US FOREST SERVICE NORTHERN RESEARCH STATION

Research *Review*

NO. 20 | SUMMER 2013

Emerald Ash Borer Research: A Decade of Progress on an Expanding Pest Problem

Beautiful, shady neighborhoods all over the Midwest and the Northeast are bare of their ash trees, cut down because of the emerald ash borer (EAB). The rapidly spreading EAB infestation has also set off a storm of scientific investigation into the ecological and social damage and the costs to affected communities. Since it was first detected in 2002 around Detroit and neighboring parts of Ontario, EAB has spread to 18 states, from Kansas City to Minneapolis/St. Paul in the Midwest, south to the Smoky Mountains National Park, and all the way north to New Hampshire and Montreal, Quebec. Since its arrival, EAB has been able to attack and kill all native species of North American ashes (genus *Fraxinus*) that it has encountered.

Much of the long-distance spread of EAB is due to human activities—people moving infested ash firewood and nursery trees out of quarantined areas. Early eradication efforts consisted of cutting and chipping or burning infested wood and prevention efforts focused on quarantines, developing detection and treatment methods for individual trees, and education efforts such as the "Don't Move Firewood" campaign. Knowledge about the EAB and how to control it, or at least slow its spread, continues to drive efforts to save ash.

Dead ash "skeletons" create openings in canopy.
Photo by Kathleen Knight, U.S. Forest Service

continued on page two

continued from page one

NORTHERN RESEARCH STATION WORKS TO UNDERSTAND EMERALD ASH BORER

Entomologists from the U.S. Forest Service's Northern Research Station (NRS) laboratory in East Lansing, MI, and other NRS scientists from Delaware, OH, are in the forefront of EAB research (along with their Michigan State and Ohio State University partners). Their efforts have involved studying many aspects of EAB biology and control—basic behavior, reactions to pesticides, detecting the larvae in logs and trees, and traps for detecting adult beetles. This information and technology have contributed to control efforts and slowing the spread of the beetle.

Biology

In China, where EAB is native, it is only a minor and periodic pest of Asian forest ash trees and very few research reports were available. When the Chinese literature was translated, there was the now-ominous note that North American ashes planted in China were susceptible and often killed by EAB. The NRS entomologists (**Leah Bauer, Robert Haack,** and **Therese Poland**) at East Lansing, MI, got to work characterizing the beetle's life history, working with colleagues at the Chinese Academy of Forestry. Flight tests showed that mated female EABs can fly considerable distances without food and water, certainly beyond the quarantine zones.

Insecticide Treatments

NRS entomologists evaluated insecticides for reducing EAB populations and protecting high-value urban trees, preferably by trunk injections or soil-drenches of systemic insecticides. **Therese Poland** and Michigan State University partners tested imidacloprid, dinotefuron, and emamectin benzoate and found that the first two provided some control but that emamectin benzoate provided > 99 percent control of EAB for up to 3 years.

Cold Temperatures

EAB has spread to Minnesota, a state with nearly 1 billion ash trees and very cold winters (winter lows can reach -25 to -30 °F). **Robert Venette,** an NRS researcher in St. Paul and his partners assessed the cold hardiness of EAB and its natural enemies. Although Minnesota winters killed substantial numbers of EAB larvae, some did survive. Thus, cold temperatures may slow growth of EAB populations and perhaps extend the lives of ash trees. Venette is generating a computer model to illustrate locations where EAB may not overwinter successfully.

Counting emerald ash borer adults on a double decker trap.
Photo by Therese Poland, U.S. Forest Service.

Adult emerald ash borer feeding on leaf.
Photo by Debbie Miller, U.S. Forest Service.

Traps and Monitoring

Traps are important in fighting any infestation, especially of nonnative invasive species. **Therese Poland** and partners at Michigan State University, the Canadian Forest Service, and USDA Animal and Plant Health Inspection Service (APHIS), have developed and evaluated different traps and lures for EAB. They found that EAB is attracted to volatiles from ash leaves and bark and to the colors purple and a bright shade of green. The most promising traps to date are purple "double decker" (aka "Barney") traps and green canopy traps. Male beetles in ash trees feeding and looking for mates are attracted to green canopy traps, whereas females feeding in the canopy and laying eggs on the trunks of ash trees prefer the purple double-decker traps. New trap designs that do not require trapping glue are being explored, as well as the inclusion of a newly discovered close-range pheromone.

Transport and Quarantine Issues

Robert Haack and **Therese Poland** studied various control treatments—chipping, debarking, heat, vacuum, and microwave treatment, and firewood

handling—that were used to develop or modify regulations that are now in place for domestic firewood and wood materials used in international commerce. In January 2013, Haack was the U.S. representative to a pest risk assessment on EAB for the European Plant Protection Organization (EPPEO). EPPO is now drafting new regulations for ash products that could harbor EAB from Asia, where EAB is native, as well as from North America and Russia, where EAB has been introduced.

