US FOREST SERVICE NORTHERN RESEARCH STATION

Research *Review*

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Preserving and Restoring Tree Species Disappearing From Our Forests

In our modern forests, entire tree species are in danger of disappearing. This loss may not be obvious because the forest is still there, but several important forest tree species are being killed by nonnative pests and diseases. These are specific to certain species, as their names imply—emerald ash borer (EAB, a tiny beetle), butternut canker (a fungus), beech bark disease (BBD, a scale insect and two fungal species), hemlock woolly adelgid (HWA, a tiny insect), Dutch elm disease (DED, two beetle species and a fungus), and chestnut blight (a fungus). There are many more, however, these particular ones are changing northern and midwestern forests.

Bill Cook, Michigan State University, bugwood.org

The pests are all tiny, but the changes are not. Over a century ago, a few fungal spores set in motion the chestnut blight, which destroyed about 4 billion American chestnut trees, the dominant species in virtually its entire range. (Fortunately, there are some geographically isolated survivors.) The EAB and the HWA are destroying five species of ash and two species of hemlock, respectively, and causing serious ecosystem changes along forest streams and rivers. Over time, our forests, fence rows, woodlots, and streets are, or will be, missing these 11 species. There are many aspects to this destruction, including the following:

- **Ecological—**The two hemlock species are irreplaceable sources of shade along many mountain streams of the northern and southern mountains, helping keep waterways cool enough for trout and other inhabitants. Many animal and plant species depend specifically on particular tree species. Ash is the dominant tree species in some floodplain and swamp ecosystems; butternut is often found in riparian areas. The gaps created by the death of these trees may facilitate invasion by nonnative plants. From insects to salamanders, trout to bats, lichens to mycorrhizal fungi, humans to pigs, these missing trees provided important habitats and nutrition for a wide variety of life forms. Chestnuts, beechnuts, and butternuts are especially important as food sources for mammals and birds.

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The Northern Research Station has many scientists who are restoring hope for our forests by restoring tree species that are disappearing from those forests.

Michael Rains, Director, Northern Research Station

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- **Economic—**The chestnut harvest was an important source of cash for mountain people in the southern Appalachians and food for their semi-wild pigs; the tree also provided excellent timber. Removal of dead and dying street trees—mainly elm and ash—has cost billions.

- **Aesthetic—**The graceful vase shape of the elm tree was iconic in the streets and parks of American towns and villages. Now, ironically, many of the ash trees planted to replace elms killed by DED are being killed by the EAB. Black ash is highly valued traditionally by American Indians and First Nation people throughout its range.

NORTHEAST AND MIDWEST VULNERABLE

Because the Northeast and Midwest have been "entry ports" for overseas freight for centuries, many invasive pest species began their nefarious careers in this region and most early forestry research in the East was focused on stopping their spread. The gypsy moth was the first big plague, arriving in Boston in 1868. The chestnut blight probably arrived around 1900 in the New York City area. Dutch elm disease probably arrived around 1928 in Ohio on elm logs imported for making furniture. Beech bark disease was first noted in 1920 in Nova Scotia and reached U.S. forests in 1932; it has now spread to the Midwest. The HWA arrived on infested ornamental hemlocks in the 1950s in Richmond, VA, but didn't spread rapidly until it got to the Blue Ridge Mountains; it now extends from the Great Smoky Mountains to southern Maine. Butternut canker was first noted in 1967 in Wisconsin, but its origin is unknown. The EAB is the most recent arrival, with infestations first being noted around Detroit in 2002; later identification of museum specimens showed that the insect was present but unrecognized in the early 1990s.

NRS SCIENTISTS BATTLE RECENT OUTBREAKS

Having learned the urgency of immediate action in past outbreaks of nonnative pest species such as the gypsy moth and chestnut blight, all those concerned with forest tree health now are getting to work quickly, seeking out natural enemies and finding resistant trees and preserving their seeds and cuttings. There are many researchers working at various stages of infestation and recovery. For some species (butternut and beech), resistant or tolerant trees are being sought and preserved while the disease is still spreading. In other species, researchers are using gene transfer to produce resistant genotypes (ash) or comparing resistant versus

Paula Murakami, U.S. Forest Service

University of Vermont graduate student Tom Saielli plants American chestnuts on the Green Mountain National Forest as part of a collaborative research project.

susceptible species (hemlocks and butternut) to identify the factors involved in resistance, in order to crossbreed or improve by gene transfer. For species (elm) where resistant strains have already been found and are sold in commerce, seedlings and saplings are being outplanted into the forests. NRS scientists are deeply involved with, and in some cases are leading, research efforts on many aspects of these tree plagues.

