Plant Diseases Caused by *Phytophthora ramorum*

A National Strategic Plan for USDA

September 14, 2005

United States Department of Agriculture
Animal and Plant Health Inspection Service
United States Forest Service
Agricultural Research Service
Cooperative State Research, Education
and Extension Service

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Purpose

This document provides the United States Department of Agriculture's national strategy for addressing the control and management of *Phytophthora ramorum* in cultivated and natural environments. This plant pest is the causative agent of sudden oak death, ramorum blight and other plant diseases. The plan has a national focus and demonstrates how USDA agencies, along with other Federal, State, Native American, and local entities will address the threat posed by *P. ramorum*.

The USDA is taking science and risk-based actions, independently and with others, to sustain the health, diversity and productivity of the Nation's nursery industry and forest and grassland ecosystems. *Phytophthora ramorum* poses a new and serious threat to forest, urban, and wildland ecosystems, as well as to horticultural nurseries, small fruit crops, and home and urban landscapes.

Goals of the Strategy

The primary objective of this strategy is to prohibit introduction, or significantly reduce the rate of introduction or reintroduction, of *P. ramorum*, into presently non-infested regions of the country, and to manage presently infested nursery systems, forests, and urban landscapes to minimize and mitigate damage.

The USDA has chosen this strategy for several reasons. The overriding goal of the Department's *P. ramorum* program is to prevent the establishment of new infestations in the United States. Taking no action is not an option since the pathogen has shown the ability to spread in natural ecosystems, and there is clear evidence that *P. ramorum* can be distributed nationally in nursery stock.

The USDA has chosen a risk management option that achieves our goal of preventing artificial spread through:

- Prevention
    - preventing artificial pathogen spread from areas where it is established in the environment
    - prevention of pathogen spread via commerce, while mitigating risk and allowing industries to continue to operate
- Detection and Monitoring
    - develop improved detection monitoring
    - continual monitoring of the nursery industry and survey of wildlands for evidence of the spread of *P. ramorum*
- Control and Management

    - regulations that restrict the movement of high risk material out of quarantined areas and regulates the movement of high risk nursery stock from other areas
    - protocols for rapidly responding to new finds of the pathogen
    - the development of best management practices to ensure the cleanliness of nursery stock
- Restoration and Rehabilitation
    - restoration and management of affected areas.

Part of the USDA's strategy is a multilayered research program involving USDA agencies, other federal agencies, state governments, academia, and industry. Investigations of the biology of the pathogen and the epidemiology of the diseases it causes are ongoing. Essential to the success of the program is operational research and methods development. These provide the tools needed to carry out specific responses to the *P. ramorum* threat, and may include survey and eradication methods, treatments, and diagnostic tests.

The successful control of *P. ramorum* will rely on a partnership among federal agencies, state agencies, affected industries and the general public. To engage and enlist the support of the various constituencies, robust outreach and educational programs are an integral part the USDA's Plan.

The USDA will continue to re-evaluate the strategy described in this plan to ensure that its goals are being met in the most efficacious way possible and to adjust the department's approach as the *P. ramorum* situation changes.

USDA Agencies Involved and Overview of Mission Responsibilities

Coordinated roles of appropriate USDA agencies and the balance between actions for Prevention, Detection and Monitoring, Control and Management, and Restoration are described, as are the needs for research information, resources, partners, and information sharing for each of these areas. Possible measures of success that may be employed to track progress towards USDA's strategic goals are described for each activity area.

USDA natural resources and environment agencies include the Forest Service (FS) and Natural Resources Conservation Services. The USDA's natural resources programs help protect nearly 75 percent of the Nation's land areas. National forests encompass 192 million acres of land, which is an area 10% larger than Texas. As the largest land managing agency within the Department of Agriculture, the Forest Service has responsibility for taking effective actions both with others and independently to sustain the health, diversity and productivity of the Nation's forest and grassland ecosystems. *Phytophthora ramorum* is a serious threat to these systems.

The Forest Service Forest Health Protection (FS FHP) staff within the State and Private Forestry Area of the Forest Service has primary responsibility for survey, detection, monitoring, and management of forest insects and diseases in the Nation's federal, state, and private forest lands. This responsibility includes working with a broad range of state partners, as well as federal partners and land managers in the Departments of Agriculture, Interior, and Defense.

Forest Service Research and Development (FS RD) is the preeminent natural resources research organization in the world. The R&D organization works closely with universities and other scientific institutions to provide understanding and technologies to federal, state, and private land owners and managers in the U.S. as well as providing information and guidance to partner natural-resource interests around the globe.

