegetating areas burned by wildfire

Cultural tactics are designed to create conditions inhospitable for the buildup of damaging numbers of a pest or disease. These include matching tree species selected for planting to suitable growing sites, controlling tree stocking through intermediate cuttings, timely harvesting of mature trees, and avoiding overgrazing on rangelands.

Mechanical tactics include practices such as using prescribed burning to reduce invasive plant numbers and washing motor vehicles and equipment when moving from an infested site to an uninfested site to eliminate seeds or fungal spores.

Genetic tactics make use of varieties of host plants that possess traits that make them less susceptible to damage by a pest or disease.

Suppression – Tactics directed against pests or diseases are considered direct control or suppression. Examples include eradication, biological control, mechanical control and chemical control.

Eradication is a procedure designed to eliminate an invasive species from an area once it becomes established. This may involve one or more chemical, mechanical or biological tactics. In order for eradication to be a viable tactic, the infestation must be relatively localized and the number of individual organisms relatively low. Since eradication measures often require use of chemical pesticides, they tend to be controversial and, therefore, difficult to implement.

Biological control involves the use of natural enemies of a pest to help keep its numbers in check. *Classic biological control* is a tactic specific to invasive species and involves the importation and release of natural enemies from the organism's native habitat to help control it. While many successful examples of the use of classic biological control exist, there is always a concern that the introduced natural enemy may ultimately attack a beneficial organism. Another concern is the accidental introduction of hyperparasites or natural enemies of the bio-control agent that could reduce its effectiveness. *Augmentative biological control* is the use of methods designed to increase the abundance and effectiveness of natural enemies already in place in an ecosystem. Use of *Biological insecticides* includes agents such as the bacterium *Bacillus thuringiensis* or virus diseases to control insects.

Mechanical tactics include removal and destruction of infested plant materials to destroy the pest. This tactic is often used to eradicate or manage invasive tree pests.

Chemical tactics involve the use of chemical pesticides to eradicate or suppress a pest species. Although use of chemicals is highly controversial because of environmental and human health hazards, it is still considered to be a viable tactic under the IPM umbrella. However, under IPM, chemicals are used more sparingly, applied with greater precision and are usually considered to be the tactic of last resort.

Restoration tactics are those activities needed to return lost ecosystem components or functions to degraded lands following invasive plant control or eradication. Without restoration, areas are subject to reinvasion by invasive plants. The objectives are to restore native plant communities and ecosystem processes to natural areas, productive crops to agricultural lands, native forage to rangelands and healthy understories to forests (FICMNEW 1998).

Integration of New Technologies

No matter how advanced, sophisticated or effective an IPM program for a specific pest or pest complex might be, there is always room to integrate new knowledge and technologies made available through research and development programs. These may include more accurate technologies for pest monitoring and prediction or more effective treatments with fewer undesirable side effects.

National, Federal, and State Responsibilities

Many Federal, State, and local government agencies conduct activities relating to management of invasive species. Executive Order 13112, signed by President William J. Clinton on February 3, 1999, established the Invasive Species Council to provide national leadership and coordination regarding invasive species management and to prepare a National Invasive Species Plan (NISC 2001) (available online: http://www.invasivespecies.gov). Membership in this council is made up of the Administrator of the EPA and the Secretaries of State, Defense, Interior, Agriculture, Commerce, and Transportation.

Federal Government[5]

Authorities, Roles and Responsibilities

The federal government has broad authorities and responsibilities for management of invasive species. These are assigned to a number of federal agencies (Fig. 2) and focus on:

1. Preventing entry of invasive species into the U.S.
2. Regulating the interstate movement of products that may be infested with invasive species.
3. Managing invasive species on federal lands.
4. Cooperating with state and local agencies to manage invasive species on state and private lands.

Federal roles and responsibilities relating to management of invasive species fall into six broad areas (NISC 2001):

1. Prevention
2. Early detection and rapid response
3. Control, management and restoration
4. Research and monitoring
5. International measures
6. Public outreach and partnership efforts

[5] For a more detailed discussion of the authorities, roles and responsibilities of the Federal government in management of invasive species, see the appendices of this paper or NISC (2001).

While many of the responsibilities and authorities for management of invasive species at the Federal level have been assigned to USDA, it is by no means the only Federal Department that has a role in their management. Moreover, within any one Department, several agencies may have responsibilities for various aspects of invasive species management (Fig 3).

For example:

1. In the area of prevention, most authorities and responsibilities are under USDA, but the U.S. Navy under the Department of Defense (DOD) also has an important role in the management of ballast water and anchor system management practices including those that affect introduction of invasive species.

2. Early detection and rapid response is the primary responsibility of USDA and is divided among four agencies: Animal Plant Health Inspection Service (APHIS), Agricultural Research Service (ARS), Forest Service (FS) and the Natural Resources Conservation Service (NRCS). However land managing agencies within USDI and other Departments have direct responsibility for carrying out detection and response activities on lands they manage

3. Control, Management and Restoration functions are shared by seven Departments: USDA, Department of Commerce (DOC), Department of Defense (DOT), The Environmental Protection Agency (EPA) and the Department of the Interior (USDI).

4. Research and Monitoring activities are shared by USDA, DOC, DOD, DOT, EPA and USDI and vary according to the type of invasive species. USDA works primarily on insects, pathogens and plants. DOC conducts research on invasive aquatic species and DOD under the Corps of Engineers develops technologies for managing aquatic plants and conducts research on the zebra mussel. USDI conducts inventories of invasive species on National Parks and other lands managed by this Department. EPA's research focuses on invasive species affecting surface waters and wetlands.

5. International measures are the primary responsibility of the Department of State in negotiating international agreements designed to prevent entry of invasive species. However negotiator privileges may be delegated to other agencies if they have the appropriate expertise.

6. Public outreach and partnership functions are conducted by USDA, DOC, DOD and USDA and are designed to keep the general public advised of the activities of various agencies involved in management of invasive species.

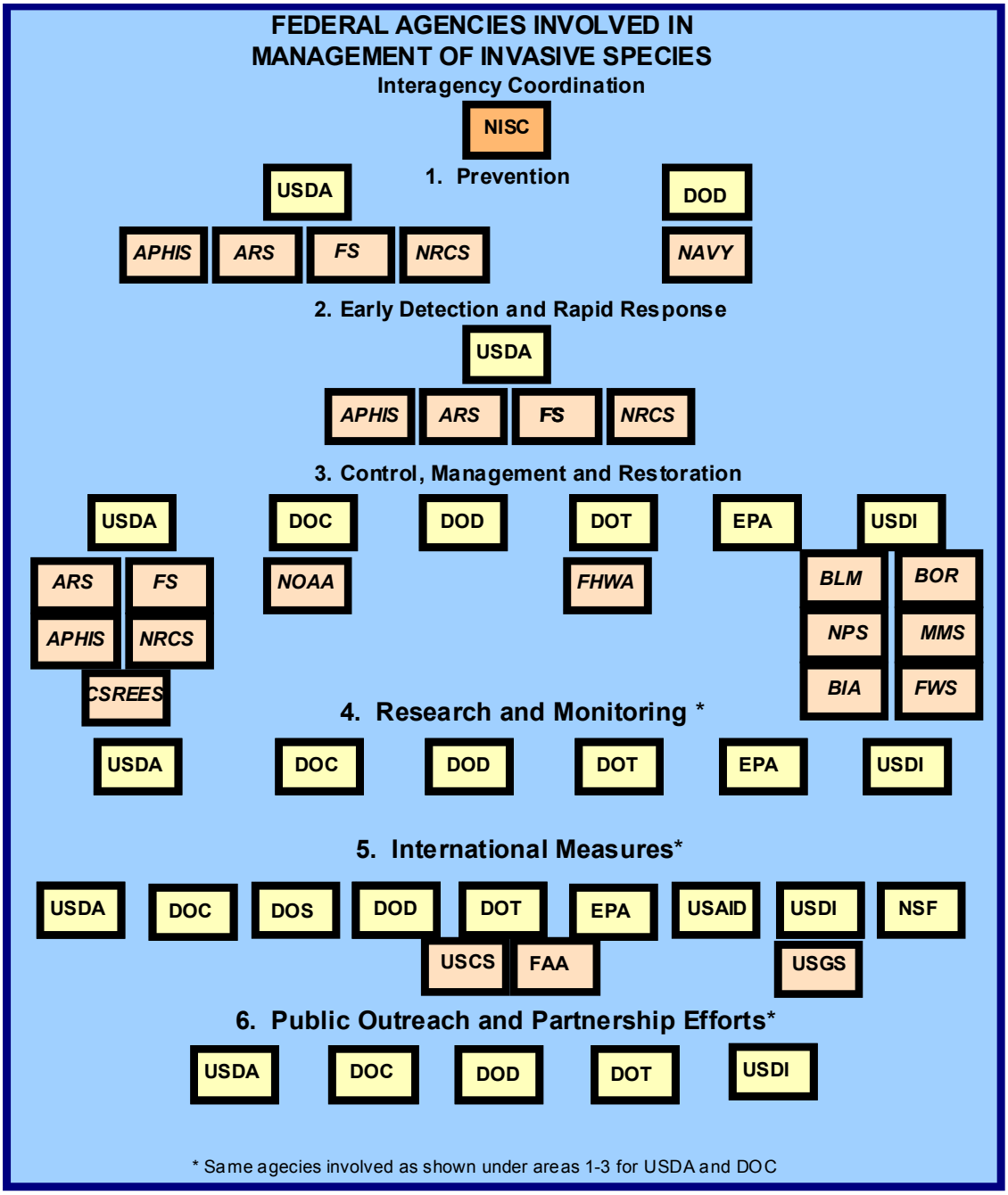

Figure 3 – Federal Agencies involved with management of invasive species

Coordinating Mechanisms

Through Memoranda of Understanding (MOUs) USDA and USDI cover research requirements of mutual concern to DOD regarding resource management activities including management of invasive species. USDA Forest Service, through an MOU with USDI provides technical assistance on forest insect and disease management to managers of lands administered by BLM, NPS, FWS and tribal lands

In response to the economic and biological threat posed by invasive plants, 17 federal agencies formed the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW). The committee's goal is to facilitate the development of biologically sound techniques to manage invasive plants on all lands. The committee promotes weed programs of individual agencies as well as cooperative projects that emphasize weed prevention, timely control, and restoration of degraded lands. Another goal is to form partnerships with state and local agencies and NGOs to identify new ways to deal with invasive plants (FICMNEW 1998, Westbrooks 1998).

As discussed in the introductory section, Executive Order 13112, signed by President William J. Clinton on February 3, 1999, established the National Invasive Species Council to provide national leadership regarding invasive species management and to prepare a National Invasive Species Plan (NISC 2001). Membership in this council is made up of the EPA Administrator and the Secretaries of State, Defense, Interior, Agriculture, Commerce, and Transportation. Duties of the council are:

1. Oversee the implementation of the Executive Order and ensure that Federal agency activities concerning invasive species are coordinated, complimentary and cost efficient and effective.

2. Encourage planning at the local, tribal, State, regional and ecosystem-based levels to ensure that goals and objectives of the National Invasive Species Management Plan are met (See item 7).

3. Develop recommendations for international cooperation in addressing invasive species.

4. Provide guidance to Federal Agencies on prevention and control of invasive species.

5. Facilitate development of a coordinated network among Federal agencies to document, evaluate and monitor impacts of invasive species.

6. Facilitate establishment of a coordinated, up-to-date information sharing system on invasive species.

7. Prepare and issue a National Invasive Species Management Plan.

NISC has developed an action plan that addresses management of invasive species and the coordination needed to accomplish this critical task (NISC 2001).

State, County, and Local Governments

As is the case in the federal government, state agencies have laws governing the movement and pest management of invasive species, and a number of state agencies have responsibility for implementing laws and regulations governing invasive species. State agriculture departments, rather than State forestry agencies, are usually the lead for invasive species management.

Responsibilities of state agencies focus primarily on the movement of invasive species within state boundaries and management of invasive species on state and private lands. Agencies at the state level involved in invasive species management include regulatory agencies, state universities, and State departments of agriculture, conservation or wildland resource management, transportation, and others. State agencies regulate the entry of invasive species within their states by prohibiting the sale or movement of plant materials that could harbor invasive species into their states and by regulating high-risk vectors such as potted nursery stock or seeds. Many western states have strict laws concerning the control of pest species including exotic invasive species.

In the case of invasive plants, county weed supervisors will often work with private landowners to control invasive plants within county weed districts that may have stricter laws than the state. In some states, if a landowner refuses to comply with state weed control laws, the state or county government will control the infestation and bill the owner for the work (Westbrooks 1998).

Potential Role for WFLC in Mitigating Impacts of Invasive Species

The Western Forestry Leadership Coalition (WFLC) was formed in 1999 and formalized the long-term working partnership between western State Foresters and the western regions of USDA Forest Service. Together, these groups implement State and Private Forestry programs throughout the West, Alaska, Hawaii, and the Pacific Island Territories.

The coalition's roles are to:

1. Improve implementation of State and Private Forestry programs that focus on the health and sustainability of all forests – private, tribal, federal and state.

2. Provide forest resource management and technical, financial and educational assistance to landowners and resource managers.

3. Protect communities and the environment from wildfire.

Providing leadership for pest management programs directed at invasive species that threaten forests is a logical and essential function of WFLC. Some opportunities for WFLC involvement include:

1. Increase awareness of invasive species and their impacts.

2. Promote partnerships.

3. Facilitate identification of gaps in authorities and responsibilities.

4. Support Integrated Pest Management as the guiding framework for all WFLC member organizations.

5. Support cross-cut budgets for invasive species.

6. Support and utilize new research and technology/methods as part of a sound IPM program directed against invasive species.

7. Promote the use of national data and mapping standards to facilitate information sharing between WFLC members and other organizations on the status of invasive species and progress of pest management programs.

Each of these opportunities is discussed in the following sections.

Increase Awareness of Invasive Species and Their Impacts

There is a continuing need to increase the awareness of invasive species and their impacts on forests and rangelands. While specialists (e.g., entomologists, plant pathologists, weed scientists) at the Federal, State and local level are actively engaged in management of invasive species, program managers may not fully appreciate the magnitude of the

problem and should be made fully aware of the invasive species issue, especially with regard to invasive species within their jurisdictions. Others that must be made more aware of the problems associated with invasive species are Federal and State legislators.

Federal and State resource managers must have an appreciation of the complex legislative authorities that affect management of invasive species and regulate the use of certain pest management tactics, such as use of pesticides. They must also be aware of the various Federal and State agencies that have responsibility for various aspects of invasive species management. Since responsibilities for invasive species management vary from state to state, State Foresters and their principal staffs should be fully aware of how authorities and responsibilities are assigned in their respective states.

Moreover, Federal and State resource management agencies must work with their publics, including NGOs, on a continuing basis to ensure that they have an understanding of the invasive species issue and the needs for appropriate pest management activities.

Publicity should include not only addressing` the extent of infestations and their impacts but also the operations underway to manage invasive species, especially those that have been successful.

WFLC could help influence curricula at state and local colleges and universities to include coursework on invasive species.

Promote Partnerships

Invasive insects, pathogens and plants do not respect ownership boundaries. They expand their ranges to wherever suitable conditions for survival exist. Therefore, effective pest management is dependent on strong working partnerships between Federal and State agencies and private landowners.

Many mechanisms are already in place for forging partnerships to combat invasive species. The long-standing partnerships between USDA Forest Service and State Foresters regarding fire management and forest insect and disease management, through cooperative programs authorized under the Cooperative Forestry Assistance Act, provide a framework from which to address the invasive species issue.

Partnerships should be forged at the local level, where action can be taken to reduce the economic, ecological, and social impacts of invasive species. Many examples exist where National Forests, state agencies, universities and local weed control agencies have worked together to effectively address an invasive pest on lands of mixed ownership (USDA Forest Service 1999b).

Other areas requiring work are: developing interagency plans for early detection and rapid response; knowing where and how to share the expertise for identification; and having MOUs in place to meet future needs.

Facilitate Identification of Gaps in Authorities and Responsibilities

Despite the large number of agencies at the Federal, state and local levels that have legislative authority to conduct work on invasive species, there may still be gaps that inhibit appropriate responses to invasive species or existing authorities may require clarification. If such gaps or questionable authorities exist, encourage appropriate action (e.g., new legislation, MOUs) to enable full implementation of pest management programs by all partners involved.

Support Integrated Pest Management as the Guiding Framework for All WFLC Member Organizations

The decision and action processes of IPM often lead to the use of one or more ecologically, economically, and socially acceptable tactics that are designed to reduce pest populations to non-damaging levels.

Support Cross-Cut Budgets For Invasive Species

Beginning in Fiscal Year (FY) 2003, the NISC will coordinate and provide to the Office of Management and Budget (OMB) a proposed cross-cut (multi-agency) budget for Federal Agency Expenditures concerning invasive species (NISC 2001). This budget will address the implementation of actions recommended in the present and future editions of the National Invasive Species Plan. The cross-cut budget will take into account views of the Invasive Species Advisory Committee, States, and the full range of stake holders. In addition, the cross-cut budget will be used as a tool for planning and coordination, giving emphasis to funding priorities to implement action items.

The WFLC could serve as a focal point to coordinate input from FS, States, Territorial Governments and other stakeholders to ensure that the needs of the Western States and the Pacific Islands Territories are recognized at the national level with regard to management of invasive species.

Consistent with Leadership and Coordination Action #7 in the National Invasive Species Council's 2001 Management Plan (NISC 2001), the WFLC could provide input and organizational support to "cross-cut budgets" that address invasive species issues (Table 1). The federal agencies are now considering an approach for Fiscal Year 2004 that includes the following key points:

1. Use the major focus areas from NISC Management Plan (i.e., Prevention, Early Detection and Rapid Response, etc.). Prioritize these areas and select 3 to 5 for development in the first phase of this effort.

2. Develop goal and action statements for the high-priority focus areas.

3. Within each of the selected focus areas pick 2 to 4 invasive species to work on.

4. Use the Criteria and Guiding Principles below to select target species.

5. By committee select invasive species to work on. Assign a lead individual for each pest who will coordinate a group across Departments to develop a module for their pest, which includes a description of the problem and what can be done about it (include resource needs "drilled down" to agency budget line items).

6. These modules can be combined into a total Invasive Species Cross-Cut Budget Request that the Invasive Species Advisory Committee can support. Each module can be supported or not by the Departments that are involved.

The following criteria are proposed for selection of target invasive species (maximum 10 points for each criterion):

1. The activities for the proposed pest would be performance measurable (i.e., there is an outcome that we can count) (10 points).