American Chestnut—The American chestnut has many adherents who want to return this species to its former range. A small number of potentially blight-resistant trees have been bred, mostly by The American Chestnut Foundation (TACF). Backcross breeding with resistant Asian chestnuts has shown some progress in the last decades and there are now candidates to test for resistance in the field. Two NRS scientists are involved. In collaboration with TACF and the University of Vermont, Paul Schaberg (Burlington, VT) is testing outplanted chestnuts for cold hardiness needed for restoration stock to survive in the cold north. Over 750 seedlings were planted on the Green Mountain National Forest to examine how silvicultural treatment influences chestnut cold hardiness and productivity. Shivanand Hiremath (Delaware, OH) is helping to find the best mycorrhizal fungi for chestnut seedlings. (Mycorrhizal fungi live symbiotically in tree root hairs and help trees absorb water and nutrients.) Hiremath is assisting a project with the Wayne National Forest (OH), TACF (Ohio Chapter), and Ohio University, Department of Environmental and Plant Biology.

The team is planting about 700 American chestnut seedlings on a reclaimed strip mine on the Wayne National Forest. Tree seedlings have been found to be good candidates for strip mine reclamation because their roots grow deeply in search of water and nutrients, allowing them to survive and grow in rocky, dry mine spoil.

American Elm—A few DED-tolerant American elm cultivars have been developed or identified and are now being widely planted in urban areas. The American elm is an excellent street tree, with a beautiful shape and generally good ability to grow in tough areas (except of course for its susceptibility to the DED). However, the American elm is also disappearing in much of the wild, where it once was an important part of rural riparian areas and fencerows. Because any elms surviving in the wild may have some level of tolerance to DED and are free to regenerate, introducing DED-tolerant elms into the wild can add more resistance genes to the natural selection process. James Slavicek (Delaware, OH) is involved in several projects to replant DED-resistant elms into forested and rural landscapes in 10 sites and a college campus in Ohio, Minnesota, Wisconsin, and Iowa. Concerns about cold hardiness of the resistant cultivars have also led his partnering with USFS Eastern Region and State & Private Forestry, the Minnesota Department of Natural Resources, and the Leech Lake Band of Ojibwe to return American elms to the Chippewa National Forest. In this project, American elm trees growing in the Chippewa National Forest have been crossed with DED-tolerant cultivar to create cold-hardy DED-tolerant seedlings for planting where they can grow and spread.

American Beech—NRS Biologist Jennifer Koch (Delaware, OH) has worked with Ohio's Holden Arboretum since 2002 and has established a breeding program that is developing disease-resistant American beech, one of American's ecologically important forests trees. "We know that about 1 to 5 percent of trees survive while adjacent trees succumb to this disease," said Koch, who is building on the work of retired NRS scientist David Houston, a pioneering expert on BBD. In BBD, either of two species of *Nectria* fungus infect bark wounds created by the nonnative beech scale. Koch and her colleagues have identified resistant trees in Michigan and Pennsylvania and are evaluating seedlings from controlled crosses. Koch is now working with the Allegheny National Forest (PA) and the Michigan Department of Natural Resources to establish seed orchards of select resistant trees to produce regionally adapted BBD-resistant seeds for restoration efforts. Furthermore, Koch and scientists from the USFS Southern Research Station are taking a molecular approach to identify genetic markers for BBD resistance to streamline screening for resistant seedlings and identify susceptible beech trees ahead of the disease front so that they can be removed.

Eastern and Carolina Hemlocks—The two species of hemlocks native to the East (eastern and Carolina hemlocks) are vulnerable to the hemlock woolly adelgid, a small sucking insect found in eastern Asia and the western United States. The six species growing in these regions are not seriously affected, being either resistant or tolerant to the HWA. Nathan Havill (Hamden, CT) has investigated the genetic relationships among hemlock species, which has helped to determine the amount of worldwide variation available for resistance work. (This study also uncovered what may be a new, cryptic species endemic to Ullung Island, South Korea.) NRS scientist Michael Montgomery (Hamden, CT) has been studying various factors that influence resistance, such as terpenoid biochemistry. He is also working with the U.S. Agricultural Research Service's National Arboretum to develop HWA-resistant hybrids. Crossing of the Carolina and Chinese hemlock has produced trees showing good growth form and resistance. The most promising crosses are being cloned and outplanted for evaluation.