The Animal and Plant Health Inspection Service (APHIS) is an agency of the USDA Marketing and Regulatory mission. APHIS safeguards agriculture and natural resources from the risks associated with the entry, establishment, or spread of animal and plant pests and noxious weeds. Fulfillment of its safeguarding role ensures an abundant, high-quality, and varied food supply, strengthens the marketability of U.S. agriculture in domestic and international commerce, and contributes to the preservation of the global environment. Plant Protection and Quarantine (PPQ) has primary responsibility for managing plant pests in the United States.

The Center for Plant Health Science and Technology (CPHST) is the scientific support organization for the Plant Protection and Quarantine (PPQ) division of the Animal and Plant Health Inspection Service (APHIS). CPHST works to identify and evaluate pathways used by invasive plant pests and weeds that threaten American agriculture and natural resources; additionally, CPHST assesses the risks that these organisms pose to food, fiber, and the environment and provides the regional offices with operationally practical and scientifically valid mitigation options. By developing, adapting and supporting technology to detect, identify, and mitigate the impact of significant exotic pests, CPHST helps to ensure that the methods, protocols, and equipment used by APHIS-PPQ and field personnel allow for effective and efficient operation.

USDA Research, Education, and Economic agencies provide federal leadership in creating and disseminating knowledge on biological, physical, and social sciences related to agricultural research, economic analysis, statistics, extension, and higher education. The Agricultural Research Service (ARS) and Cooperative State Research, Education and Extension Service (CSREES) are two of the four agencies in this mission area.

The Agricultural Research Service (ARS) is the world's preeminent agricultural research organization. The ARS research program on plant diseases develops and improves applications to reduce commodity and crop losses caused by plant pathogens. The program focuses on developing effective disease control strategies that are environmentally friendly, do not threaten the safety of consumers, and are compatible with sustainable and profitable crop production. The ARS program is conducted in cooperation with related research in other public and private institutions. ARS has responsibility for knowledge development and application in agricultural production, protecting crops from pests and disease, improving the quality and safety of agricultural products, and sustaining our soil and other natural resources.

The mission of the Cooperative State Research, Education and Extension Service (CSREES) is to advance knowledge for agriculture, the environment, human health and well-being, and communities by supporting research, education, and extension programs at Land-Grant Universities and other partner organizations. CSREES does not perform research, education, and extension, but

rather provides national partnership and funding for cooperative state and local research, education, and extension programs.

These USDA agencies (FS, APHIS, ARS and CSREES) have specific and complimentary roles in addressing new and established threats to our Nation's natural resources and agricultural production. The primary roles of these USDA agencies in addressing *P. ramorum* are summarized in the Table shown below.

Function and Primary Responsibility of USDA Agencies in Addressing the Emerging Threat of Sudden Oak Death

ACTIVITY	AGENCY PRIMARY ROLES					
	Management/Regulatory Policy Development & Implementation		Knowledge/ Technology Development & Scientific Support			
			Methods Development	Basic and Advanced Research		
	APHIS Plant Protection and Quarantine	Forest Service Forest Health Protection	APHIS-PPQ Center for Plant Health Science and Technology	Forest Service Research & Development	Agricultural Research Service	Cooperative State Research, Education, and Extension Service
PREVENTION						
Forest, Urban, & Wildland Ecosystems	X	X		X		X
Horticultural Nurseries & Small Fruit Crops	X		X		X	X
DETECTION						
Forest, Urban, & Wildland Ecosystems	X	X		X		X
Horticultural Nurseries & Small Fruit Crops	X		X		X	X
MONITORING						
Forest, Urban, & Wildland Ecosystems		X		X		
Horticultural Nurseries & Small Fruit Crops	X		X		X	
MANAGEMENT & CONTROL						
Forest, Urban, & Wildland Ecosystems	X	X		X		X
Horticultural Nurseries & Small Fruit Crops	X		X		X	X
REHABILITATION & RESTORATION						
Forest, Urban, & Wildland Ecosystems		X		X		

Background and Description of the Sudden-Oak-Death Problem

Our Nation's oak woodlands, urban forests, agricultural, forestry and horticultural industries are in jeopardy because of a microbe new to science, *P. ramorum*, which was first observed in 1995 and not identified until 2000. Shown to be the cause of sudden oak death, also known as ramorum blight, this virulent pathogen of unknown origin has spread to forests in 14 coastal California counties as well as Oregon's Curry County. It has also been found in numerous European nurseries and gardens and recently in nurseries in Washington, Oregon, and British Columbia, Canada. In 2003 and 2004, several thousand nurseries across the US received potentially infested stock from west coast nurseries. These nurseries shipped more than two million plants to nurseries and garden centers in 49 of the 50 United States. Many of these plants were planted in residential and urban landscapes. It is not known how many plants remain in the environment, but it is likely that tens of thousands of plants that are potentially infested with *P. ramorum* remain in the environment.

