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"...the most destructive non-native tree pests have been fungi, which have caused fatal diseases such as chestnut blight, Dutch elm disease, beech bark disease, and butternut canker. These diseases have changed our forests profoundly and our rural and urban landscapes irrevocably. Sudden oak death has the potential to do the same."

DR. ANDREW LIEBHOLD
Forest Service research entomologist, 2004

Sudden Oak Death—
Not Just a West Coast Problem

The recent shipment of horticultural nursery stock infected with *Phytophthora ramorum* — the newly discovered non-native invasive fungus that has been causing sudden oak death (SOD) in California — into 14 eastern states — highlights the extreme danger of this pathogen. We need to be prepared, to have strategies in place to detect the fungus in the East and procedures that can reliably eradicate it and thus protect our oaks in both forests and residential landscapes. Scientists at the USDA Forest Service's Northeastern Research Station are involved in risk-mapping to determine areas of highest risk for establishment of this disease. They are also investigating eastern forests to determine what other *Phytophthora* species are present and thus obtain a relevant "before" picture.

The Dangers of Non-native Invasives

Recently, we've heard a lot about "invasive aliens" and "non-natives." We're not talking about little green creatures from Mars — we're talking about numerous animals and plants that don't belong in North America. You've probably heard of some of them: zebra mussels clogging our waterways;

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Forest Science Review is dedicated to providing its readers with clear concise descriptions of scientific findings (and their implications) that have been recently discovered and published by the scientists of the USDA Forest Service's Northeastern Forest Research Station, which serves New England, New York, Pennsylvania, New Jersey, Delaware, Maryland, West Virginia, and Ohio, the most densely populated and most densely forested part of the United States.

We hope that land managers, policymakers, extension specialists, science communicators, environmental advocates, and educators, as well as conservationists and all others interested in the health and productivity of forests in the Northeast, will find that our quarterly newsletter offers important insights and information for them.

The NE Research Station is part of the USDA Forest Service's Research and Development national network. NE scientists work at sites in 11 states Hamden/Ansonia, CT; Newark, DE; Amherst, MA; Baltimore, MD; Bradley, ME; Durham, NH; Syracuse, NY; Delaware, OH; Warren and Newtown Square, PA; Burlington, VT; and Morgantown, Parsons, and Princeton, WV.

NERS scientists work in a wide range of laboratories and field sites all over (and even outside) the Northeast. They conduct research in 8 experimental forests, including several with long-term data sets that are unique to science, and in 6 research natural areas, sited on National Forest System lands. Two important research localities are the Forest Service's only primary quarantine laboratory on the continental U.S. (Hamden/Ansonia, CT), a facility certified for biological control research on exotic forest pests and their natural enemies, and the Baltimore (MD) Long-Term Ecological Research Site, where NE scientists and other cooperators study the ecology of an urban forest.

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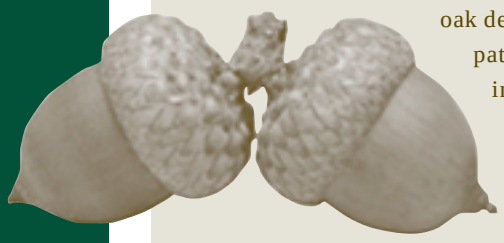
purple loosestrife growing all over our wetlands; Japanese knotweed and garlic mustard along our roadsides and in our backyards; and gypsy moths eating our oak trees and denuding the mountain forests. Some have been around for a while and are somewhat adapted here, such as starlings, honey bees, mute swans, and nutria. Others, more recent arrivals, have been hunted down with great interest — that northern snakehead fish just seems to keep reappearing and is now being caught from the Potomac River!

Non-native invasives become problems when they change our ecosystems, usually by crowding out the native species, altering soil characteristics in their favor, or by killing specific hosts. Lately, you may have read about two new dangerous non-native insect pests discovered here in the East — the Asian longhorned beetle in New York, New Jersey, and Chicago and now the emerald ash borer in Michigan, Ohio, Indiana, and Maryland. But the most devastating invasives have been fungi causing fatal diseases in our trees — chestnut blight, Dutch elm disease, beech bark disease, and butternut canker. They have changed our forest, rural, and even urban land.