2. The activities would be ecologically significant (10 points).

3. The activities would be politically significant (10 points).

4. The projects proposed would be do-able and have a science basis (10 points).

5. The proposal would involve more than one agency at a minimum and a sliding scale of points – more for each agency involved (10 points).

6. Partnerships would be formed as a result of the work (10 points).

Guiding principles for cross budget projects are:

1. Not all agencies need to be involved in each module.

2. By joining forces in a proposal, there is a synergy gained in terms of the overall effectiveness of the project.

3. The modules can be promoted as separate entities and as part of the total package.

4. The work identified in these modules would be beyond the base program of each agency.

Table 1 - Conceptual Invasive Species Cross-Cut Budget Plan for Fiscal Year 2004 Using a Pest-Specific Approach.

<table>
<tr><th>Prevention/Eradication</th><th>Early Detection & Rapid Response</th><th>Control, Management, and Restoration</th></tr>
<tr><td>Pest/Guild 1</td><td>Pest/Guild 4</td><td>Pest/Guild 6</td></tr>
<tr><td>Pest /Guild 2</td><td>Pest Guild 5</td><td rowspan="2">Pest/Guild 7</td></tr>
<tr><td colspan="2">Pest/Guild 3</td></tr>
<tr><td colspan="3">Pest/Guild 8</td></tr>
</table>

Support and Utilize New Research and Technology/Methods as Part of a Sound IPM Program Directed Against Invasive Species.

Maintaining current knowledge about invasive species and utilizing state-of-the-art treatment technologies that have minimal undesirable side effects are essential components of an effective on-the-ground invasive species management program. Current knowledge about the threat of new invasive species is continually required to prevent their introduction and establishment. One way to maintain this knowledge is through implementation of the Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) programs including surveys for invasive species. The Exotic Forest Pest Information System for North America (EFPISNA) provides current information about the most dangerous invasive forest pests that have not yet become established in the United States (available online: http://www.exoticforestpests.org).

Cooperation is needed on new technologies and methods for early detection and response similar to the recent Pilot Test Early Warning System for new invasive forest insects (Scolytids and Lymantids). The recent appearance of sudden oak death and the threat of other pathogens of unknown origin demonstrate the need for better methods to detect these "invisible" organisms. Similarly, new technologies are needed in the management/control of established invasive species and for restoration of invasive species-damaged ecosystems. Sound methods are also needed to measure the effectiveness of invasive species management programs. Therefore, research and technology development organizations at all levels-Federal (ARS, FS) and State (Universities, Agricultural Experiment Stations)-must become full partners in the management of invasive species.

Personnel engaged in management of invasive species must identify needs for additional knowledge and new technologies/methods and pass this information to the appropriate organizations for action. WFLC could play a key role in facilitating this process.

Promote the Use of National Data and Mapping Standards to Facilitate Information Sharing Between WFLC Members and Other Organizations

Inventorying and monitoring the occurrence and extent of infestations of invasive species is a critical element of successful management programs. Another need for monitoring is to assess the effectiveness of pest management programs. If public support for these programs is to continue, agencies engaged in the management of invasive species must be able to demonstrate on-the-ground accomplishments. For example, how many acres of forest or rangeland have been restored into a productive condition as a result of invasive species pest management programs? Although reasonably good information is currently available on the status of several important invasive forest insects and pathogens, much of the information on the occurrence of invasive plants is limited to presence or absence in a state.

Data and mapping standards for the inventory and monitoring of invasive plants have been recently agreed to by many federal, state/provincial, and tribal organizations in the U.S. and Canada. These standards are sponsored by the North American Weed Management Association (NAWMA) (available online: http://www.NAWMA.org).

Similar information standards are under development for the biological control agents that managers are increasingly using to minimize the impacts of invasive species. The development and maintenance of shared organizational databases on invasive species may also be a useful step in some situations. However, a better strategic first step would be for WFLC members and other organizations to agree to collect data consistently so that critical information about the occurrence, spread, and actions taken to manage invasive species could be more easily combined and shared, regardless of where the databases reside.

Part II
Technical Information on Key Invasive Species in the Western United States and Pacific Islands

Technical details of 37 key invasive species in the West, Hawaii and the Pacific Islands are presented in the following sections under five general headings:

1. Insects established in the western U.S. and Pacific Islands (9 species)
2. Pathogens established in the western U.S. (5 species)
3. Invasive plants established in the western U.S. (12 species)
4. Invasive plants established in Hawaii and the Pacific Islands (6 species)
5. Invasive species not yet established but pose an imminent threat (5 species or species groups)

One of the great dangers faced by all U.S. forests is the cumulative impact of all the additional stresses on our natural ecosystems by introduction of so many invasive species over a short period of time. It is not just the individual species themselves, but the combination of insects, diseases, weeds, vertebrates etc., linked with other human-caused changes (e.g., fire exclusion, selective harvesting and habitat fragmentation) and climate change that gives rise to serious concerns for long-term sustainability and viability of forested ecosystems.

Insects Established in the Western U.S. and Pacific Islands

Many species of forest insects have been introduced and established in forests and urban areas of the West. While some have had relatively low socio-economic impacts or have been successfully managed, others have become major pests. Presently, most forest insects introduced into the U.S. still have relatively localized distributions. Even the European form of the gypsy moth, which has defoliated millions of acres of broadleaf forests in the eastern U.S., is presently distributed over less than 10 percent of its potential range.

Exotic or invasive forest insects, which are of current or potential concern in western forests and urban areas, are reviewed in this section under two headings:

1. Established in western forests:

2. Established in urban areas

Occurrence of these insects by state is summarized in Table 2.

Table 2 - Occurrence of Key Invasive Forest and Urban Insects by State in the Western U.S. as of 2001.

Insect	State															
	AK	AZ	CA	CO	ID	KS	MT	ND	NE	NM	NV	OR	SD	UT	WA	WY
Balsam woolly adelgid					X							X			X	
Eucalyptus borer			X													
Green spruce aphid	X	X	X									X			X	
Gypsy moth*			X	X	X							X**		X	X**	
Larch casebearer					X		X					X			X	
Larch sawfly	X						X					X				
European elm scale		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Elm leaf beetle		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Oystershell scale		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

* Localized infestations or adult trap catches, which have been eradicated or are being closely monitored.

** Indicates both European and Asian forms

Balsam Woolly Adelgid

Scientific Name of Causal Agent- *Adelges piceae*

Type of Agent – Insect (Bark and twig infesting aphid)

Native Habitat - Europe

Means of Introduction - Probably infested nursery stock

Means of Spread - Infested plant material is the main means of spread. Once established in an area, immature stages are easily dispersed by air currents.

Hosts - All North American species of true fir (*Abies* spp.) are susceptible to this insect.

Type of Damage - Feeding by balsam woolly adelgid causes abnormal growth including deformities (gouting) due to attacks on twigs and branches and production of wood with a reddish discoloration (*rotholz*) due to attacks on main stems (Fig. 4). Infested trees can be killed.

Current Status - This insect is present in both eastern and western fir forests. In northern **Idaho**, some 56,426 acres were infested in 2000. Actual infested acres are probably higher with some areas not displaying crown symptoms. Areas with heaviest infestations are on the **Clearwater, Idaho Panhandle** and **Nezperce National Forests** and adjacent State, private and BLM lands. Subalpine fir of all ages and size classes are killed. Extensive gouting and bole infestations occur on grand fir but to date no trees over 5 inches in diameter have been killed. Regeneration mortality of fir is high, resulting in forest type conversions in some areas.

Balsam woolly adelgid activity was observed on 7,100 acres in 1999 and 6,300 acres in 2000 in **Oregon** and **Washington**. The majority of reported activity occurred on the **Deschutes, Mt Hood,** and **Wenatchee National Forests** and adjoining lands. Forest Health Monitoring (FHM) surveys established that this insect was present in all northeast **Oregon** counties with forests, a fact that had not been reported previously. Damaging infestations were found in subalpine fir on the **Umatilla National Forest**. Balsam woolly adelgid has nearly eliminated subalpine fir from sites where it is acting as a pioneer species in disturbed and harsh environments, such as old lava flows and avalanche tracks. Almost all of the grand fir in low valleys and coastal streams west of the Cascades has been affected and is disappearing from low elevation environments.

Pest Management Tactics - Classic biological control programs that involve the introduction of predators have not been effective. Chemical control methods give temporary protection and can only be used in areas accessible by roads.

Potential for Future Damage - Continued spread of this insect into fir forests of the interior Rocky Mountain States (**Arizona, Colorado, Montana, New Mexico, Utah, Wyoming**) and continued loss of fir as a viable component of western conifer forests.

Figure 4 – Stem attack by balsam woolly adelgid on fir.

Eucalyptus Borers

Scientific Name Of Causal Agents - *Phoracantha semipunctata* and *P. recurva*

Type Of Agent – Insect (Cambium and wood boring beetle)

Native Habitat - Australia

Means Of Introduction - Probably wooden crating, dunnage and pallets made from eucalyptus wood.

Means Of Spread - Adults are strong fliers. Once established in an area, they are capable of flying distances of around one kilometer in search of suitable trees to attack. Eucalyptus firewood serves as an excellent breeding site.

Hosts - Various species of eucalypts

Type of Damage - In Australia, these insects usually breed in logs or very unhealthy trees. In areas of Mediterranean climate where these insects have been introduced, they attack eucalypts that suffer moisture stress and kill trees. Ironically, at least one species of eucalypt is considered to be an invasive species in California (see section on blue gum eucalyptus).

Current Status - *P. semipunctata* probably arrived in **California** prior to 1985. It was first detected in southern **California** but is now distributed throughout the planted range of eucalyptus in central and coastal **California** (Paine and others 1998).

A second species, *P. recurva*, appeared in the U.S. in 1995.

All infestations occur on state and private lands.

Both of these insects have appeared in many parts of the world where eucalypts have been introduced including Argentina, Chile, Brazil, Egypt, New Zealand, Portugal, South Africa, Turkey, and Uruguay.

Pest Management Tactics - Biological control with natural enemies may provide the best long-term solution for control of eucalyptus longhorned beetles. To date four species of parasitic wasps have been introduced. Insecticides are ineffective, expensive and environmentally inappropriate for control of these insects. Borer management is best accomplished through preventative actions such as not storing firewood long periods and planting eucalypts on sites not subject to severe drought (Paine and others 2001).

Potential For Future Damage - Continued mortality of planted eucalypts with higher levels of damage during drought periods.

Green Spruce Aphid

Scientific Name Of Causal Agent- *Elatobium abietinum*

Type of Agent – Insect (Foliage feeding aphid)

Native Habitat - Europe

Means of Introduction - Unknown

Means of Spread - Winged forms are capable of flying short distances. Non-winged forms are dispersed by air currents.

Hosts - Spruces, including Engelmann, white and Sitka spruces. This insect has also occasionally been reported on pine and Douglas-fir (Furniss and Carolin 1977).

Type of Damage - The spruce aphid feeds gregariously and sucks sap from old needles. Lower and more shaded portions of host trees are more subject to injury (Furniss and Carolin 1977). Defoliation caused by this insect results in reduced tree growth and can predispose trees to attack by the native spruce bark beetle.

Current Status – Spruce aphid has been known to occur in **Alaska, California, Oregon** and **Washington** since the 1960's (Furniss and Carolin 1977).

This insect was recently discovered in **Arizona**, where some 156,880 acres were defoliated in 2000. Defoliation occurred on the **Apache-Sitgreaves National Forest** (69,290 acres); **Fort Apache Indian Reservation** (87,510 acres); 15 acres of private land and 65 acres of state trust lands. Low-level populations were also detected on the **Coconino** and **Coronado National Forests** (USDA Forest Service 2001).

In 2000, 37,500 acres of defoliation were detected in southeast **Alaska**. Seventy-five percent of this area was on national forest lands. This outbreak is the fourth during the last decade. Outbreaks in southeast **Alaska** are usually preceded by mild winters. Spruces in urban settings or along marine shorelines are most seriously affected. Some tree mortality is occurring in urban settings where development has caused root disturbance. Non-urban forested areas have small patches of localized tree mortality as a result of severe defoliation (USDA Forest Service 2001).

Pest Management Tactics - Chemical controls must be applied early (March-April) to be effective and are only practical for ornamental trees.

Potential for Future Damage - This insect could spread to other Rocky Mountain States where more extensive areas of spruce occur (e.g., **Colorado** and **New Mexico**).

Larch Casebearer

Scientific Name of Causal Agent - *Coleophora laricella*

Type of Agent – Insect (defoliating caterpillar)

Native Habitat - Europe

Means of Introduction - The means of introduction is probably via infested nursery stock. This insect first became established in the New England area prior to 1886. It was first discovered in northern Idaho in 1957 on western larch and is now known to occur throughout the natural range of this tree (Furniss and Carolin 1977).

Means Of Spread - Flying adults

Hosts - All species of larch. In the West, western larch is subject to severe damage.

Type Of Damage - Defoliation by larvae, which causes growth loss and reduced ability of larch to compete with other tree species for crown space in the forest canopy.

Current Status - This insect is now present throughout the western larch forests of **Idaho, Montana, Oregon** and **Washington** (Fig. 5). In 1999, approximately 14,000 acres of larch had aerially visible defoliation in northern **Idaho** and western **Montana**. However, in 2000 aerially visible defoliation declined significantly. The most noticeably affected areas were on the **Idaho Panhandle National Forest** where 400 acres of defoliation were recorded and in a few localized areas on the **Kootenai** and **Lolo National Forests.** In Oregon and Washington, 15,386 acres of defoliation were reported in 1999 and 7,000 acres in 2000. Most defoliation occurred on the **Colville National Forest** and intermingled state and private lands in eastern **Washington** (833 acres) and the **Mount Hood National Forest** and intermingled lands in **Oregon** (5,524) (USDA Forest Service 2001).

Parasites introduced for biological control of this insect during the 1960s (and established years ago) helped maintain low levels of larch casebearer for many years. As casebearer populations declined, so did the parasites. Parasites are expected to respond to increasing casebearer populations. However, there may be several more years of defoliation during the current cycle before the parasites increase to the point that they will reduce the casebearer populations (USDA Forest Service 2001).

Pest Management Tactics - Release of introduced parasitoids has been reasonably successful.

Potential For Future Damage - Periodic outbreaks of this insect can be expected to occur throughout the range of western larch.

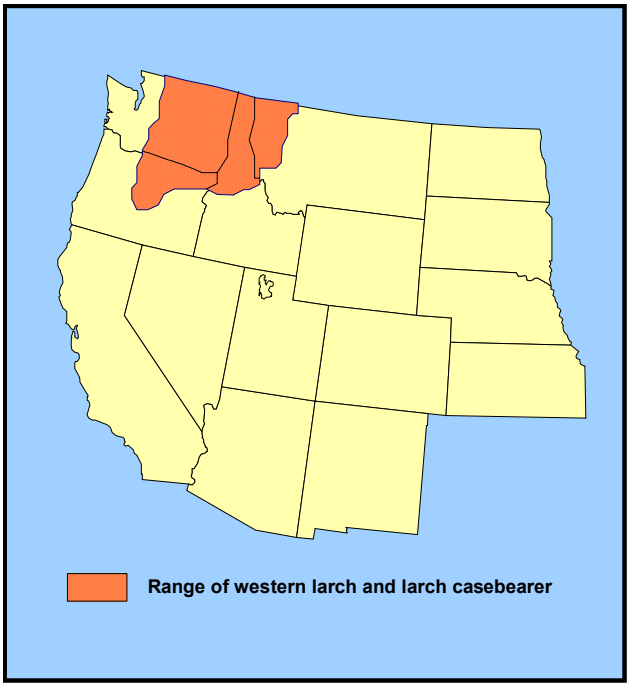

Figure 5 – Distribution of western larch and larch casebearer in the western U.S.

Figure 6 – Larch casebearer. Left: defoliation of western larch; right: overwintering larvae on branch

Larch Sawfly

Scientific Name of Causal Agent - *Pristiphora erichsonii*

Type of Agent – Insect (Foliage feeding sawfly).

Native Habitat - Two strains of this insect are native and two strains introduced into North America are native to Europe (Furniss and Carolin 1977).

Means of Introduction - Unknown – first detected in Massachusetts in 1880. Detected in **Montana** in 1964 and in **Oregon** and **Alaska**, 1965 (Furniss and Carolin 1977).

Means of Spread - Flying adults

Hosts - All species of larch are affected.

Type of Damage - Larvae defoliate trees. Repeated defoliation causes growth loss and, in some cases, tree mortality.

Current Status - Larch sawfly is currently at epidemic levels in tamarack (eastern larch) forests in **Alaska**. In 1999, 190,000 acres of defoliation were mapped. Defoliation declined to 65,000 acres in 2000. Larch mortality, attributed to several successive years of defoliation, is occurring throughout the range of larch in **Alaska** (USDA Forest Service 2001).

Defoliation by larch sawfly was observed on ornamental Siberian larch in the Anchorage area. This is the first time that this insect has been detected south of the Alaska Range and may represent a new introduction. Efforts are being undertaken to eradicate the insect from these urban areas (USDA Forest Service 2001).

Pest Management Tactics - Some exotic parasitoids have been introduced. One introduced strain of this insect has developed a resistance to one of the introduced parasitoids (Furniss and Carolin 1977).

Potential for Future Damage - Periodic outbreaks of this insect can be expected in the future.

European Elm Scale

Scientific Name of Causal Agent - *Gossyparia spuria*

Type of Agent - Insect (Twig infesting scale)

Native Habitat- Europe

Means of Introduction - Unknown

Means of Spread - Movement of immature stages by air currents.

Hosts - Elms

Type of Damage - Heavy infestations cause premature yellowing and shedding of leaves and killing of twigs and branches. Small trees may be killed. Honeydew and black sooty mold associated with infestations can be a nuisance (Furniss and Carolin 1977)

Current Status - This insect is widely distributed throughout the West.

Pest Management Tactics - Several insecticides are registered for control of elm scale in urban areas. Injection of trees with systemic insecticides is an alternative control method.

Potential for Future Damage - This insect is expected to be a continuing pest of shade and ornamental trees in urban communities and windbreak plantings in the Great Plains.

Elm Leaf Beetle

Scientific Name of Causal Agent - *Pyrrhalta luteola*

Type of Agent - Insect (Foliage feeding beetle).

Native Habitat - Europe

Means of Introduction - Unknown

Means of Spread - Adult beetles are strong fliers

Hosts - Elms

Type of Damage - Both the larvae and adults feed on the foliage of elm trees. Defoliation is often severe, especially in late summer. Adults like to overwinter in homes, thus the insect can be a nuisance. This is a serious pest of ornamentals but of little or no consequence in forests (Furniss and Carolin 1977).