Butternut (white walnut)—Butternut trees throughout North America are dying from a fungal canker that is probably of nonnative origin. This disease jeopardizes the survival and genetic resources of butternut, an important tree species that adds diversity to forest ecosystems and provides food for wildlife and wood, edible nuts, and traditional medicines for humans. NRS scientists Keith Woeste (West Lafayette, IN) and Michael Ostry (St. Paul, MN) are working with many partners to locate and propagate surviving butternut trees from forests across the species' natural range. They now have six orchards of butternuts (in Iowa, Wisconsin, Minnesota, and Indiana) as well as another safely outside the range of the fungus. Additionally, they have developed genetic tools to evaluate and understand the genetic diversity and purity of the remaining native butternuts and those currently in managed collections. Procedures for testing butternuts for resistance to the fungal canker are being evaluated for inclusion in managed seed orchards to produce regionally adapted, disease-resistant butternut seedlings. They have also begun studying the silviculture and ecology of butternut restoration.

Michael Ostry, U.S. Forest Service

Grafted butternut saplings that are candidates for resistance testing growing in a greenhouse. Melanie Moore of NRS St. Paul, has been teaching many cooperators her grafting techniques.

Ash Species—The emerald ash borer (EAB), a nonnative bark-boring beetle from Asia, is attacking and killing all ash trees in North America. There is little known resistance to EAB in all five native species (blue, black, green, white, and pumpkin ash) nor any means of complete eradication at this time. The EAB is continuing its spread through North America's forests and rural and urban areas. It has already cost municipalities, property owners, nursery operators, and forest products industries tens of millions of dollars, and the ecological costs are enormous.

Paula Pijut (West Lafayette, IN) is using gene insertion techniques to develop ash species with resistance to the EAB, inserting genes from *Bacillus thuringiensis* (*Bt*). *Bt* is toxic to caterpillars and has widespread use in controlling gypsy moth in forests. She has developed plant tissue culture and genetic methods to insert the Bt toxin gene into green, white, and black ash cells. This is a major step toward developing ash trees that could resist the EAB.

In initial reports of the emerald ash borer outbreak, there appeared to be no resistance to it in Detroit-area ash street trees. However, urban trees are usually limited to a few horticultural selections. As the beetle spread away from urban areas into genetically diverse native stands and woodlots, NRS researcher Kathleen Knight (Delaware, OH) and colleagues from Ohio State University established monitoring plots on more than 3,000 ash trees in EAB-infested forests in Michigan and Ohio. Data collected in EAB-aftermath forests showed that about 0.5 percent of the ash trees have remained alive and that 0.1 percent retained a healthy crown appearance. Even if these trees ultimately succumb to EAB, the traits that helped them survive longer may be helpful in breeding ash trees that could resist EAB. Forest Service researchers Jennifer Koch (Delaware, OH) and Therese Poland (East Lansing, MI) and collaborators from Ohio State University are working quickly to preserve these "lingering ashes" (samples from 11 individual trees were collected and grafted in 2009), so that tests can be performed to determine what mechanisms allow them to survive.

What makes a species invasive?

It is nonnative to the ecosystem under consideration.

It causes (or likely to cause) economic or environmental harm or harm to human health.

Thousands of nonnative invasive plants, insects, and animals have infested hundreds of millions of acres of land and water across North America, causing massive disruptions in ecosystem function, reducing biodiversity, and degrading ecosystem health in the nation's forests, prairies, mountains, wetlands, rivers, and oceans. Around 50,000 species of plants, microbes, and animals have been introduced into the U.S. Most of the invertebrate animals (e.g., insects, mites, and shellfish) and microbes (e.g., fungi, bacteria, and viruses) introductions were accidental, whereas vertebrate animals (e.g., cattle, horses, poultry, cats, and nutria) and plants (e.g., corn, wheat, Japanese knotweed, and butterfly bush) were usually intentionally introduced or became feral and then became pests. The total economic damage from 79 nonnative species for 85 years (1906 to 1991) was estimated to be $97 billion, according to the Office of Technology Assessment; more recently, economic costs for control and management of these species has been estimated to exceed $137 billion annually.

Jennifer Koch, U.S. Forest Service

Lingering ash surrounded by already dead ash trees.

REFERENCES AND RESOURCES

For more information on the scientists featured in this Research Review: www.nrs.fed.us/people/scientists

Other Websites:

USFS Northern Research Station, invasive species: www.nrs.fs.fed.us/disturbance/invasive_species

USFS Northeastern Area State & Private Forestry, Northeastern Area Forest Health Protection: www.na.fs.fed.us/fhp

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Northern
RESEARCH STATION
USDA Forest Service

359 Main Road
Delaware, OH 43015

Contact the Northern Research Station
www.nrs.fs.fed.us

Michael T. Rains
Station Director
11 Campus Boulevard #200
Newtown Square, PA 19073

610-577-4017
mrains@fs.fed.us

Rebecca G. Nisley
Newsletter Editor

203-230-4338
rnisley@fs.fed.us

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