Invasive Fungal Diseases of Trees

Invasive fungal diseases are highly dangerous because they can eliminate specific host species, often throughout their entire ranges, and many can quickly spread by spores in the wind or in infected wood transported commercially. (And, even when effective fungicidal treatments are developed, expenses and other factors limit their use to city and garden trees.) For example, the American chestnut, formerly a dominant tree of eastern forests and of great value to both humans and wildlife, disappeared from nearly all of its natural range within about 50 years due to infection by the fungus *Cryphonectria parasitica*. Dutch elm disease (caused by the fungus *Ophiostoma ulmi* and vectored by two beetle species) arrived before 1930 and since then has marched its way around North America, now reaching even to the isolated cities in the far northern Canadian prairies through infected firewood brought from further south. Beech bark disease (caused by *Nectria* fungal species and two species of *Cryptococcus* scale) and butternut canker (caused by *Sirococcus clavigignenti-juglandacearum*) are contemporary problems, and scientists are working to identify and propagate resistant strains of their host trees. Then there is anthracnose fungal blight that is killing and debilitating native dogwoods — it begins to seem like every species in the forest is under attack!

Sudden Oak Death— The Latest Export From California



The most recent invasive disease in the forest is sudden oak death, or ramorum blight, and it has plant pathologists, the scientists specializing in plant diseases, very scared. Even though, in North America, it is currently only affecting trees and shrubs along the West Coast (California mostly, with small

introduction spots in Oregon), plant pathologists world-wide fear that it could develop into a problem of devastating proportions in many places (a different strain has been found in Europe). There are two reasons for this danger: (1) Much of eastern North America is covered with deciduous forests that include both oaks and the shrub species that may serve as disease reservoirs; and (2) Although the SOD fungus kills mature trees of several species (trees of the red and live oak groups and tanoak), it infects but does not kill many understory shrub species — rhododendrons and azaleas, mountain-laurels, California-laurels, pieris, camellias, and others — in the wild and in commerce. These shrubs only suffer from leaf spot and twig blight and serve as of reservoirs of infection by fungal spores. Ornamental shrubs grown horticulturally could carry the disease to the East.

It Could Be Here in the Northeast!

And, unfortunately, this indeed has happened: this spring, after California inspectors found infected plants in three nurseries outside the quarantine zone in California, USDA Animal and Plant Health Inspection Service (APHIS) and state agricultural inspectors all across the country tracked down thousands of camellias that had been shipped to many garden centers and nurseries and found the SOD fungus in plants in nurseries in 14 states, including Alabama, Florida, Georgia, Louisiana, Tennessee, Maryland, Pennsylvania, and Virginia. Over 783,000 plants have been destroyed so far. Unfortunately, many of the plants shipped out of California over the past year have already been sold and planted in thousands of backyards across the nation. Efforts are under way to find, inspect, and test these plants, and if necessary, to destroy them before the disease can spread to native vegetation.

History of SOD in California

In 1995, tanoaks (*Lithocarpus densiflorus*) in Mill Valley, Marin County, California, began dying in great numbers, usually within 2 to 4 weeks after their leaves began to turn brown. The trees probably had oozing trunk infections, known as cankers, for several years before the cankers girdled the trunk and caused rapid death of the entire tree. Additionally, the disease was found to kill coast live oak (*Quercus agrifolia*), California black oak (*Q. kelloggii*), Shreve oak (*Q. parvula* var. *Shrevei*), and canyon live oak (*Q. chrysolepis*). By 1999, plant pathologists Drs. David Rizzo and Matteo Garbelotto at the University of California began working to identify the causative agent. In 2000, they identified it as *Phytophthora ramorum*, a new species of the so-called water molds, which cause many serious agricultural diseases (including the blight that resulted in the Irish potato famine in 1840s).

The California Oak Mortality Task Force

Quickly, local, state, and federal workers in California began to meet and establish programs to respond to this threat, forming the California Oak Mortality Task Force. This group began surveys; programs to identify, remove, and destroy dead and infected trees and inspect nursery stock; and scientific studies (including some by Forest Service Research and Development scientists) to determine the characteristics of the fungus, its requirements for growth, its methods of spread, and possible fungicidal and other treatments. Areas where the fungus is found are under strict federal quarantine and any introductions outside that area must be treated drastically. Unfortunately, at infection hotspots, such as those in southwestern Oregon forests, efforts to extirpate the fungus must rely on clearcutting all host trees and shrubs within 100 feet of the infection center. Stumps are then treated to prevent sprouting, and debris is piled and burned. The site must be monitored and found free of infection for 2 years before it can be released from quarantine.