Current Status - This insect is a common pest of elms in urban areas throughout most of the U.S.

Pest Management Tactics - Several insecticides are registered for control of elm leaf beetle in urban areas. Banding of trunks with insecticides to control migrating larvae and injection of trees with systemic insecticides are alternative control methods (Cranshaw and Zimmerman 1996).

Potential for Future Damage - Repeated defoliation of ornamental elms.

Oystershell Scale

Scientific Name of Causal Agent - *Lepidosaphles ulmi*

Type of Agent – Insect (Bark infesting scale)

Native Habitat - Probably Europe

Means of Introduction - Unknown

Means of Spread - Movement of immature stages by air currents

Hosts - Aspen, birch, lilac, maples, poplars, sycamore and willows (Furniss and Carolin 1975). Aspen is a common host in urban areas along the Front Range of **Colorado**.

Type of Damage - The Oystershell scale infests twigs, branches and smooth, thin barked stems of host trees. Heavily attacked trees can be weakened and killed (Furniss and Carolin 1975). This insect is only a problem in urban areas and is of no consequence in forests.

Current Status - This insect is widespread throughout North America

Pest Management Tactics - This insect can be particularly difficult to control. Dormant oils, applies at the rate of 2 gallons per 100 gallons of water can be used just before bud break. Scales can also be scrubbed from trees and shrubs with a plastic scrub pad. Several chemical insecticides are registered for application on ornamental trees when immature stages are present in early summer (Cranshaw 1996).

Potential For Future Damage - This insect will continue to be an important pest of ornamental and shade trees throughout the U.S.

Leucaena Psyllid

Scientific Name of Causal Agent – *Heteropsylla cubana*

Type of Agent – Insect (jumping plant louse)

Native Habitat – Caribbean Basin, Central and, possibly, portions of South America

Means of Introduction – Probably carried by air currents (Waterhouse and Norris 1987).

Means of Spread – Air currents

Hosts – This insect is associated with leguminous trees of the genera *Leucaena, Mimosa* and *Piptadenia.* Various species of *Leucaena*, all native to the tropical regions of the New World, are the most common hosts, especially *L. leucocephala*, a tree widely planted throughout the tropics as a multipurpose tree. A number of genetic strains of *L. leucocephala* have been developed for fuelwood and agroforestry purposes including the giant leucaena, which is known as the "fastest growing tree in the world." Wild or common leucaenas have established themselves throughout the tropics and in some areas are considered invasive species (Banpot Napompeth 1990).

Type of Damage –Nymphs and adults feeding on young shoots, leaves and flowers of leucaena (Fig 7). This can cause complete defoliation of host plants. In severe cases, plants cannot recover resulting in growth loss, dieback and tree mortality (Banpot Napompeth 1990)

Current Status – In late 1983, Leucaena psyllid was found attacking, defoliating and causing dieback of leucaena in Florida. The following year, it was reported in Hawaii. During the period 1984-86, Leucaena psyllid spread across the Pacific Islands. It was first reported in Australia in 1986 (Waterhouse and Norris 1987) insular and continental southeast Asia in 1987, the Indian Ocean islands of Mauritius and Reunion in 1991 and 1992 respectively and in East Africa (Kenya and Tanzania) in 1993 (Ciesla 1994).

This insect was discovered in American Samoa in November 1985 and Guam in March 1985 (Waterhouse and Norris 1987).

Pest Management Tactics – Chemical pesticides have been used successfully as a short- term control measure. Several predators and parasites of Leucaena psyllid have been found in Central America. Three of these, a predaceous beetle and two parasitic wasps have been introduced into **Hawaii,** Southeast Asia and the Pacific. Planting of leucaena varieties resistant to the psyllid has also been successful.

Potential for Future Damage – This insect is expected to continue to have adverse effects on multipurpose leucaena plantings throughout the tropics.

Figure 7 – Leucaena shoot and foliage infested with nymphs and adults of *Leucaena psyllid.*

Pathogens Established in the Western U.S.

Several pathogens, accidentally introduced into U.S. forests, have caused high levels of damage and have irreversibly altered the character of some forests. For example, the fungus *Cryphonectria parasitica*, which causes chestnut blight, was introduced into the United States in 1904 and spread rapidly through the forests of the East, killing virtually all native chestnuts. In some areas, one third of the trees were chestnut, a tree highly valued for its excellent wood properties, resistance to decay and edible nuts. In 1906, white pine blister rust, another native of Asia, appeared in eastern white pines. This disease also spread rapidly and in 1921 was discovered in the West, where it continues to spread today. Dutch elm disease came to the U.S. from Europe via elm logs infested by a bark beetle, *Scolytus multistriatis*, which is a vector of this disease. The introduction of Dutch elm disease virtually eliminated the American elm, a highly prized shade and ornamental tree, from cities and communities throughout the eastern and midwestern United States. Five species of invasive pathogens of concern in the western U.S. are reviewed in this section (Table 3):

Table 3 - Occurrence of Key Invasive Forest and Urban Diseases Caused by Invasive Pathogens by State in the Western U.S. as of 2000.

Pathogen	State															
	AK	AZ	CA	CO	ID	KS	MT	ND	NE	NM	NV	OR	SD	UT	WA	WY
White pine blister rust			X	X	X		X			X		X			X	X
Port-Orford cedar root disease			X									X				
Sudden oak death			X									X				
Pitch canker			X													
Dutch elm disease			X	X	X	X	X	X	X				X		X	

White Pine Blister Rust

Scientific Name of Causal Agent - *Cronartium ribicola*

Type of Agent – Fungus

Native Habitat - Asia

Means of Introduction – Initially introduced into the eastern U.S. on white pine nursery stock from Germany and to the West Coast on nursery stock imported from France.

Means of Spread - Spores carried on air currents.

Hosts - All five-needled or white pines are susceptible. In the western U.S., sugar pine, western white pine, limber pine, whitebark pine and southwestern white pine are damaged.

Currants and gooseberries, *Ribes* spp. are alternate hosts.

Type of Damage - The fungus attacks the branches and stems of host trees and produces a blister-like canker that kills the bark tissue resulting in girdling and death of all or a portion of infected trees.

A current concern about white pine blister rust is the high level of mortality it is currently causing in high elevation forests of whitebark and limber pines. The extensive tree mortality may have significant effects on forest ecosystems including water and wildlife habitat.

Current Status - This disease has spread throughout the range of eastern white pine and has changed the way white pine is managed in many areas. It was also introduced into western North America on nursery stock imported from France in 1910 and has now spread throughout much of the West affecting all indigenous five-needled pines and causing significant tree mortality (USDA Forest Service 1996).

This disease continues to spread to new areas in the West. In 1990, it was found affecting southwestern white pine in **New Mexico**. By 1995, about one-half million acres were affected, resulting in mortality of commercially valuable five-needle pines, loss of five-needle pines in fragile alpine ecosystems, and loss of a source of food for several wildlife species (USDA Forest Service 1996). White pine blister rust was found for the first time in **Colorado** on the **Roosevelt National Forest** in 1998 (USDA Forest Service 2000) (Fig. 8).

Pest Management Tactics - When the disease was first discovered, massive control programs to remove currant and gooseberry plants from areas where white pines occurred

were organized by USDA Forest Service and state forestry agencies. These programs were discontinued in the late 1960s because they were determined to be only marginally effective. Development, propagation and planting of white pines genetically resistant to white pine blister rust is being used to re-establish white pines in some areas of the West.

Potential for Future Damage - Continued spread of white pine blister rust in the southwestern United States can be expected. Spread into portions of **California, Colorado** and **Nevada** could threaten a fragile and unique resource in areas where bristlecone pine, a tree capable of living to extremely old ages (> 4,000 years), occurs.

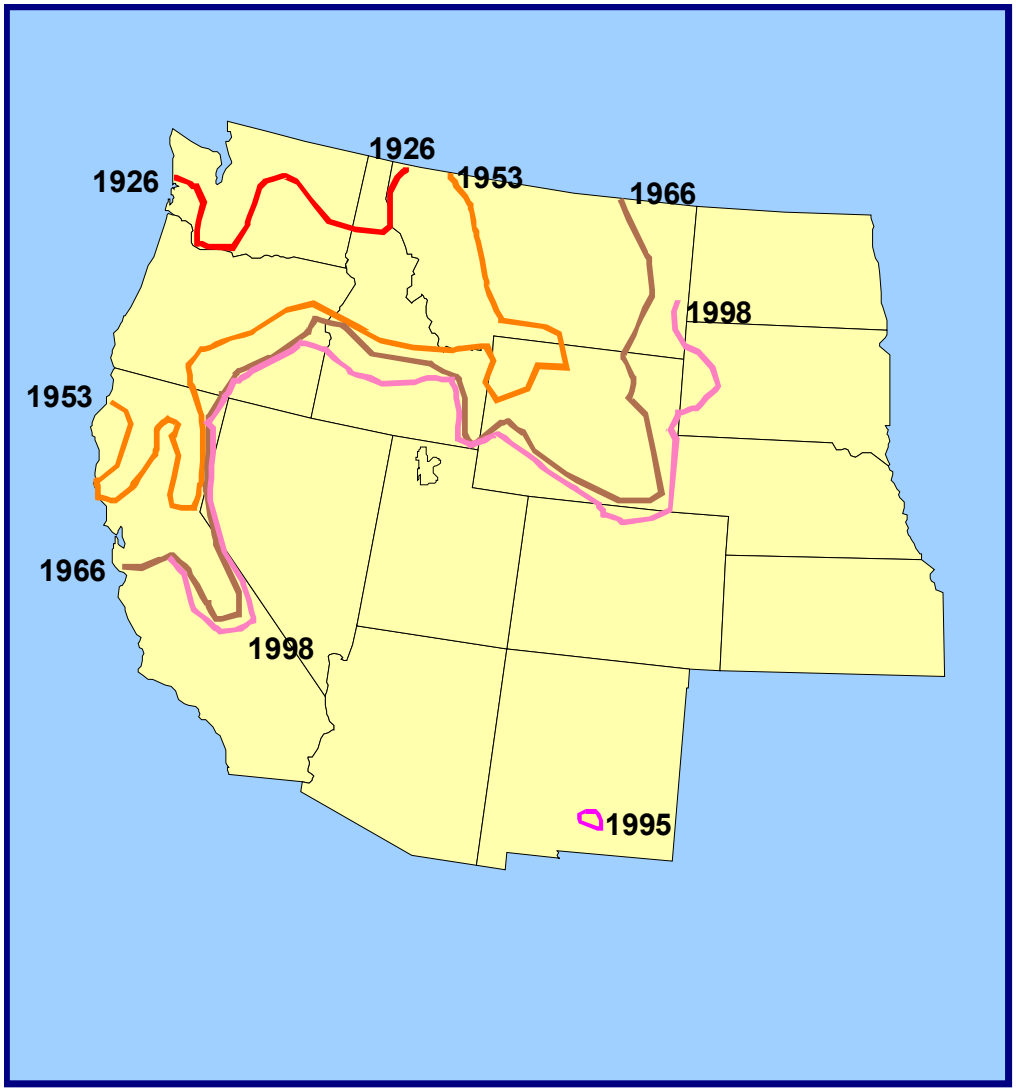

Figure 8 – Spread of white pine blister rust in the West – 1926-1998

Sudden Oak Death

Scientific Name of Causal Agent - *Phytophthora ramorum.* This species is new to science and was discovered as a result of investigations into the cause of sudden oak death.

Type of Agent - Oomycete or "water mold"

Native Habitat - Unknown. Infected plants have been found in Germany and the Netherlands.

Means of Introduction - Unknown

Means of Spread -. Short distance spread is most likely by wind driven rain and fog. Long distance spread may occur in infested bark, soil, or nursery stock. Bark beetles, which invade and breed in infected trees, could become infected and spread the disease to neighboring trees.

Hosts - Oaks: including Coast live oak, California black oak, and Shreve's oak, tanoak, California buckeye, Oregon myrtle, Pacific madrone, evergreen huckleberry, arrowood and rhododendron (Oregon Department of Agriculture 2001). Infected rhododendrons have been found in Germany and the Netherlands.

Laboratory studies indicate that at least two species of eastern oaks: northern red oak and pin oak are susceptible to the pathogen.

P. ramorum DNA has recently been recovered from dead sprouts on redwood trunks (Society of American Foresters 2002). However, redwood is not considered a host at this time.

Type of Damage - Symptoms vary depending on the host and include leaf spots, bleeding cankers, stem lesions and dieback. Oaks, tanoaks, rhododendron, Pacific madrone and evergreen huckleberry have been killed by this fungus (Oregon Department of Agriculture 2001).

Current Status - This condition was discovered near Mill Valley, **California** in 1995. By 2001, 10 counties in coastal and central **California** had confirmed cases of this disease and areas of extensive tree mortality. Sudden oak death was discovered in Curry County, **Oregon** in 2001 (Oregon Department of Agriculture 2001) (Fig. 9).

Pest Management Tactics - No control methods are available at the present time. Restricted movement of firewood and ornamental plant materials from infested to uninfested areas is recommended as a prevention tactic. The Oregon Department of Forestry has enacted a quarantine that forbids importing of tanoak, black oak, coast live oak and other host plants from infested **California** counties (Oregon Department of Agriculture 2001). An interim Federal quarantine prohibiting movement of plant

material from infested counties in **California** and the infestation zone in **Oregon** has been established. **Oregon** is attempting eradication by cutting and burning all host materials in infested areas plus a buffer. Monitoring of this eradication treatment is underway.

Potential for Future Damage - Sudden oak death has the potential to spread over long distances and threaten the biodiversity of broadleaf forests on the Pacific coast. Moreover, should this disease spread to the extensive oak forests of the eastern United States, the impact could be devastating.

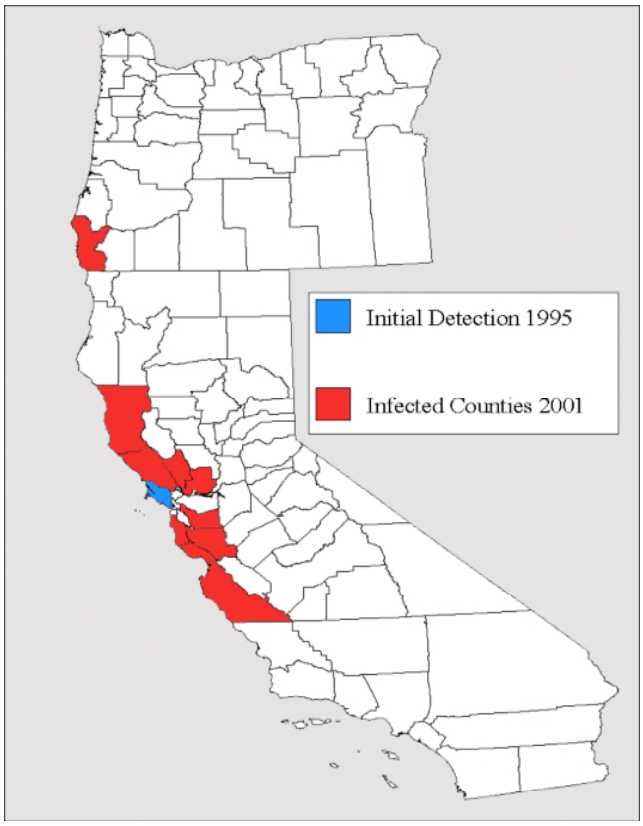

Figure 9 – Known distribution of sudden oak death as of 2001

Pitch Canker

Scientific Name of Causal Agent - *Fusarium circinatum.* Also referred to as *Fusarium subglutinans* f. sp. *pini.*

Type of Agent - Fungus

Native Habitat – Pitch canker was first reported on Virginia pine in North Carolina in 1946. The disease was subsequently reported in Haiti in 1953. Pitch canker was considered an indigenous pathogen of the southeastern U.S. for many years (Dwinnel n.d) but more recently its origin has been questioned.

Means of Introduction - Unknown

Means of Spread - The pathogen produces airborne spores that can be spread by wind and carried by native insects. Insects known to carry the pathogen include bark beetles and twig beetles, which feed under the bark of large and small diameter tree material respectively, and cone beetles, which attack cones on the host tree. Many of these insects are known to transmit the pitch canker fungus to healthy trees and are considered to be the primary means by which new infections are established. Although beetles can spread the disease to new areas, long distance spread is more likely to result from people transporting logs, nursery stock, seeds or soil in which the pathogen is known to survive for long periods of time.

Hosts - In **California**, Aleppo pine*[6], bishop pine, Canary Island pine*, Coulter pine, digger pine, Italian stone pine*, knobcone pine, Monterrey pine, ponderosa pine, shore pine, Torrey pine and Douglas-fir have been infected by pitch canker. Monterrey pine appears to be most frequently affected (Storer and others 1994).

In the southeastern U.S., all of the southern yellow pines are affected.

Type of Damage - Pitch canker causes a resinous exudation on the surface of the shoots, branches, exposed roots and boles of infested trees. Removal of bark reveals a slightly sunken, honey-colored wood that is resin soaked. Infections can result in branch dieback, tree mortality and loss of cones.

Current Status - In the United States, prior to 1986, pitch canker was only known from the southeastern states. The disease was first recognized in **California** in 1986. It has also been found in various parts of the world, including Mexico, Japan and South Africa. Within **California**, pitch canker is limited to coastal areas, mostly from San Diego to Mendocino counties. To date there are no confirmed records of pitch canker from the

[6] Asterisk indicates a host tree exotic to California

Sierra Nevada or other locations east of the central valley, or farther north than Mendocino County. All infested areas are presently on state or private lands.

Worldwide, pitch canker is found in many countries. In addition to Haiti and the U.S., it has been found in Japan and Mexico. In the 1990, it was reported to induce a root rot of containerized pine seedlings in South Africa and the mortality of pine seedlings in bare root nurseries in Spain (Dwinnel n.d.).

Pest Management Tactics - Preventing the movement of infected plant materials to areas that are presently uninfested is the primary means of containing the infestation. The California Board of Forestry has established a Coastal Pitch Canker Zone of Infestation to help accomplish this (Fig. 10). Any firewood, cones, logs, and chipped pine material should be utilized in the local area where it originated. These materials may carry the fungus, its insect vectors, or both, and increase the risk of spread of the disease if transported outside of the local area.

Potential for Future Damage - This disease has the potential to spread into the forests of the Sierra Nevada or into neighboring **Oregon**.