The pathogen has a broad host range including hardwood trees, such as coast live oak; landscape plants, such as rhododendron; herbaceous plants, such as western starflower; and softwood trees, such as coast redwood and Douglas fir. It has killed tens of thousands of coast live oak, tanoak, and California black oak trees and causes branch and twig dieback in conifers and several shrubs, as well as leaf blight in mountain laurel, camellia, and other species. Where it has become established in California, *P. ramorum* adversely affects ecosystem functions, increases fire and safety hazards, and reduces property values in developed areas.

Over 7 million people live where the initial outbreak occurred, in the urban/wildland interface of central coastal California. Neighborhoods were transformed within months; dead trees appeared in communities where green trees formerly thrived. Communities were impacted as residential yards, parks, open spaces, and recreation areas were altered and in need of costly removal of thousands of unsightly and hazardous trees. In Oregon, the pathogen was detected shortly after establishment, which resulted in action being taken on 52 acres of forest. Some trees were salvaged, while the remainder of the forest was cleared and burned to eradicate infected plants.

Disease Symptoms

Phytophthora ramorum produces three distinct disease symptoms—bark cankers, leaf spots, and twig dieback. On oaks and tanoaks, infection causes stem cankers. Cankered trees may survive up to several years, but in the final disease stage the leaves turn from green to brown within a few weeks. Black or reddish ooze often bleeds or seeps from the cankers. The cankers gradually expand until they girdle the tree, causing it to die. Other diseases cause similar symptoms, so laboratory confirmation is needed for accurate diagnosis.

On more than two-thirds of the known host plants, comprising some forest plants, a number of horticultural nursery plants, and small fruit plants, including California bay laurel, camellias, viburnum, pieris, kalmia, and rhododendron, infection results in leaf spots and twig dieback. The pathogen sporulates readily on the leaves of many of these plant species, so they can serve as reservoirs of inoculum. Spores likely are transported locally by windblown rain. On the other one-third of known host plants, the infection causes a non-sporulating stem or bole canker. These are

seemingly dead-end hosts in that they do not act as reservoirs of inoculum. Other mechanisms for short- and long-range pathogen spread are under investigation (including transport in rivers, in soil, and by animals). Spread also occurs through movement of infected nursery stock, an issue of considerable concern. The temperature and moisture conditions that are conducive to pathogen dispersal and disease spread are under study.

Current distribution

In California, the pathogen is found from Monterey to Humboldt Counties, in redwood/tanoak and coastal evergreen forests. The disease is widespread in Marin, Sonoma, and Santa Cruz Counties, and in the Big Sur area of Monterey County. The infestations are concentrated in urban/wildland interface areas, but some portions of wildlands are heavily affected. In Oregon, the pathogen was detected in 2001 via aerial survey. It is limited to an 11-square-mile area in Curry County near Brookings, Oregon, just north of the California border. Approximately 52 infested acres have been identified. Immediately after detecting *P. ramorum*, Oregon landowners in cooperation with the State Department of Agriculture and the USDA Forest Service began harvesting non-hosts and cutting and burning host plants in the affected area. All identified sites were treated, and the eradication program requires that they be intensively monitored for at least two years.

Risk maps integrating introduction pathways, susceptible plant species, and weather conditions favorable to *P. ramorum* survival and disease development have been constructed by the Forest Health Monitoring Program and the Center for Plant Health Science and Technology to guide cooperative surveys. The analysis indicates that Eastern forests and coastal areas of Oregon and Washington, as well as currently uninfested areas of coastal California, are at greatest risk of supporting establishment of the disease. Greenhouse and laboratory inoculation experiments and some detections in Europe have shown that seedlings of oak species common in Eastern forests are susceptible to the pathogen.

The temperature and moisture conditions in the modified environments of plant nurseries and greenhouses and the production of susceptible plant species in these environments may enable year-round survival and disease development at these sites.

In Europe the pathogen has not been found in forests, but it has been found on various plants of commerce in hundreds of nurseries in the United Kingdom, France, Spain, the Netherlands, Germany, and Belgium, and on oak, chestnut, and beech trees in gardens and parks. Recently the pathogen has been detected on plants shipped from nurseries in California, Washington, Oregon, and British Columbia, heightening the concern that nurseries may provide a pathway for disease introduction or spread into other nurseries, landscapes, and forests.

Economic Impact

Phytophthora ramorum could have major economic implications for forest, horticultural and small fruit agricultural industries. The U.S. ornamental nursery industry is valued at over $13 billion annually, ranking as our Nation's third highest value crop. California is the industry's leading producer of horticultural plants, valued at $2 billion a year. Oregon's industry is ranked fifth

nationally and ranks second in the production of woody plants. California and Oregon, as well as the United States, Canada, the European Union, South Korea, Australia, New Zealand, and the Czech Republic have imposed regulations for host plants and associated soil from infested areas. These regulations restrict shipment of rhododendron and other horticultural host plants from areas where the pathogen is found.