Risk-Mapping for Invasives — The NE Research Station's Contribution

In 2002, when it was determined in greenhouse experiments that seedlings of two common eastern oaks — northern red oak (*Q. rubra*) and pin oak (*Q. palustris*) — were highly susceptible to the SOD fungus, scientists in the Northeastern Research Station got to work. [Later, other eastern oak species were also found to be susceptible; these include white oak (*Q. alba*), chestnut oak (*Q. prinus*), cherrybark oak (*Q. falcata* var. *pagodifolia*), live oak (*Q. virginiana*), and laurel oak (*Q. imbricaria*).] Drs. Kurt Gottschalk and Andrew "Sandy" Liebhold of our laboratory in Morgantown, West Virginia, previously had developed extensive expertise in risk-mapping for gypsy moth spread, beech bark disease, and hemlock woolly adelgid infestations (see box on page 5).

Using plot data developed by our Northern Forest Inventory and Analysis (FIA) unit, Drs. Gottschalk and Liebhold developed an SOD risk map for the eastern United States. The in-depth understory shrub data from FIA allowed them to create a map of the Northeast that included both susceptible trees and understory shrubs. A team that included Dr. Gottschalk later incorporated this map into a national SOD risk map that included other factors, such as climate variables, understory shrub hosts, and potential pathways of movement such as rhododendron nurseries.

> *"It's the scariest thing I've seen in my lifetime."*
>
> **DR. KURT GOTTSCHALK**
> Forest Service research forester, 2004

After demonstrating that the highest potential for SOD in the eastern United States includes the central and southern Appalachians, they have pursued further research. A cooperative research agreement in 2003 with Dr. William MacDonald of West Virginia University provided the resources for conducting identification and inventory of all *Phytophthora* species in the central Appalachian Mountains. Dr. Yilmaz Balci had previously worked in Austria and Turkey, where he researched a new species of *Phytophthora* associated with declining oaks in those countries. Drs. Balci, MacDonald, and Gottschalk are now working on a plan to investigate what *Phytophthora* species are present in central Appalachian oak forests. These scientists, along with Dr. Robert Long from our laboratory at Delaware, Ohio, and Dr. Jenny Juzwik of the North Central Research Station in St. Paul, Minnesota, will work together to sample across a gradient of SOD risk from high to medium to low. Nine states are cooperating in the research, which will extend from Pennsylvania, Maryland, West Virginia, and Ohio, then across Indiana, Illinois, Michigan, Wisconsin, and Minnesota. Sampling for this study is ongoing and will continue in the fall of 2004.

Although we do not know just what the possibility of establishment of SOD in eastern forests would be, our nation's experience with chestnut blight and Dutch elm disease tells us that we really don't want to wait and find out. That is why forest scientists, plant pathologists, and many others at the federal and state agencies are working diligently to intercept, investigate, and eradicate SOD. But with so many introductions, it is critical that research address the many questions that will need to be answered in order to be able to manage SOD if it becomes introduced or established here. Where will it most likely show up? How will it behave? Will climate have effects on its range? What should homeowners, land-owners, and land managers do to identify, contain or eradicate the pathogen? The North Eastern Research Station is an important link in the network of those who seek to protect our forests through this essential research.

Just recently, scientists at the Virginia Bioinformatics Institute of Blacksburg, Virginia, and the Joint Genome Institute of Walnut Creek, California, reported the DNA sequencing of *Phytophthora ramorum*'s 65-million-units-long genome. They hope that this will lead to the development of methods for diagnosing SOD before signs of infection are visible and a method for selective treatment. ■