Monterrey pine is the most widely planted pine in the world, and extensive plantations are found in Australia, Chile, New Zealand and northern Spain. The occurrence of pitch canker in California's three relict stands of Monterrey pine and resulting tree mortality could reduce the amount of germplasm available for tree improvement programs worldwide.

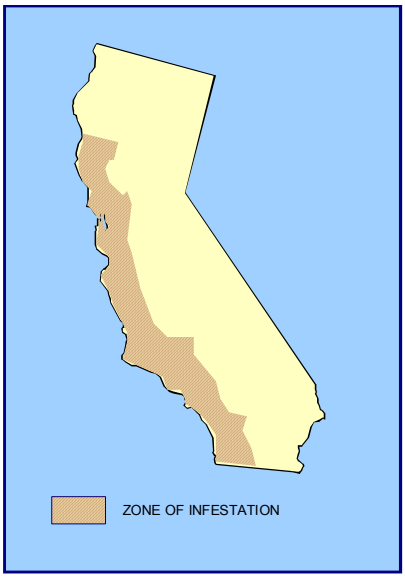

Figure 10 – Coastal Pitch Canker Zone of infestation established by the California Board of Forestry

Port-Orford Cedar (POC) Root Disease

Scientific Name of Causal Agent - *Phytophthora lateralis*

Type of Agent – oomycete or water mold

Native Habitat - The origin of this fungus is unknown, but the high susceptibility of Port-Orford cedar suggests that the fungus evolved outside the tree's natural range, possibly in Asia. Closely related Asian species are somewhat resistant to the disease, which suggests a long association between these trees and the pathogen. This fungus has not been found in Asia, however (Roth and others 1987).

Means of Introduction - Unknown.

Means of Spread - Major spread is through movement of soil from infested areas to uninfested areas during construction, road maintenance and use, and timber harvesting. Surface water is also important in moving the fungus. Mud clinging to the feet of domestic livestock or wildlife may also spread the fungus (Roth and others 1987).

Hosts - Port-Orford cedar, Pacific yew

Type of Damage - The pathogen infects the root systems of host trees and kills them. All sizes of trees, from seedlings to mature trees, are susceptible. Port-Orford cedar root disease is considered to be the most serious disease of Port-Orford cedar, perhaps the most valuable saw-timber species growing in **California** and **Oregon** (Roth and others 1987).

This disease has become so severe on ornamental trees in northwestern **Oregon** and western **Washington** that the production of horticultural varieties of Port-Orford cedar for the landscape industry, once a major industry in the Northwest, has been abandoned.

Current Status - This disease was first reported on ornamental trees near Seattle, **Washington** in 1923 and in the Willamette Valley of **Oregon** in 1942. In 1952, the disease was found in southwestern **Oregon** (Roth and others 1987). It is now found throughout most of the range of Port-Orford cedar in northern **California** and southwestern **Oregon** (Fig 11).

Recent surveys of this disease in **California** indicate that tree mortality is occurring in the upper Sacramento River Canyon. In addition, new infestations have been found on the **Six Rivers National Forest**, and the disease is continuing to spread and intensify in portions of **Redwood National Park** (USDA Forest Service 2000).

In **Oregon**, tree mortality caused by Port-Orford cedar root disease occurs primarily along creeks, in low-lying areas, and below roads where water is channeled. Aerial surveys conducted in 1999 indicated that tree mortality occurred over 4,300 acres (1.48 trees/acre) and in 2000, over 5,200 acres (0.97 trees/acre). Mortality occurs in scattered

pockets or individual trees. On National Forest lands (**Siskiyou National Forest**), slightly less than 10% of all Port-Orford cedar is affected (USDA Forest Service 2000).

Pest Management Tactics - The only viable tactic available is to restrict the movement and activities of vectors of the disease, principally humans. Active restrictions include closing roads to travel, requiring dry season timber harvesting and cleaning all vehicles before they leave infested areas or enter clean areas. Passive restrictions include locating Port-Orford cedar production areas in sites where people and their vehicles are not likely to be present (Roth and others 1987).

Potential For Future Damage - In the future, continued tree mortality from this pathogen can be expected. However, through diligent application of available pest management tactics, Port-Orford cedar should continue to be a viable tree species within its natural range

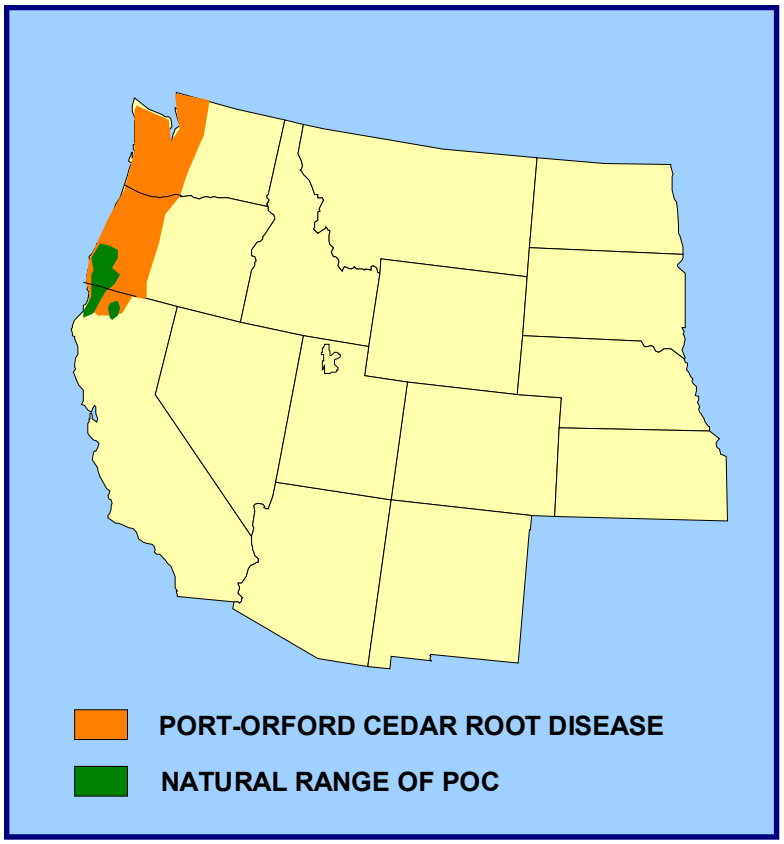

Figure 11 – Distribution of Port-Orford cedar and Port-Orford cedar root disease in California, Oregon and Washington.

Dutch Elm Disease (DED)

Scientific Name of Causal Agent - *Ophiostoma ulmi*

Type of Agent - Fungus

Native Habitat - Asia

Means of Introduction - Elm logs imported into the U.S. from Europe.

Means of Spread - Once established in an area, the disease is spread from tree to tree by two species of bark beetles: the European elm bark beetle and the native elm bark beetle. The fungus can also spread from tree to tree via root grafts.

Hosts - Elms. Most North American and European species of elms are highly susceptible to this fungus. Chinese and Siberian elms are tolerant to the disease and suffer relatively little damage.

Type of Damage - The fungus invades the tree's vascular system and prevents translocation of nutrients. Once infected, trees die. Dutch elm disease has killed millions of American elms throughout the eastern and Midwestern U.S. and has significantly reduced the viability of this tree as a shade tree.

Current Status - DED is established in a number of western states where it has become an important pest of urban trees. It is also killing native elms growing in riparian areas in several sates in the Great Plains.

This disease is continuing to spread in urban areas in **Montana** and **North Dakota**. **Montana's** heaviest losses are presently occurring in the cities of Billings and Great Falls. In **North Dakota**, heavy losses have occurred in both urban areas and in naturally occurring elms in riparian zones. In **Idaho**, DED is common in many communities along the Snake River and is slowly working its way north. DED was discovered in Moscow in 1990, but an aggressive treatment program has limited losses to only a few trees per year for the past several years. DED has also been discovered in Genesee and Palouse, **Idaho** and Pullman, **Washington** (USDA Forest Service 2001).

DED has been a continuing problem in urban areas of **Colorado**, especially on the eastern plains. In 2000, losses were below recent historical levels, however. This disease continues to be a problem in riparian areas and cities throughout **Nebraska**. **Kansas** also had numerous reports across much of the state. DED has been so widely established in **Kansas** that tree mortality associated with the disease is considered "normal (USDA Forest Service 2001)."

Pest Management Tactics - Pest management measures include prompt removal and destruction of infected trees, application of insecticides during the flight period of the insect vectors of DED and elimination of suitable breeding sites for elm bark beetles such

as elm firewood. Some DED resistant elms have been developed and are being evaluated.

Potential For Future Damage - The potential for spread into additional parts of the West is high and is expected to continue. Continued tree mortality of elms in communities where they are still important landscape trees can be expected.

Invasive Plants Established in the Western U.S.

Of the thousands of introduced plant species established in the U.S., about 1,400 are recognized as pests. Currently 94 species of exotic plants are officially listed as Federal Noxious Weeds, and many more species are designated on state noxious weed lists. Experts estimate that invasive plants already infest well over 100 million acres and continue to increase by 8 to 20 percent annually (Westbrooks 1998).

Invasive plants threaten agricultural production and biodiversity. Croplands, rangelands, forests, parks, preserves, wilderness areas, wildlife refuges and urban spaces are all adversely affected. The habitat of about two thirds of all threatened and endangered species is threatened by invasive plants (FICMNW 1998). Many invasive plants are primarily pests of rangelands. However they are also capable of invading open forests and can cause major changes in forest ecosystems.

On Federal lands in the western United States, invasive plants or weeds occur on more than 17 million acres. On **National Forest System (NFS**) lands, an estimated 3.6 million acres[7] are currently infested.

Invasive plants do not constitute a separate biological category. However, they do have certain characteristics that allow them to rapidly invade new areas and compete with native plants for available light, water, and nutrients. These include (Westbrooks, 1998):

1. Early maturation
2. Profuse reproduction by seeds and/or vegetative structures
3. Long life in the soil
4. Seed dormancy that ensures periodic germination and prevents seedlings from sprouting during unfavorable conditions
5. Adaptations for spread with crop seeds and by natural agents and humans
6. Production of biological toxins that suppress the growth of other plants
7. Prickles, spines or thorns that can cause physical injury and repel animals
8. The ability to parasitize other plants
9. Seeds that are the same size and shape as crop seeds, which makes cleaning difficult.

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[7] Personal communication, Rita Beard, Range Ecologist, USDA Forest Service, Fort Collins, CO.

Cheatgrass

Scientific Name Of Causal Agent - *Bromus tectorum*

Type of Agent - Annual grass

Native Habitat - Mediterranean Europe and North Africa

Means of Introduction - Introduced from the Mediterranean Region in the late 19th century with packing material. Cheatgrass was first found in the U.S. near Denver, **Colorado** in the late 1800s (Westbrooks 1998).

Means of Spread - Cheatgrass reproduces by seeds. Since its introduction, cheatgrass has been spread by trains, livestock and wildlife (Westbrooks 1998).

Type of Damage - Cheatgrass is highly competitive and has replaced most of the natural bunchgrasses in the sagebrush ecosystem of the Great Basin. Growing more densely than the naturally scattered bunchgrasses, it utilizes much of the open space between shrubs. During the dry summers of this region, cheatgrass rapidly dries out and becomes an abundant and pervasive source of fuel. The highly flammable cheat grass alters the frequency and intensity of fires on western rangelands. Instead of major fires occurring every 60 years, they now occur every three to five years. The restoration and reconstruction of facilities lost in cheatgrass fires costs millions of dollars annually. Moreover, native sagebrush and grassland communities have been displaced in many areas (Westbrooks 1998).

Cheatgrass is a major weed pest in winter wheat in the **Pacific Northwest** and the **Great Plains**. In the Palouse Region of **Idaho** and **Washington**, a population density of about 105 cheatgrass plants per square yard reduces wheat yields by 27% (Westbrooks 1998).

By the 1950s, cheatgrass had also invaded piñon-juniper woodlands, and fires became more common in this forest type. Trees were slow to return, and little cover was reestablished even after 60 years. Cheatgrass, however, was quick to reestablish. Therefore, some piñon-juniper woodlands have been replaced by cheatgrass (Billings 1994).

Current Status - By the 1940s, this grass had spread into every state in the U.S. and portions of Canada and Mexico. It is now universally present on 100 million acres of rangeland in the western U.S. (Mitchell 2000). In **Nevada** and **Utah**, almost 17.5 million acres are almost totally infested by cheatgrass (Westbrooks 1998).

FIA data from the Rocky Mountain Research Station, USDA Forest Service, indicate that the occurrence of cheatgrass in piñon-juniper forests is still relatively low. The westwide average of the FIA plots occurring in piñon-juniper woodlands having $\geq$ 5 percent cheatgrass cover is 1.7 percent (Table 4).

Table 4 - Levels of Cheatgrass Infestation in Piñon-Juniper Forests in the U.S.

State	Year of last FIA survey	Number of FIA plots In pinion-juniper forests	Number of plots with ≥ 5 percent cheatgrass cover	Percent of plots with ≥ 5 percent cheatgrass cover
AZ	1999	2065	21	1.0
CA	--	58	3	5.2
CO	1983	326	9	2.8
ID	1991	141	11	7.8
MT	1989	240	2	0.8
NV	1989	482	12	2.5
NM	2000	1919	12	0.6
SD	--	17	0	0.0
UT	1993	1483	42	2.8
WY	2001	269	8	3.0
Total		**7000**	**120**	**1.7**

Source: FIA, Rocky Mountain Research Station, Ogden, UT.

Pest Management Tactics - This grass has become so widespread that control is no longer feasible except in a few localized areas.

Potential For Future Damage - Continued invasion of cheatgrass into new areas can be expected, including an increase and intensification of cheatgrass populations in piñon-juniper forests.

Dalmation Toadflax

Scientific Name of Causal Agent - *Linaria damatica* ssp. *damatica*

Type of Agent - Perennial plant

Native Habitat - Southeastern Europe

Means of Introduction - Unknown

Means of Spread - Transport of seed via air currents, wildlife, trucks and heavy equipment.

Type of Damage - Once established, this plant develops an extensive and deep root system that outcompetes native plant species and reduces species diversity. It has limited forage value for livestock and wildlife (Westbrooks 1998).

Current Status – Dalmation toadflax occurs in all 16 states of the continental western U.S. It is listed as a noxious weed in 11 western states.[8] In **Wyoming**, dalmatian toadflax was discovered about 30 years ago in the BLM Raymond Mountain Wilderness Study Area near Border Junction. The source of the infestation is believed to be a phosphate mine adjacent to the Study Area. During the years the mine was in operation, trucks and heavy equipment transported seeds to the mine site. By 1991, toadflax had invaded 63 acres in the Wilderness Study Area and 148 acres of adjacent private land. Area of infestation has increased 4x (Westbrooks 1998).

Pest Management Tactics - Aerial application of the herbicide Tordon is being used. A flower-feeding beetle has been introduced and appears to be overwintering in areas of cold winter temperatures such as Wyoming.[9]

Potential for Future Damage - Continued spread and intensification of infestations can be expected.

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[8] Source: http://plants.usda.gov

[9] Personal communication, Rita Beard, Range Ecologist, USDA Forest Service, Fort Collins, CO.

Leafy Spurge

Scientific Name of Causal Agent - *Euphorbia esula*

Type of Agent- Perennial herb (Fig 12).

Native Habitat - Leafy spurge is native to Eurasia with its center of distribution being the Caucuses region of Georgia and Russia (Haber 1997)

Means of Introduction - Leafy spurge was brought into the U.S. as a seed contaminant around 1827.

Means of Spread - Leafy spurge is a prolific seeder. Seeds can float downstream in waterways and readily produce new infestations.

Type of Damage - Leafy spurge can successfully compete against native plants and often forms dense stands that crowd out most other vegetation. Infestations cause loss of plant diversity, loss of wildlife habitat, and reduction of land values.

Leafy spurge is primarily a problem on rangelands. Cattle refuse to graze in areas with 10 to 20 percent leafy spurge cover because the milky sap produced by the plant is a digestive irritant and causes lesions around their eyes and mouth. From a management standpoint, a range with 80 percent leafy spurge cover reduces the carrying capacity of the land to zero. Leafy spurge also infests forest openings and displaces more desirable native plants (Westbrooks 1998) (Fig. 12).

While leafy spurge is primarily a pest of rangelands, it is capable of invading open forests and woodlands and displacing understory vegetation.

Current Status - Leafy spurge is present throughout the U.S. except for the Southeast. The most widespread and heaviest infestations are in the northern and central Great Plains, with the most extensive infestations reported for **Montana, North Dakota, Nebraska, South Dakota** and **Wyoming**.

In 1991, estimates of economic impacts of leafy spurge indicated that ranchers and landowners lost $2.2 million in Montana, $1.4 million in South Dakota and $200,000 in Wyoming. Studies of direct and secondary impacts on grazing, wildlife, and the state, economy, **North Dakota** was expected to lose in excess of $87 million due to leafy spurge infestations. Almost 6 percent of the untilled land in North Dakota is infested with leafy spurge (Westbrooks 1998).

In 1994, grazing capacity lost to leafy spurge in Montana, North and South Dakota, and Wyoming would have supported a head of about 90,000 cows generating about $37.1 million in livestock sales.

Pest Management Tactics - Pest management tactics include application of herbicides, cultural methods, grazing by goats and sheep and classic biological control. Biological control research has discovered 13 species of insects that will feed on and suppress leafy spurge.

Potential For Future Damage - Continued spread and intensification of leafy spurge infestation can be expected despite control efforts and will be accompanied by more severe economic and ecological impacts.

Figure 12 – Leafy spurge. Left: close-up of flower; right: field infested with leafy spurge.

Yellow Star Thistle

Scientific Name Of Causal Agent - *Centaurea solistitalis*

Type of Agent - Annual herb.

Native Habitat - Yellow star thistle is native to dry habitats in Mediterranean Europe

Means of Introduction - This plant was first introduced into southeastern **Washington** as a contaminant in alfalfa seed during the early 1900s.

Means of Spread - Alfalfa and clover seed contaminated with yellow star thistle seeds are important agents of spread. Contaminated grass seed, used to stabilize soils following a wildfire in the Hells Canyon area of **Oregon**, resulted in the introduction of this invasive. Small infestations have been associated with movement of recreational vehicles.

Type of Damage - Yellow star thistle competes with and displaces native plants. Several species of endemic plants are threatened by its presence. The plant is spiny and can be a nuisance.