Forest plants are also susceptible. In addition to the culturally significant and aesthetically-valued oak species, coast redwood and Douglas-fir are hosts. Although damage on these species appears to be limited to foliage and small branches, regulatory actions could impact the redwood and Douglas-fir industry in California at an estimated $50 million a year.

The potential economic and ecological loss to the vast commercial Douglas fir forests in Oregon, Washington, and western Canada are even greater. This impact could increase markedly if the pathogen became established in Christmas tree plantations. Nationally, Christmas tree production is valued at $500 million a year. Oregon leads national production, with California and Washington among the top 7 producers. The Christmas tree economy depends on nation-wide distribution, which could be adversely affected by regulations.

East of the Mississippi river, oak forests dominate the landscape with millions of acres at risk. Recent detections in Europe have shown that eastern oaks such as pin oak and northern red oak are susceptible. The oak hardwood forest is the largest forest type in the U.S., and its potential vulnerability to this pathogen is of considerable economic and ecological concern.

The best defense against the establishment of *P. ramorum* in eastern oak forests is to prevent its introduction. Delineation of infested areas and aggressive containment of the pathogen in California, Oregon, and Europe through quarantine and eradication in some areas are underway. Early detection, through ongoing surveys of nurseries and wildlands is essential. Eradication from newly infested cultivated and wildland areas will be critical if the pathogen escapes containment.

Approach for a National Strategy

This plan outlines the USDA national strategy where the first defense is to prevent pathogen introduction and disease development in new areas. Where new pathogen or disease occurrences are detected through an aggressive monitoring program, where appropriate there will be a rapid response to eradicate the pathogen, or otherwise control, manage, and mitigate impacts. In areas impacted by the disease, restoration and rehabilitation activities will be needed to reestablish forests, residential yards, parks, open spaces, and recreation areas to their previous condition and function.

The following sections on Prevention, Detection and Monitoring, Control and Management, and Restoration and Rehabilitation describe planned activities, clarify agency roles in these activities, and elucidate the needs for research, resources, partners, and information sharing and provide possible measures of success in order to evaluate program effectiveness. These efforts provide a science-based, collaborative and cooperative approach to problem solving. The approaches will be continually updated as new information and needs are identified.

PREVENTION

The most effective technique to combat an invasive species is to prevent its introduction, establishment, or spread. Prevention includes professional and public education and outreach to raise the awareness of the problem and reduce the chance of an unintentional introduction. By enlisting the skills of our science and education programs, we can achieve a successful prevention awareness campaign on a national scale. Establishing effective domestic and international partnerships is also critical for effective prevention programs.

Currently there is no pesticide identified that will kill *P. ramorum*; current fungicides in use are fungistatic, not fungicidal, therefore restorative treatment of infected plants is not feasible. In order to limit pathogen spread, regulatory actions are being implemented and enforced worldwide. In February 2002, APHIS-PPQ issued an interim rule on *P. ramorum* governing interstate shipment of host plants and associated soil to prevent pathogen spread from the known infested area. California and Oregon have similar regulations. These regulations, which are continuing to evolve, cover lumber, logs, mulch, wood chips, firewood, nursery plants, soil, yard waste, florist materials, and many other commodities. Land managers are charged with enforcing the regulations on public lands; private landowners must also comply.

In addition, sound management recommendations are needed for nursery production, arborists, firewood collection, wildland Christmas tree cutting, timber sales, recreation areas, landslide repair, and road maintenance and construction to minimize the accidental spread of the pathogen.

Through training programs and outreach activities, the USDA and its State and local partners will train professionals and educate the public on symptom identification, sanitation measures, and regulatory compliance.

Objective: Since only central coastal California and a small area in Oregon are currently infested, our objective is to prevent pathogen spread from these areas or other places (i.e., domestic or foreign nurseries) to any new locations. This effort includes the prevention of pathogen spread via commerce while allowing industries to operate. Specific agency responsibilities to prevent the spread of *Phytophthora ramorum* include:

APHIS PPQ PDMP -- The primary prevention responsibility of the USDA Animal and Plant Health Inspection Service is to assess the risk of establishment and to develop and deploy a science and risk-based regulatory response for forest, urban, nursery and other crop settings as necessary. The assessment of risk includes an identification of potential pathways of introduction and spread (both domestic and international). In the assessment of risk, data gaps will be identified which will generate research needs for CPHST, FS-R&D, or ARS to address as appropriate.

Development of a sound regulatory response based on science and risk will identify partners and stakeholders with whom actions will be coordinated and risk communicated. Successful implementation of the regulatory response will involve a cooperative effort among APHIS-PPQ and other countries as well as with federal, Native American, state, and county partners.