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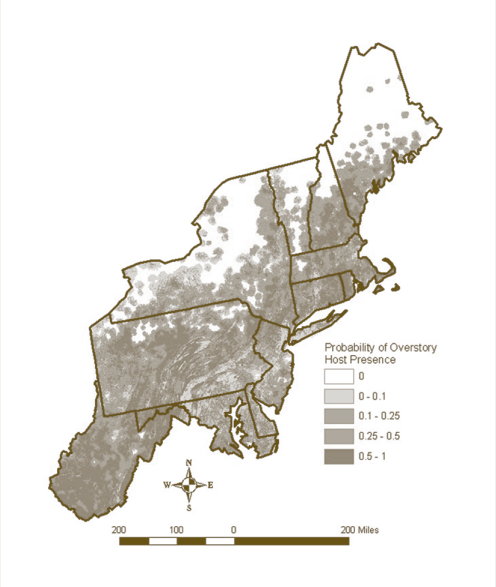
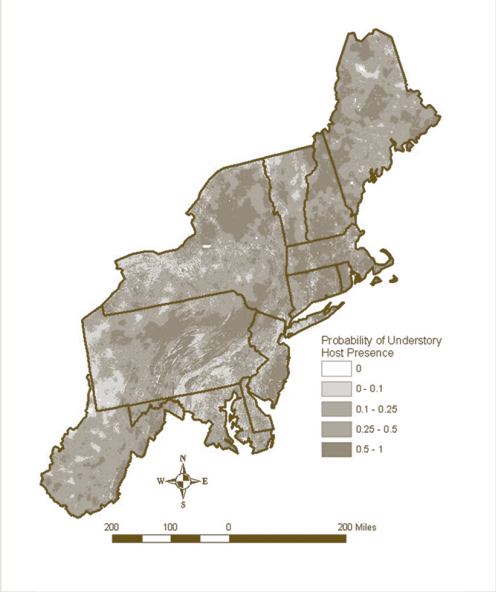
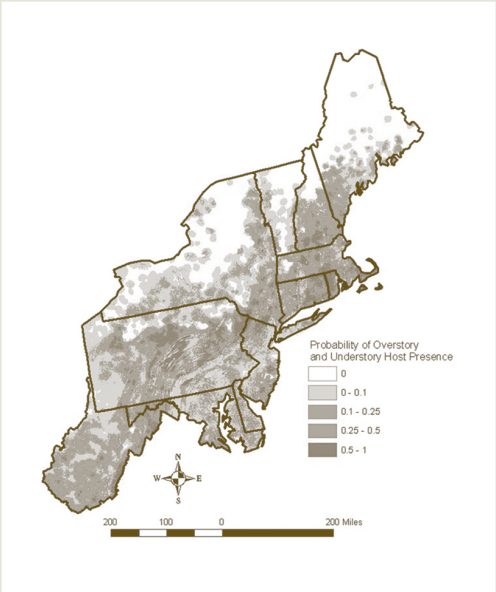
Risk–Mapping for SOD

Given the ever-increasing number and potential severity of non-native invasive pests and diseases, developing better tools and coordinated management strategies are urgent research priorities. One critical "tool" is risk assessment, that is, evaluating the potential dangers of a non-native pest both before and after it arrives in a new habitat. Developing maps that represent the geographical extent of estimated future disturbance caused by non-native species are a critically important part of risk assessment.

Predicting risk in forest ecosystems is often limited by the lack of data and models for estimating the geographical extent of damage. Here we illustrate some details of the approach taken by NE scientists Gottschalk and Liebhold (working with NE operations research analyst Randall Morin) to overcome these limitations and produce a risk-map for sudden oak death syndrome in the eastern United States. Thus, evaluating the risk of SOD here requires plotting the densities of both overstory host oaks (**top**) and the understory host shrub species (**middle**) that act as disease reservoirs. Both of these maps are "smoothed" representations plotted from field sampling of forests in 10,000 plots as part of Forest Service Research and Development's Forest Inventory and Analysis Program, which measures our nation's forest resources. Then, values from these two maps were combined to yield an overall probability of presence of both overstory and understory fungal hosts. Cartographic manipulation using geographical information systems (GIS) software is the powerful computer tool used to manipulate these map data. The final map (**bottom**) represents the team's best prediction of areas at risk for establishment of SOD, information that is being utilized by state and federal forest pest management personnel to guide and prioritize surveys for the presence of the disease.







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Dr. Kurt W. Gottschalk (left) received a BS in forestry from Iowa State University (1974) and a master's degree in silviculture and forest ecology (1976) and a PhD in tree physiology (1984) from Michigan State University. He joined the USDA Forest Service's Northeastern Research Station in 1979 and transferred to the forest insect and disease research unit at Morgantown, West Virginia, in 1983. Since May 1987, Dr. Gottschalk has led the group now called "Disturbance Ecology and Management of Oak-Dominated Forests," with the mission to study oak regeneration, silviculture, and rehabilitation of oak forests undergoing disturbance and decline due to gypsy moth and other agents, including invasive plants, insects, and diseases. Dr. Gottschalk is recognized worldwide for his expertise in oak silviculture and gypsy moth management and served as editor of the *Northern Journal of Applied Forestry* from 1995 to 2002.

Dr. Andrew "Sandy" Liebhold (right) is a research entomologist with the USDA Forest Service's Northeastern Research Station in Morgantown, West Virginia. His research focuses on invasion biology and various aspects of the population biology and landscape ecology of forest insects. Dr. Liebhold received his BS in biology from Allegheny College (1978) and his PhD in entomology from the University of California at Berkeley (1984). He has worked for the Forest Service since 1988. He received the Northeastern Research Station Director's Award for Research Excellence in 1994 and the Forest Service National Forest Insect and Disease Research Award in 1995. Dr. Liebhold is a member of the editorial boards of the *Canadian Journal of Forest Research* and *Agricultural and Forest Entomology.* He is also the leader of the International Union of Forestry Research Organizations (IUFRO) Working Party 7.03.07, "Population Dynamics of Forest Insects."

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