Current Status – Found throughout the western US except **Alaska**. It is currently estimated that yellow star thistle infests 9.25 million acres of rangeland in the western U.S. including 8 million acres in **California**, 1.1 million acres in **Idaho**, 10,000 acres in **Oregon**, and 135,000 acres in **Washington**. In California, yellow star thistle has expanded its range at an alarming rate, increasing from 1.25 million acres in 1958 to 8 million acres in 1991. To date, all known infestations of yellow star thistle in **Montana** have been eradicated (Westbrooks 1998)

In the **Hells Canyon National Recreation Area** (on the border of **Idaho, Oregon** and **Washington**) infestations of star thistle threaten the existence of a rare species of mariposa lily that grows only in Hells Canyon (FICMNEW 1998a).

Pest Management Tactics - Herbicides can be used to treat infestations but are unrealistic to apply in remote areas (e.g., **Hell's Canyon NRA**). A cooperative project, involving the **Nezperce National Forest,** the Salmon River Weed Management Area and the University of Idaho is underway in **Idaho** to evaluate insects that damage the seed heads of yellow star thistle. In **California**, prescribed burning has been used to control infestations (USDA Forest Service 1999).

Potential For Future Damage - Continued spread and intensification of yellow star thistle infestations can be expected. Some rare and endemic plants could be threatened with extinction.

English Ivy

Scientific Name of Causal Agent - *Hedera helix*

Type of Agent - Vine

Native Habitat - Eurasia

Means of Introduction - English ivy was introduced as an ornamental during colonial times.

Means of Spread - This vine easily escapes cultivation and becomes established in forested areas.

Type of Damage - English ivy forms "ivy deserts" in forests, which inhibit regeneration of wildflowers, trees, and shrubs. It adds weight to the canopy structure and can make trees more susceptible to storm damage (Westbrooks 1998).

Current Status - This plant occurs in **Arizona, California, Oregon, Utah** and **Washington**.[10] It is especially invasive in western **Oregon** and **Washington** (Westbrooks 1998).

Pest Management Tactics - Mechanical removal of infestations is effective. In **Oregon** and **Washington**, citizens groups spend weekends removing infestations from natural areas (Westbrooks 1998).

Potential For Future Damage - Continued spread and intensification of infestations can be expected.

[10] Source: http://plants.usda.gov

Spotted Knapweed

Scientific Name of Causal Agent - *Centaurea beiberstainii,*

Type of Agent - Biennial or short-lived perennial plant.

Native Habitat - Southern Europe to north central Ukraine (Beck 1995)

Means of Introduction - Introduced as a contaminant in alfalfa and clover seed.

Means of Spread - Each plant produces up to 25,000 seeds that are dispersed by wind, animals, and people. Seeds may remain viable for 8 years. This plant becomes established on disturbed soils. Early spring growth gives the plant an advantage in competition for soil moisture and nutrients.

Type of Damage - Invades rangelands and open woodlands and displaces native vegetation. The flowers produce a locally important honey.

Current Status - Spotted knapweed is widely distributed in the U.S. and is present in every western state and **Hawaii**.[11]

In **Colorado**, the worst infestations occur along the Front Range in Larimer, Boulder, Douglas and El Paso counties. Severe infestations occur in Archuleta and La Plata counties (Beck 1995). A 1998 survey found 3,900 acres infested with spotted knapweed. Spotted knapweed was first observed in Gallatin County, **Montana**, in the 1920s, but is now found in all Montana counties. Today, over 4.7 million acres are infested.

Pest Management Tactics - Several biological control agents, a seed head moth and 2 seed head gallflies have been effective. Many insects are being evaluated for biological control of diffuse and spotted knapweeds. Researchers at Montana State University believe it will take a complex of insects (perhaps 12) to reduce spotted knapweed populations. Livestock (e.g., sheep, goats, cattle) will eat spotted knapweed.

Recent research completed by Colorado State University shows cattle grazing diffuse knapweed twice in spring decreased seed set by 50 percent. Cattle were managed to achieve 50 percent utilization of pasture and were allowed to graze at two 10-day intervals when diffuse knapweed was bolting and about 6 to 12 inches tall.

Herbicides can be used to control spotted knapweed.

Potential For Future Damage - Continued intensification of infestations and accompanying loss of native vegetation.

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[11] Source: http://plants.usda.gov

Klamath Weed (Saint John's Wort)

Scientific Name of Causal Agent - *Hypericum perforatum*

Type of Agent - Creeping perennial plant.

Native Habitat - Europe

Means of Introduction – Unknown. First reported in **California** in the early 1900s.

Means of Spread - This plant is a prolific seeder.

Type of Damage - Klamath weed contains substances that are toxic to livestock. It is also an aggressive invader of overgrazed rangeland that displaces native plants, which are important for maintaining soil nutrients, microbial activity and water cycling (Westbrooks 1998).

This plant is also a popular herbal medicine known as St. John's Wort.

Current Status – Currently found in all western states and **Hawaii** except **Arizona, New Mexico** and **Utah**. Klamath weed was first reported in northern **California** near the turn of the twentieth century. By 1944, it was found over 2 million acres in 30 counties (Delfosse 2001). This perennial has been a documented noxious weed in **California** since the 1920's. It is also frequently found in the Pacific Northwest and throughout the eastern half of the U.S. A large area in the north-central portion of **Colorado** and scattered areas in western **Colorado** are infested. Some localized infestations occur in **Rocky Mountain National Park**.

Pest Management Tactics - A successful biological control program has been in existence in **California** since 1946 using two beetles that are specific to Klamath Weed. The adult beetles can be found from May - July. Beetles have also been released in **Idaho, Montana, Oregon** and **Washington.** This has been one of the more successful programs of biological control of an invasive weed. Today in **California**, Klamath weed is regarded as "just another uncommon roadside weed" (Delfosse 2001).

Potential For Future Damage - Continued infestations in areas where this plant is currently established and possible spread into additional areas.

Scotch Broom

Scientific Name of Causal Agent - *Cytisus scoparis*

Type of Agent - Woody perennial plant

Native Habitat - Scotch broom originated in the Mediterranean area of Europe, and has a preference for the Mediterranean climate of mild winters and summer drought.

Means of Introduction - Scotch broom was introduced as a garden ornamental by early settlers of the Pacific Coast. It has spread far beyond the bounds of cultivation and now covers many acres west of the Cascades from British Columbia to California.

Means of Spread - Seeds are the principal means of spread. Its spread may be limited by either severe winter conditions or extreme summer drought. Locally, Scotch broom spreads slowly but persistently. Seedpods split suddenly at maturity and eject the seeds. Also, it is reported that ants aggressively collect the seed of Scotch broom, assisting in dispersal. Birds also assist with spread, but how well the seeds survive digestion varies with the species of bird (Parker and others 1994).

Type of Damage - The major negative impact of Scotch broom on the west coast is the threat to biodiversity in sensitive ecosystems. Wherever it grows, this aggressive plant spreads to form pure stands at the expense of desirable forbs, grasses, and young trees. Because it is a threat to native plant species and indirectly to animals that feed on the displaced plants, Scotch broom is a Class B noxious weed in **Washington** and **Oregon** (Parker and others 1994). Scotch broom is also a fire hazard because it increases fuel loading in the Sierra Nevada region of **California.**

Scotch broom has been reported by Europeans to be toxic to livestock (livestock loss is rare in the U.S.). Scotch broom contains small amounts of the toxins quinolizidine alkaloids, sparteine and isosparteine. These toxins probably are found in all parts of the plant. Children develop nausea and vomiting from sucking on the flowers of French broom, a related species (Parker and others 1994). Some people are allergic to the pollen.

Current Status - In **California**, it has spread across more than a half-million acres of rangeland. Scotch broom is moving rapidly into forestlands of western **Oregon** and **Washington**, where it is interfering with re-establishment of conifer seedlings on harvested lands. Scotch broom also is being found more frequently in areas east of the Cascades (Parker and others 1994).

Pest Management Tactics - Main control methods are pulling and cutting the plants. Pulling the plants disrupts the soil, which aids in sprouting of the seed bank - a possible benefit if resources are available to remove the new broom plants. Broom resprouts readily from a cut bush. However, the resprouting is reduced if the plant has been subjected to the stresses of flower/seed production and drought.

Biological control agents (e.g., a twig mining moth, a seed weevil, and a shoot tip moth) are available for control of Scotch broom but are only partially effective.

Herbicides are available that can control this weed.

Potential For Future Damage - Infestations are expected to continue to spread and intensify.

Russian Olive

Scientific Name of Causal Agent - *Elaeagnus angustifolia*

Type of Agent - Woody plant (Fig 13).

Native Habitat - Russian-olive is native to southern Europe and western Asia.

Means of Introduction - Russian-olive was first introduced for use as an ornamental tree and a windbreak in the United States in the late 1800s.

Means of Spread - In addition to sexual reproduction and the setting of abundant seeds and seedlings, Russian-olive also propagates itself by sprouts from adventitious buds formed on the root crowns and by root suckers. Burned areas are readily re-colonized through the production of root crown sprouts and offsite seed sources (Haber 1999).

Type of Damage - Russian-olive takes over stream banks, lake shores and wet meadows throughout the West (Westbrooks 1998).

Russian-olive has been promoted for a variety of beneficial uses such as erosion control, shelterbelt plantings, a source of wildlife food and honey production. However, it is increasingly being recognized for its invasiveness in natural areas, especially in riparian ecosystems. The plants can also rapidly colonize lowland fields and choke irrigation ditches in the western U.S. (Fig 13). Many marshlands in **South Dakota** have been replaced by Russian-olive woodlands. The wood of Russian-olive is of no commercial value, but the species is considered to be a fire-resistant plant (Haber 1999).

Communities dominated by Russian-olive are, generally, considered inferior wildlife habitats to those consisting primarily of native vegetation. The species forms dense thickets in riparian habitats to the exclusion of native species (Haber 1999).

Current Status - In the U.S, Russian-olive is now known to occur in 36 states. It was naturalized in **Utah** and **Nevada** by the mid 1920s and by the 1950s was also established in Colorado. Russian-olive is well established within the Platte River Drainage of **Colorado** and **Nebraska**. In the arid regions of the western U.S., Russian-olive is widely established within riparian ecosystems. In **Utah**, concern over the spread of Russian-olive has caused it to be declared a noxious weed (Haber 1999).

Pest Management Tactics - Once Russian-olive is established in unwanted areas, it is difficult to control and almost impossible to eradicate because of its habit of forming root shoots and suckers. Efforts at control have included mowing seedlings and sprouts, cutting or girdling stems, burning and herbicide application. Perhaps the most effective method of eliminating a tree is to cut the trunk or stem and apply an herbicide to the cut surfaces. Repeated aerial application of herbicides has been used in **Nebraska** as a means of controlling large trees (Haber 1999).

Natural disease agents are already present in North America that effect Russian-olive. Verticillium wilt and phomopsis canker, both fungal diseases, are now serious disease problems in some areas. This disease has caused extensive damage to Russian-olive in the eastern half of **Kansas** (Haber 1999).

Fort Collins, Colorado, has undertaken an active program of tree removal because of the extent of the species' impact on natural landscapes in the state (Haber 1999).

Potential For Future Damage - It is anticipated that if the species continues to expand as it has, it could become the dominant woody plant along **Colorado's** rivers where it has been estimated to occupy thousands of acres of cottonwood-willow riparian woodlands.

Figure 13 – Field invaded by Russian-olive (above), close-up of foliage (below)

Siberian Elm

Scientific Name of Causal Agent - *Ulmus pumila*

Type of Agent - Tree

Native Habitat - Siberian elm is native to northern China, eastern Siberia, Manchuria, and Korea.

Means of Introduction - Siberian elm was introduced to the U.S. in the 1860's and planted because of its fast growth. It has also been widely used in windbreak and shelterbelt plantings.

Means of Spread - If there is a nearby seed source, the tree can invade prairies and, in a few years dominate them, particularly if they have been subjected to past disturbance.

Type of Damage - Invades dry areas and moist soils along stream banks in pastures, prairies and along roadsides from **Utah** and **Idaho** eastward (Westbrooks 1998).

Current Status - Siberian elm is now established from Minnesota south to Arkansas and west to **Utah**.

Pest Management Tactics - Girdling trees is the preferred management technique where practical. If girdling is not an option, trees and any of their subsequent sprouts should be cut. If time constraints prevent cutting the new sprouts, the stumps created by the initial tree cutting can be treated with herbicides to prevent resprouting. Seedlings can be pulled out by hand, and small trees can be removed carefully by grub hoe.

Potential For Future Damage - Continued invasion of areas where this tree has escaped cultivation and possible spread westward can be expected.

Saltcedar

Scientific Name of Causal Agents - *Tamarix ramosissima, T. chinensis* and *T. parvifilia*

Type of Agent - Large shrub or small deciduous tree.

Native Habitat- Saltcedars are native to the arid regions of Eurasia.

Means of Introduction - These trees were first introduced into the United States as ornamentals in the early 19th century.

Means of Spread - Saltcedars are prolific seed producers and can quickly colonize moist areas (Westbrooks 1998).

Type of Damage - These trees are robust invaders of riparian rangeland ecosystems. Saltcedars have replaced native riparian trees such as cottonwoods and willows. Saltcedar invasion is a severe threat to the structure and stability of native plant communities. In some areas, water management practices and dam construction have stopped repeated scouring of riverbanks, thus further reducing the competitiveness of the native trees. Saltcedar has an extremely high transpiration rate and can lower water tables on its own, which gives it a competitive advantage.

Current Status - Saltcedars have successfully invaded nearly every drainage system in arid and semi-arid areas in the southwestern U.S. By 1961, at least 1,400 square miles of floodplain in the western United States were infested (Westbrooks 1998). Saltcedars now occupy most suitable habitats west of the Great Plains, north into **Montana** and south into northwestern Mexico, over 1 million acres. Since the 1960s 70 percent of the native vegetation in Afton Canyon, **California,** has been replaced by saltcedar. Along the floodplains of the Rio Grande in **New Mexico**, thick stands of saltcedar have limited the number of germination sites that are suitable to native riparian species. This has led to a precipitous decline in cottonwood populations (Westbrooks 1998).

Pest Management Tactics - There are no practical means of treating infested areas. Mature plants can resprout following fire, flood or treatment with herbicides (Westbrooks 1998).

Potential For Future Damage - Continued intensification of infestation and accompanying decline of native riparian species can be expected in the future.

Bluegum Eucalyptus

Scientific Name of Causal Agent - *Eucalyptus globulus*

Type of Agent - Tree

Native Habitat - Tasmania, Australia.

Means of Introduction - Eucalypts were planted throughout **California** in the 1800s as timber, windbreaks and decorative groves.

Means of Spread - Each tree drops hundreds of nuts each year. After cutting, the stumps or fallen trunks will sprout multiple whole new trees.

Type of Damage - Trees constantly drop their aromatic leaves, which slowly decompose and produce a heavy detrius layer that chokes out other vegetation, and affects the acidity level of creeks and water sources. The thick and high leaf canopy also robs other native species of light and moisture. Leaves dropped by these trees produce a layer of fire prone litter. Forests of eucalyptus in Australia are considered the most flammable in the world. Eucalypts are invasive in wildland settings, especially grasslands and shrublands in **California** (Westbrooks 1998).

Eucalypts, including bluegum are widely planted throughout the world. They grow quickly; produce lumber, honey and essential oils and are excellent windbreak plantings

Current Status - Bluegum eucalyptus is found in the coastal and central valley regions of **California.**

Pest Management Tactics -There are no effective measures available for treating this tree. Cut trees will resprout, and sprouts can grow at rapid rates. Several insects damage eucalypts (see section on eucalyptus borers); however, these insects would also damage and kill eucalypts on sites where they are desired.

Potential For Future Damage - Continued establishment of stands in unwanted areas resulting in additional areas of increased fuel levels. This tree is unlikely to spread beyond California.

Invasive Plants in Hawaii and the Pacific Islands

Oceanic islands throughout the world are especially susceptible to invasions of exotic species. Island plant ecosystems have evolved in isolation from forces to which plants and animals on large continents are routinely exposed. These include trampling by herbivores, predation, virulent diseases and wildfires. As a result island species lack adaptive mechanisms to protect themselves. Consequently they are less capable of competing with invasive species (Westbrooks 1998).

The Hawaiian Islands and the Pacific Islands territories have suffered severe invasions of higher animals, a subject not within the scope of this paper. On the island of Guam, for example, the invasive brown tree snake that was introduced in the 1940s has had severe impacts on the native fauna. This snake has eliminated 8 species of birds, 2 species of bats, and several reptiles. It is also detrimental to the electric utility industry and is a threat to human health and safety (NISC 2001). On many islands, feral goats and pigs have had severe impacts on native vegetation. Grazing by goats introduced onto the Mexican island of Guadalupe has eliminated natural regeneration of a relict, natural stand of Monterrey pine on this island. The Monterrey pine population on this island has some unique characteristics of value in tree improvement programs in the southern hemisphere (Eldridge 1978). Other examples of invasive higher animals include mongoose, birds, deer, feral cats and frogs.

The Hawaiian Islands vegetation is especially sensitive to biological invasions because they are the most remote from any of the world's major continents and from any islands of appreciable size (Carlquist 1980). The native biota of the Hawaiian Islands can be accounted for by one successful migrant species every 35,000 years for a period of 70 million years (Westbrooks 1998). As a result of geographic isolation, many of these migrant species evolved into plants that are found nowhere else in the world. A classic example is the silverswords (Fig. 12). Five species occur on the islands. All are rare and found in only one or two locations. Their existence is threatened by feral goats, first introduced by Captain Cook (Ciesla 1983).

Upon the arrival of the first Polynesians in the 4th century A.D., the rate of immigration increased to about three or four species per century for about 1,400 years. Since European contact in the 18th century, the rate of insect immigration has increased to 15 to 20 species per year. The Hawaiian archipelago has more than 8,000 introduced plant species or cultivars. This represents a rate of 40 introductions per year over the past 200 years. Presently, 861 or 11 percent of these plants now occur in the wild and have reproducing populations (Westbrooks 1998).

As of 2001, there were at least 149 non-native plants present in Hawaii that pose a threat to native ecosystems[12]

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[12] Source: http://www.botany.hawaii.edu/faculty/cw_smith/aliens.htm.

Figure 14 – The rare and beautiful Haleakala silversword, found only in the crater of Haleakala Volcano on the Hawaiian Island of Maui, has been threatened by feral goats and humans.

Banana Poka or Passion Flower Vine

Scientific Name Of Causal Agent - Commonly reported as *Passiflora mollisima.* The identity of this species has been controversial and has recently been shown to be a new species, *P. tarminian* (Fig. 15).