APHIS PPQ CPHST -- The primary prevention responsibilities of the Center for Plant Health Science and Technology are to identify, develop, adapt, validate, and support the basic and applied knowledge and technologies necessary to identify the organism, to identify susceptible plants, to assess risk, and to determine and describe national and international pathways of spread through domestic and international trade, and in nursery and landscaped environments and to provide scientifically valid and operationally practical management and mitigation options.

FS-FHP -- The primary prevention responsibilities of the Forest Service, Forest Health Protection are to work with stakeholders to identify and communicate the issues and risks, and to provide technical assistance with the development and implementation of proactive prevention strategies for state, private, Native American, and federal lands. This effort is concentrated in rural forest and urban environments.

FS-R&D -- The primary prevention responsibilities of Forest Service Research and Development are to develop the basic and applied knowledge necessary to identify the organism, to identify susceptible plants, to assess risk, and to determine and describe national and international pathways of spread to rural forests and the urban wildland interface.

ARS -- The primary prevention responsibilities of the Agricultural Research Service are to expand our basic and applied knowledge regarding the taxonomy, biology, and behavior of the pathogen and disease expression, including host, site, and environmental information. ARS has responsibility for examining soil characteristics and environmental aspects conducive for disease development. ARS scientists have responsibility for host range testing of nursery and landscape species to assess risk and determine susceptibility of commercial and landscape species to Sudden Oak Death.

CSREES and Its Partners: Prevention includes professional and public education and outreach to raise the awareness of the problem and reduce the chance of an unintentional introduction. By enlisting the skills of our science and education programs, such as the Extension Master Gardeners, we can achieve a successful prevention awareness campaign on a national scale. CSREES-Partners also through research and extension develop and disseminate sound management recommendations for nursery production including Christmas tree plantations, arborists, and landscapers.

Measures of Success: The success of these prevention efforts ~~can~~ may be evaluated through examining the: (1) awareness of the disease in all 50 states; (2) availability of diagnostic guides and pest alerts; (3) number of new disease sites detected in forests, urban settings, nurseries and small fruit plantings; (4) number of trading partners self-inspecting and certifying shipments; (5) number of pathways for spread identified and safe-guarded against spread.

DETECTION AND MONITORING

Monitoring to detect pathogen presence is a critical component of the *P. ramorum* management strategy. Activities needed include port inspections, nursery surveys, aerial and roadside surveys in wildland and urban forest settings, forest inventory and monitoring plots, and public employees trained to look for the disease. There are numerous critical components of detection, all of which

have as a fundamental basis the ability to identify the organism in suspect material. There is a critical need for the rapid development and application of accurate and consistent detection technologies.

As an example of the magnitude of the problem, California and Oregon have more than 20 million acres of potential habitat for *P. ramorum*. It has been identified in 75 different plant hosts and its known host range is expected to increase as monitoring and detection methods continue. Aerial surveys are being conducted in regions where known *P. ramorum* host species are abundant. Dead trees are being ground-checked and tested for the presence of *P. ramorum*.

Federal, state, and county personnel are inspecting nurseries, firewood dealers and other businesses that handle host commodities within infested areas for compliance with federal regulations. A national survey of forests at risk, focusing on high and moderate risk states, is being conducted by the Forest Health Monitoring program and its partners to determine whether the pathogen occurs outside the quarantined areas of California and Oregon. APHIS-PPQ is conducting a national survey of nurseries throughout the United States to determine the risk of spread and establishment of the pathogen through nursery plants.

Since *P. ramorum* is a quarantine pathogen, maps identifying infestations are required. Surveys are needed to delimit infestations and assist with regulatory design and enforcement. Records of pathogen distribution will be maintained in a national web-accessible GIS database (http://ceris.purdue.edu.napis/) and linked to California's *P. ramorum* database at www.suddenoakdeath.org. This resource will aid in economic analysis and prediction of the potential impact on natural resources.

Objective: The objective of the detection and monitoring component of this strategy is to rapidly and accurately determine where the pathogen and disease are located and to be able to reliably verify pathogen presence or absence in areas considered to be uninfested. Specific agency responsibilities for the detection and monitoring of disease occurrence and pathogen spread include:

APHIS PPQ PDMP -- The primary detection and monitoring responsibility of the USDA Animal and Plant Health Inspection Service is to deploy an aggressive national survey plan and regulatory response with a sound science and risk basis, and safeguarding actions to detect and appropriately deal with new occurrences of the pathogen. This effort includes port inspections, nursery surveys, and other actions in coordination with state partners and other stakeholders, as well as the clarification of pathways of risk.