LONG-TERM NRS RESEARCH FOR SAVING ASH SPECIES

Unfortunately, totally eradicating the EAB does not seem possible, and forest managers and scientists are gravely concerned about preserving the ecological and social values provided by ash trees. NRS scientists and partners have estimated costs of treatment, removal, and replacement of ash trees, which are mostly born by local governments and landowners. Others have discovered and introduced natural enemies from EAB's Asian homelands and still others are looking into modes and rates of spread. Research on ecological impacts of EAB, including how fast ash trees die and fall, what happens to EAB populations over time, and studies on methods to restore EAB-impacted forests, have been helpful to land managers planning their responses. Scientists are also hoping to save ash trees by breeding for resistance to EAB and by genetic transformation and plant tissue culture research.

Costs and Economics

Several NRS scientists are working on estimating the costs of dealing with the EAB. These numbers are useful to government program managers to justify the benefits of continued EAB research and eradication and treatment programs. **Robert Haight** of St. Paul, MN; **Andrew Liebhold** of Morgantown, WV; and partners used simulations of EAB spread and infestation to estimate the 10-year costs of ash treatment, removal, and replacement of 38 million ash trees on developed land in 25 states—around $10 billion (and this does not include reductions in property values). They estimate that preventing the establishment or slowing the growth of new EAB populations such as the one in Minneapolis/St. Paul, can slow the regional spread and delay damage, potentially saving billions of dollars over the next decade. **Matt Bumgardner**, of Delaware, OH, and colleagues surveyed community representatives with urban tree canopy responsibilities in four Midwestern states to determine potential economic losses from EAB. The total costs due to EAB for just these communities, including landscape losses, tree removals, and replacements, are estimated at $13.4 billion to $26 billion. Haight is developing a computer model to help city foresters evaluate the benefits and costs of strategies to slow EAB spread within city boundaries, including investments in ash monitoring, treatment, and removal.

Parasitoid wasp (*Tetrastichus planipennis*).
Photo by David Cappaert, Michigan State University, used with permission.

Biological Control

Integrated pest management using natural enemies or "biological control" is a long-term, sustainable method for reducing populations of EAB and saving ash trees in North America. In 2003 and 2004, **Leah Bauer,** with staff from East Lansing and research collaborators at Michigan State University (MSU) and the Chinese Academy of Forestry in Beijing, discovered two new species of small parasitoid wasps that attack and kill EAB eggs or larvae. With regular shipments from China to the MSU East Lansing quarantine laboratory, Bauer's research team studied the biology, host ranges, and rearing methods for these parasitoids and in 2007, they were approved by APHIS and Michigan for release into heavily infested ash stands. They were later released in neighboring states and are now established throughout much of Michigan as well as areas of Ohio, Indiana, Illinois, and Maryland. These early successes led to the USDA EAB Biocontrol Program in 2009 and construction of the APHIS EAB Parasitoid Rearing Facility. As of 2012, these parasitoids have been released in 14 states with known EAB infestations. Bauer works with an interagency team of scientists from FS, ARS, and APHIS, faculty from several universities, and federal, state, and city land managers to assess parasitoid spread and to evaluate their impacts on ash health and regeneration.

DID I REALLY FIND AN EMERALD ASH BORER? (LOOK-ALIKES):
www.emeraldashborer.info/files/E2944.pdf

REPORT AN EMERALD ASH BORER TO YOUR STATE AUTHORITIES:
www.emeraldashborer.info/#sthash.BDuEHYUx.dpbs

Saving Ash Species

NRS scientists are working on two different breeding approaches to develop EAB-resistant ash. One approach relies on local ash trees that have survived heavy EAB infestation. Another involves cross-breeding native ash with EAB-resistant Asian ash. The EAB-resistant Manchurian ash readily hybridizes with black ash and 10 additional Asian ash species are being tested for EAB-resistance as part of a collaborative project funded by APHIS. Partners at Ohio State and Wright State Universities are searching for biomarkers for resistance that may help speed up the breeding process.

Work at the Delaware, OH, location includes efforts by **Kathleen Knight** to search out "lingering ash"—ash trees that survive when all the others nearby have died. **Jennifer Koch** collects branches from these survivors and replicates them through grafting. In greenhouse experiments, EAB larvae (hatched from eggs supplied by **Therese Poland**) feeding on these grafted lingering ash show significant developmental differences relative to those feeding on known susceptible ash. This indicates that lingering ash may indeed contain substances toxic to EAB. These promising results will have to be verified in additional studies and field plantings. Koch and colleagues hope that by breeding surviving ash to each other, they can create ash populations that are even more resistant to EAB attack and could be used for forest restorations.

EAB eggs on an ash tree in the greenhouse.
Photo by Jennifer Koch, U.S. Forest Service.