Type of Agent - Vine

Native Habitat - This plant is native to the Andean Region of South America

Means of Introduction - Introduced into **Hawaii** as an ornamental plant about 1900.

Means of Spread - Seeds of banana poka are spread by feral pigs, birds and humans (Starr and others 1999).

Type of Damage - Covers and chokes out native forests**.**

Current Status - Banana poka is present on the **Hawaiian Islands** of **Hawaii**, **Kauai** and **Maui**. Total area covered by this plant in 1983 was over 190 square km (19,000 hectares). The area has doubled since then with over 40,000 ha of Hawaiian forests infested (Starr and others 1999).

Pest Management Tactics - Entomologists and plant pathologists from various state and federal agencies have conducted extensive exploration in Colombia, Ecuador, and Venezuela in search of potential biocontrol agents for this vine. As a result, several such agents have been imported into quarantine in **Hawaii**. Whereas testing of potential insect agents under quarantine has yielded encouraging results, field releases have been disappointing. Hyperparasites of biocontrol insects released previously for other target pests have presumably made subsequent releases of biocontrol agents, (e.g., such as those for banana poka) ineffective. In addition to insects, a University of Hawaii plant pathologist has received permission to release a powdery mildew fungus from the native South American habitats that has been shown to be specific to *Passiflora.* Results of these releases appear highly effective in some districts of the island of Hawaii, but are variable elsewhere.

Potential For Future Damage - Continued spread of this vine on islands where it is presently established and establishment of new infestations on other **Hawaiian Islands** and in the **Pacific Islands Territories** can be expected.

Figure 15 – Flower of the banana poka (Photo courtesy of the Missouri Botanical Garden, http://ridgewaydb.mobot.org/mobot/passifloraceae/economic.asp)

Miconia[13]

Scientific Name Of Causal Agent - *Miconia calvescens*

Type of Agent - Miconia is a small to medium tree that can reach a height of 50 feet at maturity.

Native Habitat - Native to tropical forests in Central America.

Means of Introduction - Miconia was introduced into the Hawaiian Islands as an ornamental in the 1960s.

Means of Spread This invasive plant spreads quickly in moist habitats (rainfall >60 inches per year), infesting farms, pastures, roadsides, and forests. After only a few years' growth, a single plant can produce millions of seeds that are dispersed by birds, animals or people who inadvertently carry them to new areas on muddy boots or vehicles.

Type of Damage - When a miconia forest becomes established, all other plant life ends. It forms dense thickets that block sunlight from reaching the forest floor so that few understory plants are able to survive (Westbrooks 1998). Miconia is shallow rooted and subject to windthrow, which can damage watersheds (USDA Forest Service 1999b).

Current Status - In 1990, a large patch of naturalized Miconia was discovered in East Maui, some 20 years after its introduction at a botanical garden near the community of Hana. As of 2002, the current infestation covers over 12,000 acres. A similar large infestation was found on the Hamakua Coast on the island of Hawaii. Extensive surveys indicate that population covers over 20,000 acres. Other smaller populations have been located in the Kona District of Hawaii and on the islands of Oahu and Kauai. Miconia is broadly recognized as one of the most critical threats to the majority of the state's native rain forests and agricultural lands. *Miconia calvescens* was declared a “noxious weed” in 1992 by the state of Hawaii

By the mid 1980’s Boy Scout troops and 4-H clubs were killing Miconia as part of community service projects. Coordinated containment and control efforts on Maui, Hawaii, and Oahu began in 1994 (Westbrooks 1998).

Pest Management Tactics - Mechanical and chemical removal of plants is the only proven means of control. The state of **Hawaii** recently launched "Operation Miconia," which teams federal, state, and county agencies, businesses, and nonprofit organizations in the largest mobilization effort in state history to eradicate an invasive alien weed. Authorities hope to prevent miconia from reaching the islands of **Molokai** and **Lanai**,

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[13] Much of the information presented in this section was provided by Duane Nelson, Forest Health Coordinator, Institute of Pacific Islands Forestry, USDA Forest Service, Hilo, HI

and they hope to eliminate it completely on **Oahu** and **Kauai**. The invasion is so extensive on Maui and Hawaii that current efforts focus on containment and reduction strategies. A leaf-spot pathogen has been introduced into core populations on Maui and Hawaii. Establishment is highly variable and it is still too early to assess the impacts of the pathogen. An active program is underway to locate, test and evaluate additional insects and diseases from its home range.

POTENTIAL FOR FUTURE DAMAGE – The Maui Invasive Species Committee estimates potential range for Miconia to exceed 180,000 acres on Maui. The Big Island Invasive Species Committee estimates that over 500,000 acres on Hawaii are potentially suitable. Due to the scale of the current infestation, the long-lived seed bank, and immense production of bird disseminated seed, it is highly unlikely that Miconia will ever be eradicated from Maui and Hawaii. Containment and control efforts will have to continue for several decades, even with the assistance of a yet undiscovered effective biological control. Control programs on these two islands alone exceed $1.5 million per year.

Smaller, but widely distributed populations of Miconia have been found on Oahu and Kauai. If these populations are not eradicated immediately, thousands of acres on each island will soon be contaminated with highly viable seed, setting the stage for an explosive invasion.

If control efforts cease, we can predict the outcomes by observing the experience from Tahiti. First introduced at the Papeari Botanical Garden in 1937, it now occurs over 65% of the island and as dense, monospecies stands over 25% of the island (Meyer 1996). Ecosytems become completely transformed as *M. calvescens* gains dominance, due to its creation of deep shade, which no native species can tolerate (Meyer 1996). In Tahiti, 70-100 native plant species, including 35-45 species endemic to French Polynesia, are directly threatened by invasion of *M. calvescens* into native forests.

The risk is not unique to Hawaii. All subtropical and tropical islands in the Pacific are at risk. Programs have already started in several Pacific islands to educate plant quarantine agents and the general public to prevent introduction of Miconia onto other islands.

Firetree or Faya Tree

Scientific Name of Causal Agent – *Morella faya,* also referred to as *Myrica faya.*

Type of Agent – Tree

Native Habitat - Firetree is native to the Canary Islands, Madiera and the Azores (Seibold n.d., Westbrooks 1998).

Means of Introduction – This tree was introduced into the Hawaiian Islands as an ornamental, probably by Portuguese laborers, who made wine from its fruit. It was first recorded on Hawaii in 1900 (Westbrooks 1998).

Means of Spread – The seeds of firetree are dispersed by birds.

Type of Damage – Firetree invades new sites created by volcanic eruptions. Normally the low nutrient content of these soils limits plant growth. However firetree is a nitrogen fixer and increases the amount of nitrogen available to other plants by about 4x. The extra nitrogen changes the patterns of plant succession on new volcanic soils and favors other nonnative species and changes the composition and dynamics of an entire ecosystem (Westbrooks 1998).

Current Status – This invasive tree is known to occur on the islands of **Hawaii, Kaui, Lanai, Maui** and **Oahu**. It may be present on **Molokai**. Firetree has become a major pest in the **Hawaiian Volcanoes National Park** on the Island of **Hawaii** where it is invading lava flows (HEAR 1997).

Pest Management Tactics – Herbicides such as injections of Roundup (glyphosate) are effective, but their use on National Parks is avoided. A fungus, *Botrytis cinerea,* has been shown to diminish firetree communities and poses little or no threat to native species (Siebold n.d)

Potential For Future Damage – Firetree is expected to be a continuing problem on the **Hawaiian Volcanoes National Park** and other recent lava flows on **Hawaii**.

African Tulip Tree[14]

Scientific Name of Causal Agent – *Spathodea campanulata*

Type of Agent – Evergreen tree (Fig. 16)

Native Habitat – West Africa

Means of Introduction – African tulip tree was introduced into new locations by humans as a decorative shade tree because of its attractive orange-red tulip-like flowers (Fig. 16).

Means of Spread – Seed pods produce large numbers of small seeds with transparent wings that are easily dispersed by winds

Type of Damage – This tree is among the first of large trees to colonize disturbed areas, abandoned agricultural areas and low elevation forests where it displaces native vegetation.

Current Status – In **Hawaii**, tulip tree is found in wet habitats from sea level to about 3,200 feet on all major islands. Major infestations occur in almost every rain forest valley along the northern and eastern slopes of **Hawaii, Kauai, Oahu** and East **Maui**.

Pest Management Tactics – African tulip may be controlled with mechanical and herbicide methods. Due to its large size, trees to be removed in residential areas must be handled with extreme caution to avoid hazard to people and structures, therefore control may be extremely expensive. This tree has not yet been evaluated as a candidate for biological control and its adaptation to fire is not known.

Potential For Future Damage – Continued invasion of suitable habitats throughout **Hawaii** and other **Pacific Islands** can be expected in the future with resultant displacement of native vegetation.

[14] Data sources: http://www.botany.hawaii.edu/faculty/cw_smith/spa_cam.htm, http://www.naturia.per.sg/buloh/plants/african _tulip.htm and Duane Nelson, USDA Forest Service, Hilo Hawaii

Figure 16 – Left: African tulip tree, *Spathodea campanulata*. Right: close up of flower. (Source: http://www.botany.hawaii.edu.)

Ivy Gourd[15]

Scientific Name of Causal Agent – *Coccinia grandis*

Type of Agent – Vine

Native Habitat – Africa, India and Asia

Means of Introduction – The shoot tips are edible and used in Asian cooking. This plant was intentionally introduced into new locations by humans.

Means of Spread – Ivy gourd is spread by pieces of vines or cuttings, bird dispersed seeds, and probable dispersal by feral pigs. On **Guam** only male plants are present. Therefore spread is entirely by roots, pieces, and cuttings.

Type of Damage – Ivy gourd is an aggressive smothering vine, capable of covering trees and killing native vegetation (Fig. 17).

Current Status – Ivy gourd is present of the **Commonwealth of Northern Mariana Islands (Saipan), Federated States of Micronesia, Guam, Hawaii (Maui and Kauai)** and the **Marshall Islands**. On the Hawaiian Islands, it is found on dry to moist areas at elevations from sea level to 800 feet.

Pest Management Tactics – Cutting has little effect. Treatment with herbicides is only partially effective. Because of its climbing habit, use of foliar herbicides is difficult without causing damage to the underlying vegetation.

Potential For Future Damage – Continued spread into suitable habitats and resultant damage can be expected.

[15] Data source: http://www.hear.org/pier3/cogra.htm

Figure 17 - Infestation of ivy gourd, *Coccinia grandis* (Source: http://www.hear.org)

Fountain Grass[16]

Scientific Name of Causal Agent – *Pennisetum staceum*

Type of Agent – Bunchgrass

Native Habitat – Africa

Means of Introduction – Probably a purposeful introduction. This plant is cultivated in French Polynesia.

Means of Spread – Fountain grass is a prolific seed producer. The seeds are dispersed by wind.

Type of Damage – Fountain grass invades dry forest, roadsides, grasslands and lava fields. It is capable of crowding out other herbs and seedlings. It is a fire-stimulated grass that carries intense fires throughout its natural and introduced ranges.

Current Status – This plant is present on **Guam** and the **Hawaiian Islands**, where it occurs on all major islands with a major infestation on the Kona side of the Big Island of Hawaii. It also occurs in southern **California**.

Worldwide, this plant has been introduced into Fiji, French Polynesia, New Caledonia, Australia, Indonesia and the Canary Islands. Fountain grass is considered to be very invasive in the Canary Islands.

Pest Management Tactics – Fountain grass is related to sugar cane and any attempt to introduce biological control agents is expected to be opposed by the sugar industry. Herbicides must be used on all infestations except for isolated plants.

Potential For Future Damage - Continued spread, coupled with ecological effects such as increased wildfire occurrence in ecosystems not adapted to wildfire.

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[16] Data sources: http://www.hear.org/pier3/peset.htm and http://www.botany.hawaii.edu/faculty/cw_smith/pen_set.htm

Invasive Species Not Yet Established But Pose an Imminent Threat

New invasive species appear continuously throughout the world. To a limited extent, their appearance in certain locations can be predicted based on knowledge of the invasive agent's biology and ecology, trade routes and patterns of spread. This knowledge can be used to conduct pest risk assessments and alert inspectors at ports of entry to look for specific potentially invasive pests. This procedure is effective for early detection of certain insects that are either potentially damaging or can serve as disease vectors.

In the case of pathogens, predicting the likelihood of a new invasive appearing in a certain area is much less certain. For example, three of the five invasive pathogens discussed in this report (pitch canker, Port-Orford cedar root disease and sudden oak death) are of unknown origin. They appeared without warning and with no knowledge of their biology, ecology or range of susceptible hosts. In each case the causal agent was new to science. These agents may have evolved in another location and were subsequently introduced or they may be innocuous indigenous species that more recently have evolved into aggressively pathogenic forms. Regardless of their origin, the occurrence of pathogens attests to the unpredictable nature of some invasive species.

Predicting the likelihood of a new invasive plant species appearing in an area is also a difficult process because many plant species have been introduced into new areas because of their value as a food source, aesthetic qualities or other commodity values. Moreover, in their native habitats, these plants are not invasive and are often considered beneficial.

In the following sections, four species or species groups of forest insects, which are considered to be a potential threat to forest ecosystems in the western U.S. are reviewed. Three (Asian longhorned beetle, gypsy moth and European pine shoot beetle) are already established in portions of the eastern US. Gypsy moth and citrus longhorned beetle have appeared in the West several times but thus far are not known to be established. The fourth (European wood wasp) has become a major pest of plantations of pines indigenous to North America established in the southern hemisphere. In addition, kudzu, an invasive plant long established in the eastern U.S. and recently discovered in two localized sites in Oregon and Washington, is reviewed. Obviously, these are only examples. Many other species could be considered imminent risks to western forests (see www.exoticforestpests.org).

Asian Longhorned Beetle and Related Species

Scientific Name of Causal Agent - Asian longhorned beetle (ALB), *Anoplophora glabrippenis*; citrus longhorned beetle (CLHB), *A. chinensis*; and white spotted citrus longhorned beetle (WSCLB), *A. malasiaca.* At least 12 species of *Anoplophora* occur in Asia. All have the potential for causing damage to forests and urban trees in the U.S.

Type of Agent- Insect (longhorned woodborer).

Native Habitat - China, Japan, Korea. ALB is a serious pest of mature poplar plantations in east central China. A common control method for this insect in China is to hire a large number of people to climb plantation trees when the adults are emerging, collect the beetles, and kill them by dropping them into a jar of kerosene (Author's observation). CHLB and WSCLB are pests of fruit trees, especially citrus in China and Japan

Means of Introduction - Wooden crates, pallets and dunnage used in international trade. CHLB and WSCLB occur in bonsai trees imported from Asia.

Means of Spread - Adults are strong fliers and disperse when seeking host trees. Transport of infested firewood to uninfested areas is the reason for establishment of at least one infestation in the New York area.

Hosts - This group of insects is capable of attacking a wide range of broadleaf species important in forestry, arborculture and agriculture.

ALB– Apple, pear, plum, cherry, willow, poplar, elm, maple, horse chestnut and others.

CLHB – Citrus trees, apple, pear, fig, cherry, loquat, willow, poplar, mulberry, elm and others.

WSCLB – Alder, birch, buffalo berry, maple, plane tree, apple and citrus.

Type of Damage - Beetles breed in the wood of living trees. Repeated attacks weaken and eventually kill trees.

Current Status - Asian longhorned beetle was discovered in Brooklyn and Amityville, Long Island, New York in 1996. Since then, other infestations have been detected in the greater New York area, and in 1998 infestations were found in the Chicago area (Haack and others 1997, USDA Forest Service 2001).

Thus far, no established infestations of Asian longhorned beetle have been detected in the West. However, Asian longhorned beetle infestations have been found at 26 warehouses in 14 states across the U.S., including warehouses in **California** and **Washington** (Excalibur Pallet Group 2000, USDA APHIS n.d.) (Fig. 18) and the insect has been

intercepted at ports of entry in the western USA (Washington State Department of Agriculture 2001).

In 1999, CLHB and WSCLB were intercepted in bonsai imported from China, in Georgia and Wisconsin (USDA APHIS n.d.). In August 2001, the citrus longhorned beetle was discovered near Tukwila, **Washington.** Introduction was via a shipment of ornamental maple nursery stock from Korea. It has not yet been determined if this insect is established (Washington State Department of Agriculture 2001).

Pest Management Tactics - The primary means of reducing the spread of these insects is to cut and destroy infested trees. This, of course, has a severe impact on the aesthetics of urban areas, especially when large trees must be removed. In the Chicago area, 1,450 trees have been destroyed since the infestation was first discovered. Another treatment is to inject the insecticide into the tree trunks and soil with the insecticide imidalcloprid. In 2000, over 11,000 trees were treated in this manner in the Chicago area (USDA Forest Service 2001).

A Federal quarantine encompasses all known infested areas in Chicago and New York (USDA Forest Service 2001).

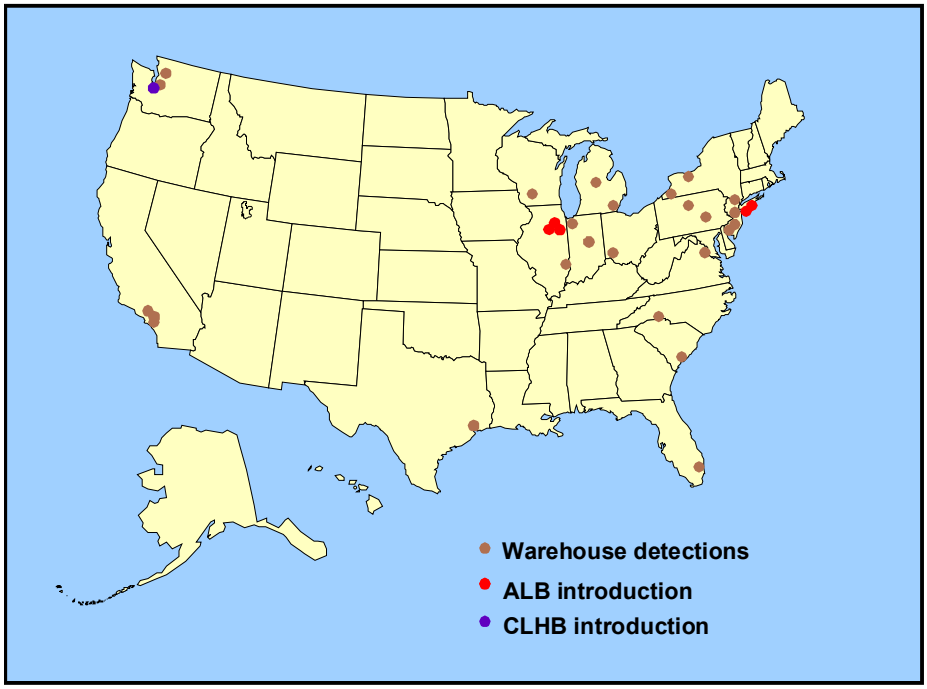

Figure 18 - Status of Asian longhorned beetle (ALB) and citrus longhorned beetle (CLHB) in the United States (Source USDA APHIS n.d.)