PDMP coordinates its survey plan and regulatory actions with state partners and other stakeholders who need to be made aware of their roles and responsibilities. PDMP shares information regarding new detections domestically and internationally. PDMP continues to work with CPHST, ARS, CSREES, FS-R&D, the academic community, and others to obtain and validate the best detection technologies research can provide. In conjunction with the states APHIS-PPQ develops its monitoring scheme for horticultural nurseries, urban landscapes, and nursery perimeters and coordinates these surveys with the Forest Service-FHP in their detection and monitoring efforts in

wildlands and forested urban areas. APHIS maintains an accurate database of pathogen interceptions and hosts.

APHIS PPQ CPHST -- The primary detection and monitoring responsibility of the Center for Plant Health Science and Technology is to identify, develop, adapt, validate, and support the basic and applied knowledge and technologies needed to detect and track *P. ramorum* in nursery systems and the landscaped environment. CPHST works with APHIS-PPQ program and field staff to develop sampling protocols for disease detection and monitoring in nurseries and landscapes. Emphasis is on developing and validating fast, accurate, inexpensive, and user-friendly detection and diagnostic methods to use in these and other environments. CPHST develops sampling protocols for disease detection and monitoring in nursery crops and other types of hosts.

FS-FHP -- The primary detection and monitoring responsibilities of the USDA Forest Service Forest Health Protection are to identify and track new infestations on forest lands and in the urban-wildland interface and to implement monitoring activities in these areas. Forest Health Protection will work with federal, Native American, state and other partners to maintain an accurate database of new disease detections as well as disease distribution, spread, and impact. In conjunction with FS R&D and others, FHP provides training in sampling, survey methods, and pathogen recognition.

FS R&D -- The primary detection and monitoring responsibility of USDA Forest Service Research and Development is to develop basic and applied knowledge regarding the taxonomy, biology, and behavior of the pathogen and disease dynamics, including host, site, and environmental interactions with an emphasis on the wildland and urban forest environments. The latter will require working with FS FHP to develop sampling protocols for disease detection and monitoring in forested landscapes, including urban forests. Emphasis is on development of fast, accurate, inexpensive, and user-friendly detection and diagnostic methods for use in wild land forest and urban environments.

ARS -- The primary detection and monitoring responsibility of the USDA Agricultural Research Service is to develop the basic and applied knowledge necessary to identify the organism, and to determine and describe pathways of national and international spread within nurseries, horticultural crops, and small fruit industries. Emphasis is on the development of fast, accurate, inexpensive, and user-friendly detection and diagnostic methods for use in port inspections, in nursery crops, and other hosts. ARS has responsibility for systematically evaluating and characterizing the geographic diversity of the genus *Phytophthora*, in order to develop improved molecular detection and identification methods.

CSREES – The land grant university plant diagnostic clinics analyze plant samples, suspected of being infected with P. ramorum, that are submitted by extension faculty, private firms and individuals and extension master gardeners. The clinics are also connected through the National Plant Diagnostic Network for early detection and movement of invasive species.

Measures of Success: The success of these detection and monitoring efforts may be evaluated through examining the: (1) number of plants with disease symptoms intercepted at ports of entry; (2) number of early detections that would permit eradication; (3) number of at-risk forest acres

surveyed and found to be disease free; (4) number of at-risk nurseries found to be disease free; (5) number of acres of small fruit crops maintained as disease free; (6) effective response to reports of new disease outbreaks.

CONTROL AND MANAGEMENT

In natural areas considered infested with *P. ramorum*, such as the central coast of California, eradication is no longer feasible; only projects to slow the spread are practicable alternatives to manage the disease. Isolated new infestations may be treated even if they are within the generally infested area, but quarantines and public education will need to be utilized to contain the pathogen within the limited areas that are currently infested.

In Oregon, where infection is believed to have occurred fairly recently, all newly detected wildland sites during 2002, 2003, and 2004 were treated to eradicate *P. ramorum*. Treatment immediately following detection is considered desirable, and initiating treatments at the earliest detectable point after infection occurs improves the likelihood of success. The current eradication methods are to: outline affected areas based on symptoms and add a 100-foot buffer; cut, pile, and burn host material; then broadcast burn to consume the litter layer. Intensive follow up monitoring is being conducted, with re-treatment as necessary.

In areas where clear-cutting is not an option due to adverse environmental impacts, the value of trees, or other considerations, removal of infested California bay laurel or other foliar hosts that are known to support pathogen inoculum production may be recommended to slow the spread of the pathogen. Eradication can only be successful if the disease is detected early and its distribution is limited.

In nurseries, eradication of the pathogen is the primary objective. Through protocols for tracing infected plants and mitigating infested nurseries *P. ramorum* may be eliminated from nursery stock. Successful eradication can be demonstrated through scientifically valid survey and sampling plans. The implementation of clean stock programs and best management practices for nurseries can ensure that nursery stock moving in commerce is free of *P. ramorum.*

Objective: The objective of the control and management component of the strategy is to limit pathogen spread to uninfested areas and to slow disease development within these infested areas.