Paula M. Pijut at the NRS Hardwood Tree Improvement and Regeneration Center in West Lafayette, IN, is conducting genetic transformation and plant tissue culture research to develop ash with EAB resistance. She has developed laboratory methods to genetically transform green, white, pumpkin, and black ash from mature seed explants; regenerate and root transgenic shoots; and acclimatize transgenic plants to the greenhouse. Pijut and her Purdue University graduate students continue to optimize these methods and are genetically transforming these ash species with a *Bacillus thuringiensis* (*Bt*) gene to impart EAB resistance. In collaboration with Ohio State University scientists, she will be inserting additional genes into ash species for resistance to the EAB and to a fungal pathogen. These novel methods also allow her to propagate non-transgenic ash species to conserve existing germplasm.

Finally, **Melody Keena,** working in the Forest Service's Ansonia (CT) Quarantine Laboratory, has developed an artificial diet for raising EAB that does not contain any ash materials. Extracts from the wood of possibly resistant ashes can thus be added to the diet to test its effects on EAB larvae. The diet is already in use by her Ohio partners and Keena and her partner at the Connecticut Agricultural Experiment Station are studying EAB reproductive behaviors and population increases for improving mass rearing techniques for EAB.

Range Expansion

Andrew Liebhold, at Morgantown, WV, has studied EAB as one of many nonnative insect species to understand the dynamics of the invasion process. The ability to predict how local habitat variation affects the expansion of new populations is essential for efficiently targeting resources. The team of **Louis Iverson, Stephen Matthews**, **Anantha Prasad,** and **Matthew Peters** at Delaware, OH, have used models similar to those they developed for the Climate Change Response Atlases to develop risk maps for the EAB expansion front. Their models for Ohio, Michigan, and Minnesota have been successful at predicting risk and general timing of infestations and have been used to site traps and monitoring activities.

HELPING NATIVE AMERICAN BASKET MAKERS

Black ash is found in wet and swampy areas of the North Woods, across northern New England and the upper Midwest. It is used by crafters of many tribal nations—Abenaki, Maliseet, Menominee, Meskwaki, Mic'maq, Mohawk, Passamaquoddy, Penobscot, Potawatomi, and Ojibwe, for example—in traditional basket-making. **Therese Poland** and **Marla Emery** examined the traditional methods for preparing black (aka brown) ash and found that submerging logs for 3 months killed any EAB larvae in the logs but did not lower the quality of the wood for basket making. However, EAB infestations that reach tribal locales will certainly endanger the ash trees this art form depends on, and NRS breeding efforts are specially focused on the black ash.

Tossing an infested black ash log into a river for testing.
Photo by Therese Poland, U.S. Forest Service.

BIOGRAPHIES (see www.nrs.fs.fed.us/scientists for more details)

Leah Bauer, **Robert Haack**, and **Therese Poland** are research entomologists in the NRS unit "Ecology and Management of Invasive Species and Forest Ecosystems" in East Lansing, MI. **Melody Keena**, a research entomologist in in Hamden, CT, and **Andrew Liebhold**, a research entomologist in in Morgantown, WV, are also members of this unit.

Matt Bumgardner is a research forest products technologist in the "Ecological and Economic Sustainability of the Appalachian Forest" unit in Delaware, OH.

Marla Emery is a research geographer and a member of the "People and Their Environments" unit stationed in Burlington, VT. **Robert Haight** is a research forester in that unit in St. Paul, MN.

Louis Iverson, Stephen Matthews, **Anantha Prasad**, and **Matthew Peters** are the landscape ecology team at Delaware, OH.

Kathleen Knight is a research ecologist and **Jennifer Koch** is a research biologist in the "Genetics, Biological Control, and Management of Invasive Species" group in Delaware, OH.

Paula Pijut is a research plant physiologist at the "Hardwood Tree Improvement and Regeneration Center" in West Lafayette, IN.

Robert Venette is a research biologist in the "Biological and Environmental Influences on Forest Health and Productivity" in St. Paul, MN.

RESOURCES AND REFERENCES

Web Resources:

European Plant Protection Organization: www.eppo.int/

USDA Agricultural Research Service:
www.ars.usda.gov/is/AR/archive/apr11/pest0411.htm

USDA Animal & Plant Health Inspection Service:
www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/index.shtml
www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/eab-biocontrol.pdf
stopthebeetle.info/
hungrypests.com/the-threat/emerald-ash-borer.php

USDA Forest Service, Forest Health Technology Enterprise Team (archive of Proceedings of the Emerald Ash Borer Research and Technology Meetings)
www.fs.fed.us/foresthealth/technology/pub_titles.shtml#E
www.nrs.fs.fed.us/disturbance/invasive_species/interagency_forum/#archive

USDA Forest Service, Northern Research Station:
www.nrs.fs.fed.us/disturbance/invasive_species/eab/
www.nrs.fs.fed.us/sustaining_forests/conserve_enhance/special_products/maine_ntfp/plants/ashbrown/

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