Potential for Future Damage - Without adequate surveillance and awareness, Asian longhorned beetle could become established in other urban areas and in native broadleaf forests. A potential host is quaking aspen, a major broadleaf species in forests in the Rocky Mountains. Possible introduction of members of this group of insects is also of concern in **Hawaii** and other **Pacific Islands**[17].

At least 12 species of *Anoplophora* are known from Asia. All are striking in their appearance (Fig. 19). Most are considered pests in their native habitats. Should any of these species become established, the results could be devastating.

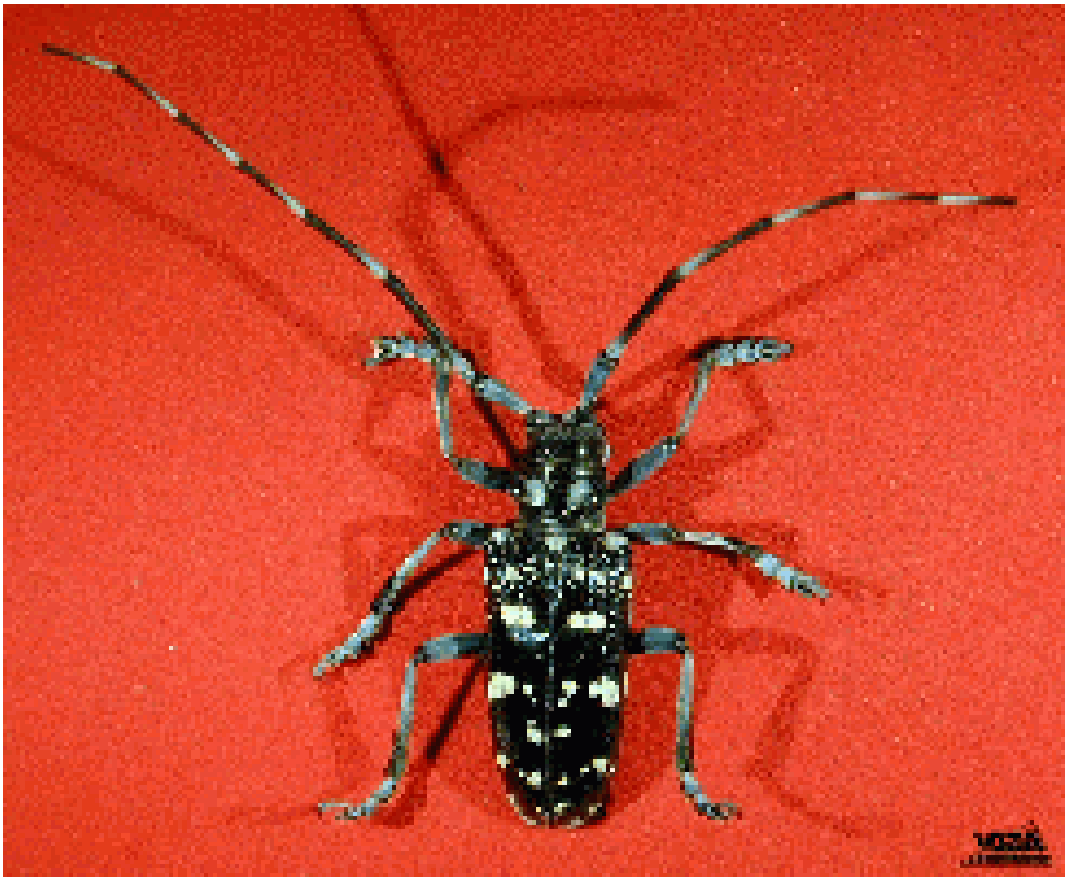

Figure 19 – Asian longhorned beetle adult (Photo courtesy of Robert Haack, USDA Forest Service, North Central Research Station).

[17] Personal communication, Duane Nelson, USDA Forest Service, Hilo, HI.

European Pine Shoot Beetle

Scientific Name of Causal Agent - *Tomicus piniperda*

Type of Agent – Insect (Bark beetle and shoot borer)

Native Habitat - Europe and Asia

Means of Introduction - Infested crates, pallets and dunnage used in international trade.

Means of Spread - Adults are strong fliers and can easily move from tree to tree in search of feeding sites or breeding material.

Hosts - Pines. Scotch pine is a favorite host in Europe. Where it has been introduced in the U.S., Scotch pine plantations are most severely affected but some native pines (e.g., white pine, red pine) are also attacked.

Type of Damage - Adult beetles feed on the shoots of pine and kill them. Damage can cause reduced growth and misshaped tree crowns. Large numbers of dead shoots on Christmas trees makes them unsightly and unacceptable. Breeding occurs in the cambium layer of pines. Usually freshly killed trees, recently cut logs or fresh logging slash are used as breeding sites, however, in Europe the insect is capable of attacking and killing weakened trees.

Current Status - *Tomicus piniperda* has often been intercepted at U.S. ports of entry. Between 1985 and 1998, it was intercepted 120 times, primarily in shipments of trade goods from France, the United Kingdom, Spain, and Italy (Haack and Cavey 1998, Stephen and Gregorie 2001). This insect was first discovered in North America in 1992 near Cleveland, Ohio. By the end of 1992 it was found in 43 counties in six states in the Great Lakes Region of the U.S.A. (Haack 1997, Haack and Kucera 1993). As of 1998, this insect had been found in 243 counties in nine states in the U.S. (Illinois, Indiana, Maryland, Michigan, New York, Ohio, Pennsylvania, West Virginia and, for the first time, Wisconsin) (USDA Forest Service 1999). In 1999, infestations continued to spread and were detected for the first time in New Hampshire and Vermont (USDA Forest Service 2000). This insect is not yet present in the West, but surveys have been conducted in several western states (**Colorado** and **Kansas**).

Pest Management Tactics - In 1992, a Federal quarantine was imposed by APHIS on the movement of pine material from infested to uninfested counties (Haack 1997). Use of introduced natural enemies is under investigation (Haack and others 1997).

Potential for Future Damage - Although this insect has not yet been detected in the West, it has the potential to spread over much of the USA and Canada, causing damage primarily to ornamental trees and Christmas tree plantations.

European Wood Wasp

Scientific Name Of Causal Agent - *Sirex noctilio*

Type of Agent - Insect (Wood boring wasp)

Native Habitat- Europe and North Africa

Means of Introduction - Infested crates, pallets and dunnage used in international trade

Means of Spread - Adults are capable of flying over considerable distance in search of suitable trees for breeding sites.

Hosts - In its native habitat, pine, spruce, fir and larch are attacked. Attacks are confined to dead, dying or severely weakened trees.

In areas where this insect has been introduced, pines native to North America have been killed. Monterrey pine, loblolly pine, slash pine and ponderosa pine have been attacked and killed in southern hemisphere pine plantations (Fig. 20).

Type of Damage - The European wood wasp is a vector of a fungus that can invade the vascular system of pines and kill them. Some pines are also highly sensitive to a toxic mucus injected into trees by female wasps during egg laying. The larvae feed in the wood and construct large tunnels, which reduce the structural integrity of the wood of infested trees (Fig. 21).

Current Status - This insect does not yet occur anywhere in the U.S. although it is frequently intercepted at ports of entry.

European wood wasp has been introduced into Australia, New Zealand, South Africa and South America (Argentina, Brazil, Chile and Uruguay) where it is causing severe damage to exotic pine plantations, especially plantations of Monterrey, loblolly and slash pines.

Pest Management Tactics - In the southern hemisphere, overstocked plantations are especially susceptible to attack and thinning will reduce damage. A parasitic nematode that attacks the female wasp's reproductive system and renders her unable to lay eggs is an effective biological control method. Parasitic wasps are another relatively effective control agent.

Potential for Future Damage -This insect is not yet established in the U.S. but is frequently intercepted at U.S. ports of entry in pine crating, dunnage and pallets. Should this insect become established, it could cause severe damage in natural pine stands throughout the country, especially overstocked stands.

Figure 20 – Aerial view of tree mortality caused by European wood wasp in a loblolly pine plantation in Santa Catarina State, Brazil

Figure 21 – European wood wasp, larvae, pupae and boring tunnels in loblolly pine, Santa Catarina State, Brazil

Gypsy Moth (Asian and European Forms)

Scientific Name of Causal Agent - *Lymantria dispar*. Two distinct forms or races are recognized, the Asian form, which has a female that is capable of flight and the European form, which has a female that cannot fly (Fig. 22).

Type of Agent - Insect (Defoliating caterpillar).

Native Habitat - The European form of the gypsy moth is native to Europe and parts of North Africa. The Asian form is found from Central Asia east to Siberia, China and Japan.

Means of Introduction - The European form of this insect was originally introduced into Massachusetts in 1886 by a French scientist, who was seeking an alternative source of silk. Some of the insects escaped and established themselves in surrounding oak forests (McManus 1980). Gypsy moth has since spread over much of the northeastern and Mid-Atlantic U.S. and is moving into the Midwest despite millions of dollars spent on attempts to slow its rate of spread

The Asian form has appeared in several locations in both the U.S. and Canada and was introduced via merchant ships carrying imported goods or military equipment.

Means of Spread - Females lay eggs on a variety of surfaces including lawn furniture, lumber, and even the insides of loose hubcaps on motor vehicles and trailers. Therefore, the potential for transporting egg masses into new locations is high.

Young larvae are subject to movement from tree to tree by air currents.

The female of the Asian form of the gypsy moth is capable of flying and can disperse and lay eggs at considerable distance from where they emerged from pupal cases.

Hosts - Gypsy moth larvae can feed on at least 500 species of woody plants. In the eastern U.S., favored trees include oaks, apple, alder, basswood, birches, willows, poplars and hawthorne. Older larvae can feed on some conifers (McManus 1980).

Type of Damage - Larvae feed on the foliage of host trees. Repeated defoliation can cause growth loss, dieback and tree mortality. Large numbers of larvae in urban areas can be a nuisance

Current Status - A zone of general infestation occurs in the eastern U.S. from New England south to Virginia and west to Ohio and Michigan. Defoliation of broadleaf forests, sometimes in the millions of acres, has occurred in this region. In 2000, 1,623,500 acres were defoliated (USDA Forest Service 2001).

Spot infestations have occurred in many areas including the western states of **California, Colorado, Idaho, Montana, Oregon, Utah and Washington**. In 1988, for example,

gypsy moth was detected along the Wasatch Front in **Utah**. Between 1989 and 1993, almost 72,000 acres of Federal, State and private lands were treated with the bacterial insecticide, *Bacillus thuringiensis* (USDA Forest Service 2001). In 1995, after two years of trapping resulted in no moth captures, the infestation was declared eradicated. Additional moths were caught in subsequent years and small areas have been treated.

In 2000, cooperative detection surveys involving APHIS and western states using pheromone traps captured small numbers of adult moths in **California, Colorado, Kansas, Montana, Oregon, Utah** and **Washington**.

Small eradication projects were conducted in 2000 in **Oregon** (19 acres), and **Washington** (751 acres) (USDA Forest Service 2001).

Several localized introductions of Asian gypsy moth occurred in 1991 in **Oregon** and **Washington** and were subsequently eradicated. These introductions coincided with a major outbreak of this insect in Siberia.

Pest Management Tactics - Early detection of infestations is done with traps baited with a chemical (pheromone) that is attractive to male moths. Pest management measures include inspection of materials moving from the generally infested area in the East to presently uninfested areas of the U.S. Eradication usually involves treatment of infested areas with multiple aerial applications of biological or chemical pesticides or mass trapping of infested areas with pheromones. These same materials can be used to control outbreaks and reduce defoliation. A fungus disease native to Japan has been effective as a natural control agent, and a naturally occurring virus is available for treatment of infestations.

Potential for Future Damage - The general area of infestation will continue to spread west and south. In 2000, defoliation occurred for the first time in Wisconsin.

Ports of entry in the western U.S. receive large shipments of goods from Asia and are at high risk of introduction of Asian gypsy moth, especially during outbreaks in its native range.

Figure 22 – Female adults and egg masses of gypsy moth.

Kudzu

Scientific Name of Causal Agent – *Pueraria montana*

Type of Agent – Vine

Native Habitat – Asia

Means of Introduction – First introduced as an ornamental at the Centennial Exposition in 1876 as part of the Japanese garden exhibit. Later it was widely used for forage and erosion control.

Means of Spread – Birds, humans

Type of Damage – Known as the "weed that ate the south," kudzu is an aggressive vine that can grow as much as one foot/day in summer, climbing and completely covering trees, power poles and sometimes homes. While this plant is an effective means of erosion control, the vines can kill trees and damage forests by preventing trees from getting sunlight.

Current Status – Kudzu is widely distributed across the southeastern U.S. and, more recently, infestations have appeared in several northeastern and north central states. Some 7 million acres are believed infested (Westbrooks 1998).

Within the past two years, localized infestations have been found in **Oregon** and **Washington**. The first report of the occurrence of Kudzu west of Texas was in Clackamas County, **Oregon**, in late 2000 when a patch of about one-half acre was detected and promptly destroyed. In 2002, Kudzu was found near Vancouver, **Washington.**

Pest Management Tactics – Grazing by goats will help keep infestations from spreading.

Potential for Future Damage – Additional introductions could occur, especially in parts of northern **California**, western **Oregon and Washington**.

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Appendices

Executive Order 13112

By the authority vested in me as President by the Constitution and the laws of the United States of America, including the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.), Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, as amended (16 U.S.C. 4701 et seq.), Lacey Act, as amended (18 U.S.C. 42), Federal Plant Pest Act (7 U.S.C. 150aa et seq.), Federal Noxious Weed Act of 1974, as amended (7 U.S.C. 2801 et seq.), Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.), and other pertinent statutes, to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause, it is ordered as follows:

Section 1. Definitions.

(a) "Alien species" means, with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species that is not native to that ecosystem.

(b) "Control" means, as appropriate, eradicating, suppressing, reducing, or managing invasive species populations, preventing spread of invasive species from areas where they are present, and taking steps such as restoration of native species and habitats to reduce the effects of invasive species and to prevent further invasions.

(c) "Ecosystem" means the complex of a community of organisms and its environment.

(d) "Federal agency" means an executive department or agency, but does not include independent establishments as defined by 5 U.S.C. 104.

(e) "Introduction" means the intentional or unintentional escape, release, dissemination, or placement of a species into an ecosystem as a result of human activity.

(f) "Invasive species" means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.

(g) "Native species" means, with respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem.

(h) "Species" means a group of organisms all of which have a high degree of physical and genetic similarity, generally interbreed only among themselves, and show persistent differences from members of allied groups of organisms.

(i) "Stakeholders" means, but is not limited to, State, tribal, and local government agencies, academic institutions, the scientific community, nongovernmental entities

including environmental, agricultural, and conservation organizations, trade groups, commercial interests, and private landowners.

(j) "United States" means the 50 States, the District of Columbia, Puerto Rico, Guam, and all possessions, territories, and the territorial sea of the United States.

Section 2. Federal Agency Duties.

(a) Each Federal agency whose actions may affect the status of invasive species shall, to the extent practicable and permitted by law,

(1) identify such actions;

(2) subject to the availability of appropriations, and within Administration budgetary limits, use relevant programs and authorities to: (i) prevent the introduction of invasive species; (ii) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner; (iii) monitor invasive species populations accurately and reliably; (iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded; (v) conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and (vi) promote public education on invasive species and the means to address them; and

(3) not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere unless, pursuant to guidelines that it has prescribed, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions.

(b) Federal agencies shall pursue the duties set forth in this section in consultation with the Invasive Species Council, consistent with the Invasive Species Management Plan and in cooperation with stakeholders, as appropriate, and, as approved by the Department of State, when Federal agencies are working with international organizations and foreign nations.

Section 3. Invasive Species Council.

(a) An Invasive Species Council (Council) is hereby established whose members shall include the Secretary of State, the Secretary of the Treasury, the Secretary of Defense, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Transportation, and the Administrator of the Environmental Protection Agency. The Council shall be Co-Chaired by the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce. The Council may invite additional Federal agency representatives to be members, including representatives from subcabinet bureaus or offices with significant responsibilities concerning invasive species, and may

prescribe special procedures for their participation. The Secretary of the Interior shall, with concurrence of the Co-Chairs, appoint an Executive Director of the Council and shall provide the staff and administrative support for the Council. (b) The Secretary of the Interior shall establish an advisory committee under the Federal Advisory Committee Act, 5 U.S.C. App., to provide information and advice for consideration by the Council, and shall, after consultation with other members of the Council, appoint members of the advisory committee representing stakeholders. Among other things, the advisory committee shall recommend plans and actions at local, tribal, State, regional, and ecosystem-based levels to achieve the goals and objectives of the Management Plan in section 5 of this order. The advisory committee shall act in cooperation with stakeholders and existing organizations addressing invasive species. The Department of the Interior shall provide the administrative and financial support for the advisory committee.

Section 4. Duties of the Invasive Species Council.

The Invasive Species Council shall provide national leadership regarding invasive species, and shall:

(a) oversee the implementation of this order and see that the Federal agency activities concerning invasive species are coordinated, complementary, cost-efficient, and effective, relying to the extent feasible and appropriate on existing organizations addressing invasive species, such as the Aquatic Nuisance Species Task Force, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, and the Committee on Environment and Natural Resources;

(b) encourage planning and action at local, tribal, State, regional, and ecosystem-based levels to achieve the goals and objectives of the Management Plan in section 5 of this order, in cooperation with stakeholders and existing organizations addressing invasive species;

(c) develop recommendations for international cooperation in addressing invasive species;

(d) develop, in consultation with the Council on Environmental Quality, guidance to Federal agencies pursuant to the National Environmental Policy Act on prevention and control of invasive species, including the procurement, use, and maintenance of native species as they affect invasive species;

(e) facilitate development of a coordinated network among Federal agencies to document, evaluate, and monitor impacts from invasive species on the economy, the environment, and human health;

(f) facilitate establishment of a coordinated, up-to-date information-sharing system that utilizes, to the greatest extent practicable, the Internet; this system shall facilitate access to and exchange of information concerning invasive species, including, but not limited to, information on distribution and abundance of invasive species; life histories of such

species and invasive characteristics; economic, environmental, and human health impacts; management techniques, and laws and programs for management, research, and public education; and

(g) prepare and issue a national Invasive Species Management Plan as set forth in section 5 of this order.