Specific agency responsibilities to control and manage occurrences of *Phytophthora ramorum*:

APHIS PPQ PDMP -- The primary control responsibility of USDA APHIS is the regulation of interstate and international commerce as a mechanism to manage the disease. A list of regulated articles and inspection procedures, treatments, standards and methods are developed and deployed by APHIS. This information is shared with state agencies and regulatory partners. APHIS PPQ PDMP also works with state, private, Native American and other federal partners in disease control and management efforts through regulatory activities.

PDMP develops control and management protocols to support its regulatory program. These protocols guide federal and state agricultural officials in tracing the movement of potentially infected plants and in responding to detections of the pathogen in nurseries and landscaped environments. PDMP will partner with the States and nursery industry to develop and deploy clean stock programs and best management practices for the long-term control and management of *P. ramorum*.

Internationally, APHIS PPQ works with trading partners to reduce the threat of *P. ramorum* in Europe and North America. For example, APHIS PPQ is working with Canada to harmonize trade regulation, sampling detection, and diagnostic and response protocols. In Europe, we exchange knowledge of the biology of the pathogen as well as expertise in diagnostics. The sharing of current information on detection details in known and potentially novel hosts enhances our knowledge base and improves response to program needs.

APHIS PPQ CPHST --The Center for Plant Health Science and Technology evaluates and validates control and management strategies primarily for use in nurseries and urban landscapes. These may include chemical and non-chemical treatments, cultural practices, monitoring programs and risk assessments. CPHST also supports APHIS-PPQ and industry partners in the development of clean stock programs and best management practices for the long-term control and management of *P. ramorum* by identification of procedures that best limit pathogen establishment and spread.

FS FHP -- Forest Health Protection of the Forest Service has primary responsibility to coordinate control and management actions on forested federal lands and to assist state, Native American, and private partners in their control and management efforts in wildland and urban forest environments. These activities include technology transfer of control strategies and post suppression monitoring and evaluation of control actions to judge their effectiveness and improve their efficiency through adaptive management. Control demonstration projects may also be used to showcase disease management strategies.

FS R&D -- The Forest Service's Research and Development branch has a basic charge to develop effective control for the disease in forest environments. To accomplish this task it must develop basic and applied knowledge regarding the taxonomy, biology and behavior of the pathogen and disease dynamics, including host, site, and environmental interactions with an emphasis on the wildland and urban forest environments. Information gained through this research can be used to develop and test various management and disease control actions in wildland and urban forest environments. Certain control strategies can be evaluated in a virtual environment without implementing large scale and long term on-the-ground experiments. Such tests could be particularly useful for predicting consequences of the disease outside of currently infected areas. The successful treatments need to be communicated to FHP for implementation as needed by federal, state and private land managers.

ARS – The control and management responsibilities of the Agricultural Research Service are to study the biology of the pathogen including distinguishing molecular traits, pathogenicity, and factors impacting potential spread with the emphasis on horticultural nurseries, small fruit industries and other non-forest plants. ARS has responsibility for evaluating the etiology, genetics

and epidemiology of *Phytophthora* species affecting nursery crops and monitoring of the spread and population structure of *P. ramorum.* ARS develops and integrates cultural, biological and chemical controls for management of *Phytophthora* diseases under commercial conditions including fungicide trials to determine if certain compounds are efficacious. ARS identifies genes expressed in *P. ramorum* during host-pathogen interactions in order to better understand the genetics of infection.

CSREES-Partners – The extension service of the CSREES and the Land Grant Universities in each state actively educates growers (such as nursery-greenhouse growers), landscape managers (parks, woodlots, and other planted areas), and the public on prevention and management of P. ramorum plant diseases.

Measures of Success: The success of these control and management efforts may be evaluated through examining the: (1) acreage of susceptible areas free of disease; (2) number and size of sites where the disease was eradicated; (3) evidence of a decrease in the rate of disease spread; (4) the number of nursery shipments passed as disease free; (5) proactive involvement of states and communities in mitigation efforts.

RESTORATION AND REHABILITATION

There is a need to replant disease-damaged areas with non-susceptible species or resistant host varieties to prevent exotic weed invasion and restore ecological function, as well as to maintain recreational landscapes and visual beauty in wild land and urban forest settings. Our knowledge of disease dynamics and the extent of susceptible hosts is growing rapidly; however, our understanding of the full extent of disease expression is still unknown on nearly all sites impacted by *P. ramorum*. Thus, the development of restoration strategies and actions are in their infancy. Their development will continue as we gain more information through ongoing and planned research and monitoring activities. Timely implementation of restoration activities is important, but must await the development, testing, and approval of effective strategies in order to avoid the possibility of costly mistakes.