Section 5. Invasive Species Management Plan.

(a) Within 18 months after issuance of this order, the Council shall prepare and issue the first edition of a National Invasive Species Management Plan (Management Plan), which shall detail and recommend performance-oriented goals and objectives and specific measures of success for Federal agency efforts concerning invasive species. The Management Plan shall recommend specific objectives and measures for carrying out each of the Federal agency duties established in section 2(a) of this order and shall set forth steps to be taken by the Council to carry out the duties assigned to it under section 4 of this order. The Management Plan shall be developed through a public process and in consultation with Federal agencies and stakeholders.

(b) The first edition of the Management Plan shall include a review of existing and prospective approaches and authorities for preventing the introduction and spread of invasive species, including those for identifying pathways by which invasive species are introduced and for minimizing the risk of introductions via those pathways, and shall identify research needs and recommend measures to minimize the risk that introductions will occur. Such recommended measures shall provide for a science-based process to evaluate risks associated with introduction and spread of invasive species and a coordinated and systematic risk-based process to identify, monitor, and interdict pathways that may be involved in the introduction of invasive species. If recommended measures are not authorized by current law, the Council shall develop and recommend to the President through its Co-Chairs legislative proposals for necessary changes in authority.

(c) The Council shall update the Management Plan biennially and shall concurrently evaluate and report on success in achieving the goals and objectives set forth in the Management Plan. The Management Plan shall identify the personnel, other resources, and additional levels of coordination needed to achieve the Management Plan's identified goals and objectives, and the Council shall provide each edition of the Management Plan and each report on it to the Office of Management and Budget. Within 18 months after measures have been recommended by the Council in any edition of the Management Plan, each Federal agency whose action is required to implement such measures shall either take the action recommended or shall provide the Council with an explanation of why the action is not feasible. The Council shall assess the effectiveness of this order no less than once each 5 years after the order is issued and shall report to the Office of Management and Budget on whether the order should be revised.

Section 6. Judicial Review and Administration.

(a) This order is intended only to improve the internal management of the executive branch and is not intended to create any right, benefit, or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies, its officers, or any other person.

(b) Executive Order 11987 of May 24, 1977, is hereby revoked.

(c) The requirements of this order do not affect the obligations of Federal agencies under 16 U.S.C. 4713 with respect to ballast water programs.

(d) The requirements of section 2(a)(3) of this order shall not apply to any action of the Department of State or Department of Defense if the Secretary of State or the Secretary of Defense finds that exemption from such requirements is necessary for foreign policy or national security reasons.

WILLIAM J. CLINTON
THE WHITE HOUSE,
February 3, 1999.

Summary of Federal Roles and Responsibilities with Regard to the Management of Invasive Species[18]

Prevention –The Department of Agriculture (USDA) and the Department of Defense (DOD) have authority to prevent the introduction of invasive species.

Department of Agriculture - Several agencies within USDA are involved in prevention activities:

1. The Animal Plant Health Inspection Service (APHIS) is the primary agency charged with preventing invasive species from entering the U.S. Under current authorities APHIS can prohibit, inspect, treat, quarantine or require mitigation measures prior to allowing entry of plant materials, plant pests, biological control organisms, animals, animal products and by-products or their host commodities or conveyances.

2. The Agriculture Research Service (ARS) provides support to APHIS in identification of invasive species and development of monitoring methods and technologies for eradication and management of invasive species.

3. The Forest Service (FS) has authority for management of forest pests (including invasive species) on the National Forests and Grasslands. The Forest Service can also help other Federal, State and private entities to prevent the spread of invasive species on non-federal lands. The Forest Service also develops technologies to prevent, monitor and manage invasive species on forestlands.

4. The Natural Resources Conservation Service (NRCS) has the authority to aid in prevention through education and outreach.

Department of Defense - DOD has responsibilities for:

1. Development of transportation regulations that provide for routine maintenance and washing of vehicles following military field operations to prevent introduction of invasive species.

2. Ballast water and anchor system management practices including management of liquid discharges from vessels of the armed forces and pest management of ships, aircraft and shore facilities (U.S. Navy).

[18] Source: NISC 2001

Early Detection and Rapid Response – Various USDA agencies provide early detection and rapid response activities. These include:

1. Identification and control of incipient invasions of exotic species – APHIS, FS.

2. Cooperation with states to conduct surveys to monitor for the occurrence of high priority pests through the Cooperative Agricultural Pest Survey Program (CAPS) - APHIS.

3. Maintenance of a nation-wide database that summarizes results of CAPS activities and ancillary data on the status of potentially invasive species – APHIS.

4. Organization of new pest advisory groups, composed of knowledgeable experts charged with recommending appropriate responses when a new invasive species is detected – APHIS.

5. Research to support early detection and rapid response activities – ARS, FS.

6. Providing information on invasive and noxious plants through the PLANTS website - NRCS.

Control, Management and Restoration – Activities concerning the management of established populations of invasive species and restoration of affected areas is shared by several Federal Agencies including those in USDA, Department of Commerce, DOD, and the US Department of Interior (USDI).

Department of Agriculture - Activities conducted by USDA include:

1. Management of invasive species on National Forests and Grasslands – FS.

2. Cooperation with states on management of invasive species on state and private lands - FS.

3. Control of invasive plants in the Pacific Islands Territories – FS.

4. Programs for management of invasive species such as the "Slow the Spread" program against gypsy moth (APHIS and FS) and the Cooperative Boll Weevil Eradication Program (APHIS).

5. Ecosystem-level research in support of control, management and restoration activities in cooperation with land management agencies - ARS, FS.

6. Sharing of technical information regarding the management of invasive species with private landowners and non-governmental organizations (NGOs)– NRCS.

7. Funding and support for Land Grant Universities in research, extension and education programs designed to manage exotic species – Cooperative State Research, Education and Extension Service (CSREES).

Department of Commerce - The National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce (together with the Fish and Wildlife Service (FWS)) has responsibility for control and management of invasive aquatic species. NOAA administers the Sea Grant Program, which conducts research on methods to reduce the impact of zebra mussels and other invasive aquatic species. The NOAA Restoration Center, within the National Marine Fisheries Service, restores coastal and estuarine habitats.

Department of Defense - The DOD manages invasive species on over 25 million acres of lands on military installations and restores affected sites.

Department of Interior - Land management agencies within USDI (e.g., BLM, National Park Service (NPS), FWS, Indian reservations (BIA)) have direct responsibility for the management of invasive species on lands under their administration. FWS also provides leadership in management of aquatic invasive species and restores habitats degraded by invasive species. The Bureau of Reclamation (BOR) is responsible for programs that control invasive species that infest water systems including reservoirs, rivers and canals. The Minerals Management Service (MMS) conducts research on the control of invasive species that use offshore oil wells as habitat or are moved about by activities relating to offshore oil wells.

Environmental Protection Agency – The EPA has regulatory authority over the use of chemical and biological pesticides and may place limitations on how they may be used. EPA is also the lead agency for the administration of the National Environmental Policy Act (NEPA), which may require preparation of environmental analyses (EA) or environmental impact statements (EIS) prior to the implementation of pest management programs.

Department of Transportation – The Federal Highway Administration (FHWA) has an oversight role on federally funded highway projects that include both Interstate and State highways and guides state departments of transportation on invasive species issues.

Research and Monitoring – Research and monitoring activities related to invasive species are conducted by several Federal agencies under USDA, DOC, DOD, USDI and EPA.

Department of Agriculture – Both ARS and FS conduct research on the prevention, eradication, and control of invasive species. ARS also evaluates new agricultural non-indigenous species before they can be commercially distributed and provides leadership

to the development of biological control technologies for invasive species. FS conducts surveys of forest insects and diseases on all Federal lands and cooperates with state forestry agencies. NRCS conducts plant screening to investigate new species for their potential invasiveness and usefulness. CSREES works primarily through the Land Grant University System to support research and extension activities.

Department of Commerce – NOAA conducts research on invasive aquatic species and NOAA's Sea Grant Program manages a competitive research grant program for all aspects of aquatic invasive species. NOAA's National Ocean Service monitors non-native species in marine sanctuaries.

Department of Defense – The Corps of Engineers has several research programs focused on invasive species including development of technologies for managing aquatic plant problems. DOD also conducts research on the zebra mussel.

Department of the Interior – USGS assists resource managers to obtain reliable information on invasive species through its Biological Monitoring and Research rogram. NPS is establishing inventories and monitoring networks on National Parks.

Environmental Protection Agency – EPA evaluates ecological indicators, including invasive species for surface waters, effects of non-native species on wetland restoration and conducts studies on non-native submerged vegetation. The Agency's research grant program funds research on "biological pollution."

International Measures - International measures are conducted to assess potential risk of additional invasive species entering the U.S. and to cooperate with other countries to prevent and manage invasive species on a global scale.

Department of Agriculture – APHIS represents the U.S. on bilateral, regional and global plant and animal international conventions and agreements that address invasive species. Most significant is with the World Trade Organization regarding application of sanitary and phytosanitary measures affecting international trade. ARS works in partnership with international groups with common interests in invasive species. FS provides assistance that promotes sustainable development worldwide including management of invasive species. CREES works in partnership with international groups where there is a common interest in research or extension involving invasive species.

Department of Commerce – NOAA is engaged in projects that integrate research and education on aquatic invasive species in several regions of common interest to Canada, Mexico and the U.S. NOAA also works with aquatic invasive species in the South Pacific Region.

Department of Defense – DOD has the responsibility to ensure that movement of U.S. military personnel, equipment and supplies around the world does not provide a pathway for invasions by non-native species. It actively supports research education and policy development with regard to movement of invasive species.

Department of the Interior – USDI works on invasive species internationally through a wide variety of scientific, technical and policy activities.

Department of State – The Bureau of Oceans and International Environmental and Science Affairs is the U.S. focal point for foreign policy formulation and implementation on global environment, science and technology issues. DOS has delegated lead negotiator privileges to other agencies when it is in the U.S.'s best interest to do so.

Department of Transportation- The U.S. Coast Guard works with other agencies to develop and enforce international fisheries and maritime agreements including those regarding ballast water management. The Federal Aviation Administration (FAA) addresses air transport issues and considers invasive species issues in the various actions it takes.

Environmental Protection Agency – EPA leads U.S. activities under the North Agreement for Environmental Cooperation, which includemanagement of invasive species.

Agency for International Development (USAID) – USAID has responsibility for ensuring that the U.S.'s international development assistance programs do not lead to introduction of invasive species in other countries.

National Science Foundation (NSF) – NSF enables and encourages scientists, engineers and their institutions to enhance their research and education programs through international cooperation.

Office of the U.S. Trade Representative – Leads and directs U.S. negotiations with other countries regarding trade. Increasingly invasive species are considered in trade negotiations.

Public Outreach and Partnership Efforts – These programs are designed to keep the general public advised of agency activities including those related to management of invasive species and to provide for cooperative funding for management and publicity efforts. These are carried out by various agencies in USDA (APHIS, NRCS, FS, CREES), DOC, DOD and USDI.

Federal Legislative Authorities

Federal Agencies conduct work on invasive species under a number of legislative authorities. The primary legislative authorities are summarized in the following sections:[19]

Department of Agriculture

Legal authorities available to USDA include:

1. Plant Protection Act.
    a. Prohibits or restricts the importation of plants, plant products, biological control agents, weeds or means of conveyance from entering the U.S.
    b. Provides for control of Mormon cricket and grasshoppers on Federal lands.
    c. Mandates development of Integrated Pest Management (IPM) plans for noxious weeds.
    d. Provides for cooperation with other Federal agencies, States, etc.
2. Federal Seed Act – Requires accurate labeling and purity standards for seeds in commerce.
3. Animal Quarantine Laws – Authorize regulation of the importation and interstate movement of invasive animal species.
4. Virus-Serum-Toxin Act – Authorizes USDA to regulate veterinary biological products intended for use in treatment of diseases of animals.
5. Animal Damage Control Act of 1931 as Amended in the Agriculture Appropriations Act Of 2001 – Provides the general authority under which APHIS' Wildlife Services programs function. This is the lead program responsible for research and control of the brown tree snake in Guam.
6. Organic Administration Act – Provides for protection of National forests from "fire and depredations." This law has been interpreted to include invasive species.

[19] Source: NISC 2001.

7. Multiple-Use Sustained Yield Act of 1960 – National Forests shall be administered for outdoor recreation, range, timber, watershed, wildlife and fish.

8. Cooperative Forestry Assistance Act of 1978 – Authorizes the Secretary of Agriculture to assist other Federal, State and private entities in managing forest pests including invasive species.

9. Hawaii Tropical Forest Recovery Act of 1992- Authorizes the Secretary of Agriculture to protect indigenous plant and animal species and essential watersheds from non-native animals, plants and pathogens and to implement programs to improve the health of tropical forests and related ecosystems in the state of Hawaii

Department Of Commerce

Legal authorities available to the Department of the Commerce include:

1. Non-Indigenous Aquatic Nuisance Prevention and Control Act – Provides authority to NOAA and FWS to undertake prevention and control of aquatic invasive species.

1. Coastal Zone Management Act – Provides for inclusion of invasive species issues in State Coastal Zone Management Plans and allows for funding of projects through cooperative agreements. Establishes the National Estuarine Research Reserve System under which research on invasive species could be sponsored.

2. Fish and Wildlife Coordination Act – Authorizes National Marine Fisheries Service to review development projects proposed by other Federal agencies. Makes funds available through grants and cooperative agreements that could include invasive species.

3. National Marine Sanctuary Act – Requires the Department of Commerce to take actions to promote and coordinate research, monitoring and education. Grant and contract funds are available for conservation and management activities including management of invasive species.

Department of the Interior

Legal authorities available to the Department of the Interior include:

1. The Lacey Act – Prohibits importation of animal species determined to be injurious to humans, the interests of agriculture, horticulture, forestry or wildlife. Authorizes the FWS to export or destroy injurious species at the expense of the importer.

2. Non-Indigenous Aquatic Nuisance Prevention And Control Act – Creates a task force co-chaired by FWS and the undersecretary of Commerce for Oceans and Atmosphere to develop and implement a program to prevent introduction and dispersal of nuisance species.

3. Land Management Authorities – All land management agencies under USDI have the authority to manage resources on their lands, including taking action to protect these resources from invasive species. Specific statutes include:

    a. National Park Service Organic Act

    b. National Wildlife Refuge System Administration Act

    c. Federal Land Policy and Management Act – (BLM)

4. Endangered Species Act – Contains provisions regulating import and export of listed species. Also requires that all federal land management agencies consult with FWS or the National Marine Fisheries Service regarding the potential impacts of any land management action, including control of invasive species, on listed species.

Environmental Protection Agency

1. Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) – Provides for Federal control of pesticide distribution, sale, and use. Gives EPA authority to study adverse effects of pesticide use, require licensing of pesticide applicators and register pesticides for specific uses. This law affects management of invasive species whenever pesticides are used.

2. Clean Water Act – Protects waters including lakes, rivers, aquifers and coastal zones. May provide authority to control and manage invasive species through permits or other requirements and programs. EPA is currently reviewing its authorities under this act with regard to invasive species.

Statutes Affecting all Federal Agencies

The National Environmental Policy Act can identify actions that are likely to affect invasive species or to be affected by them. Provisions of this act may require that agencies prepare EAs or EISs to analyze consequences of actions taken to manage invasive species.

International Agreements and Authorities

In addition to Federal statutes, the U.S. has entered into a number of international agreements that have provisions designed to reduce the hazard of introductions of invasive species. Some key agreements include:

1. Convention on Biological Diversity - 1993[20]
2. World Trade Organization (WTO) Agreement On The Application Of Sanitary And Phytosanitary Measures – 1995
3. International Plant Protection Convention (IPPC), 1951, With Revision In 1987.
4. Convention on International Trade in Endangered Species of Wild Fauna And Flora – 1973
5. North American Agreement for International Cooperation – 1994
6. South Pacific Regional Environmental Program

[20] Signed by the U.S. but not ratified by Congress.

Website Databases That Provide Information On Invasive Species

1. APHIS maintains a database that provides a wealth of information on current invasive species activities.

   Website address - http://www.aphis.usda.gov

2. Exotic Pest Information System for North America (EXFOR) – A joint undertaking of forest entomologists in Canada, Mexico and the U.S., developed under the North American Forestry Commission of the Food and Agriculture Organization of the United Nations (FAO). It contains detailed descriptions of exotic forest insects and diseases, their current distributions and a risk assessment of their potential impacts, should they become established in North America.

   Website address – http://www.exoticforestpests.org

3. Exotic Pests Online Symposium – Contains a series of individually authored papers on the introduction, spread, economic, social and ecological impacts of exotic forest insects and diseases, which have been introduced into North America and other parts of the world.

   Website address – http://exoticpests.apsnet.org

4. Screening aids, designed to assist taxonomists and parataxonomists in identification of exotic bark beetles are available.

   Website address – http://www.barkbeetles.org/exotic/btlscrng.html

5. The Bugwood database, maintained by the University of Georgia is an excellent unline source of information on all forest pests, exotic or indigenous.

   Website address – http://www.bugwood.org

6. The NRCS maintains the PLANTS database, which provides invasive species information, integrated state noxious weed lists, invasive plant lists, links to key sources of weed species biology and management information throughout the U.S. and the world. Also included is APHIS information on key species targeted for exclusion.

   Website address – http://plants.usda.gov

7. Hawaiian Ecosystems at Risk Project (HEAR) – Alien species map index. Provides distribution maps of alien species in Hawaii.

   Website address - http://www.hear.org/alienspeciesin Hawaii/maps

8. USDA Forest Service, Pacific Southwest Research Station, Institute of Pacific Islands Forestry, Pacific Island Ecosystems at Risk (PIER). Provides listings and descriptions of plant species that threaten Pacific Island ecosystems.

   Website address - http://www.hear.org/pier/

9. National Agricultural Plant Protection Organization (NAPPO) Phytosantiary Alert System. Provides pest alerts and news releases of new introductions worldwide with links to other networks.

   Website address – http://www.pestalert.org/resources.html

10. USDA Forest Service, Forest Health Protection. Provides information on the current status of both indigenous and introduced forest insects and pathogens.

    Website address – http://www.fs.fed.us/foresthealth/