Objective: The objective of the rehabilitation component of the strategy is to restore and maintain ecosystem functions and benefits in areas impacted by *P. ramorum.*

Specific agency responsibilities to restore areas impacted by *Phytophthora ramorum*:

APHIS PPQ -- The Animal and Plant Health Inspection Service has no specific restoration responsibilities.

FS FHP -- As appropriate planting and other restoration strategies are developed, Forest Health Protection has an advisory role in coordinating these efforts on federal, Native American, state, and private forest lands, including urban and community forests. Before specific restoration activities are implemented, FHP also has an advisory role in hazard tree management and developing safety guidelines for workers removing trees killed by *P. ramorum* in wildland and urban forest settings.

FS R&D -- Forest Service Research and Development needs to describe the full extent of impacts caused by *P. ramorum* in forested environments. These include effects of the disease on ecological functions. As these impacts become more fully understood, FS R&D can design and test potential treatments to restore ecological function as well as maintain recreational landscapes and visual beauty in wild land and urban forest settings. As effective restoration treatments are developed, including the possibility of utilizing disease resistance in susceptible hosts, they need to be transferred to FS FHP for dissemination to affected federal, Native American, state, and private land managers.

ARS -- The Agricultural Research Service has no specific restoration responsibilities.

CSREES – The Cooperative Research, Education and Extension Service has no specific restoration responsibilities.

Measures of Success: The success of these restoration and rehabilitation efforts may be evaluated through examining the: (1) number of acres successfully replanted; (2) number of ecological functions restored to a pre-disease state; (3) acres of restoration backlog that are restored.

Resource Allocation and Needs

Summary of USDA Agency Funding For Sudden Oak Death. FY 2000 – 2005 (in thousands of dollars)

AGENCY	2000	2001	2002	2003	2004	2005
USDA						
FS	120	4,150	973	3,700	3,700	4,400
APHIS	0	0	1,000	2,000	18,500	17,000
ARS	0	0	0	620.8	1,250	1,000
CSREES	0	0	0	300	300	115
State	0					
Oregon	0					
California	100	3,586	2,000	0	0	
Private		1,000			2,484	
Total	$220	$8,736	$3,973	$6,621	$26,234	$20,815

Future resource needs are difficult to project owing to the interaction of complex circumstances. For example, if prevention and detection efforts are successful in keeping the disease from becoming established in eastern forests, then large increases to deal with the disease in these environments will not be necessary. In contrast, if research uncovers additional pathways of spread, additional resources would be needed to safe-guard these pathways to protect yet uninfected forests, nurseries, and small fruit crops. As the host list for the disease continues to increase, each new addition raises new concerns.

Summary

By working in concert with private, state, Native American, and other federal partners, the USDA is going forward with a proactive approach to regulate *P. ramorum*, and to detect and monitor outbreaks of *P. ramorum* in order to prevent its spread to and establishment in new locations. In areas impacted by the disease, control and management strategies are being developed and implemented. Plans are in progress to rehabilitate severely damaged sites. The successful deployment of all of these strategies is dependent on markedly increasing our knowledge regarding this organism and the disease that it causes, as *P. ramorum* has been known to science for a relatively short time. This plan also requires adequate resources, continuing interagency cooperation and coordination, and full engagement of state and private partners as well as the general public in all phases of the effort.

References

1) Sudden Oak Death Report: Protecting America's Woodlands from *Phytophthora ramorum*. FS-FHP Report.

2) Sudden Oak Death: A 5-year Plan to Address the Emerging Threat. This is the Research Plan prepared by the PSW Research Station.

3) The SOD Pest Risk Assessment prepared by the Forest Service (John Kliejunas).

4) The Evaluation of Risk Associated with the Movement of Wood (Logs, Lumber, Firewood, Bark, and Wood Chips) from *Phytophthora ramorum* Infested Areas and Potential Mitigation Measures. This is the Draft PRA that Betsy Randall-Schadel is preparing for APHIS.

5) 7CFR301.92, Interim Rule: *Phytophthora ramorum* (Feb 2002)

6) APHIS PPQ, Emergency Federal Order Restricting Movement of Nursery Stock from California, Oregon, and Washington Nurseries (Dec. 21, 2004).

7) California Oak Mortality Task Force Web-site

8) Plant Health Progress Diagnostic Guide for *Phytophthora ramorum*.

9) Risk Analysis for *Phytophthora ramorum* Werres, de Cock & In't Veld, Causal Agent of Sudden Oak Death, Ramorum Leaf Blight And Ramorum Dieback, USDA APHIS PPQ CPHST, May 2005

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