

CHAPTER 8

Northeast Forest Diseases

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The national Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, has provided a means to address important forest tree disease conditions that continue to threaten the survival and prevalence of valuable tree species. A range of Evaluation Monitoring (EM) projects has been conducted related to native and introduced diseases in the Eastern United States. The topics include various forest declines such as hickory, basswood, oak, northern white cedar, ash, and black ash; forest health conditions in the Allegheny and Ozark forests; Eastern dwarf mistletoe damage; butternut resource viability and canker progression; and beech bark disease impact, extent, and host resistance. The projects relating to beech bark disease and butternut canker have helped to provide information to evaluate the continued impact of these long-time established pathogens.

Beech bark disease is a complex tree disease involving an introduced scale insect, *Cryptococcus fagisuga*, and specific species of the *Nectria* (*Neonectria*) fungus. Millions of board feet of the American beech (*Fagus grandifolia*) have been lost due to mortality from the pathogen that gains entry through feeding wounds caused by the scale (Miller-Weeks 1983). The scale was first introduced on imported European beech in Halifax, Nova Scotia, in the Canadian Maritimes, in the 1890s (Ehrlich 1934). By the early 1900s, mortality was occurring in eastern Maine. The insect spread naturally through New England, into New York and Pennsylvania, and southward to Virginia, West Virginia, North Carolina, and Tennessee, and now also occurs in eastern Ohio and northern Michigan (Houston 1994a, 1994b, Heyd 2005). Tree mortality, caused by the *Nectria* spp., has followed close behind in the areas where the scale has infested, and continues throughout the range of the insect (Lohman and Watson 1943). The areas affected are referred to as the “advancing front,” “killing front,” and “aftermath zone” (Shigo 1972).

For many years, numerous research and biological evaluation projects have been conducted to determine the extent and impact of this disease on the beech resource, along with

possible host resistance. The ongoing effects of beech bark disease, including dieback and tree mortality, have been recorded during the detection phase of the FHM program, both within the extensive permanent plot network and during the annual aerial and ground surveys conducted by both State and Federal forest health specialists. Several projects were recently funded through the EM aspect of the FHM program. The range of projects included current and future impact and extent of the disease, along with host resistance.

The beech bark disease studies focus on impacts and management guidelines, provide further evaluation of the associated insect and pathogen, along with the disease progression, and help to provide a model to assess impact on forest composition from an introduced species. The projects also help to determine needs for future research (e.g., resistance studies and trials). One project looked at the advancement of the disease at the edge of the killing front, finding that there were twice as many standing dead trees within the disease-affected areas. Another looked at forest composition in the aftermath zone and influences of site factors on host tree sustainability, noting that beech was still a significant component of the forest stands, although there were larger numbers of smaller trees. Another project reviewed the historical records to predict future mortality and define areas most at risk, determining that the disease would continue to expand south and west throughout the range of American beech. The most recent project allowed for development and testing of a technique to assess individual tree resistance, and found that resistance is heritable and that seedlings resulting from experimental crosses can be challenged to test that resistance.

Butternut (*Juglans cinerea*) has a native range from eastern Canada west to Minnesota and south to Arkansas, Alabama, Georgia, and Mississippi. First reported in 1967, butternut canker caused by the fungus *Ophiognomonia clavigignenti-juglandacearum* (*syn Sirococcus clavigignenti-juglandacearum*) is killing butternut throughout its range (Nair and others 1979). Extensive tree mortality has resulted in butternut being a “species of concern” or a “sensitive species” in many States, a Regional Forester Sensitive Species in the Eastern Region on 13 of the 16 national forests, and is listed as endangered in Canada (Schultz 2003). Butternut

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is not a common tree but occurs as widely dispersed small groups with many other tree species in several hardwood forest types. The current health status and prospects for the future of the species in much of its range is poorly known.

The FHM program has coordinated butternut conservation and restoration activities among private landowners, universities, State and Federal agencies and Native American tribes to raise awareness of the issues. EM-funded projects related to the butternut resource in the Midwestern and Northeastern United States have focused on obtaining the frequency of butternut occurrence within different habitats, incidence and severity of disease, disease progression, rate of tree mortality, status of tree regeneration, silvicultural prescriptions for butternut retention and regeneration, and locating, collecting, and propagating potentially canker resistant trees (Ostry and others 1994, Woeste and others 2009). Based on these projects, a map and a predictive model of the probability of butternut occurrence was developed that can be used for intensive surveys of butternut to identify candidate trees with possible canker resistance. Another project helped to determine the rate of expected mortality in Vermont, noting that almost all of the butternut would succumb to the pathogen by 2011.

It is important to continue supporting efforts to evaluate and understand exotic disease impact, progression, and resistance. Studies of established introduced diseases yield valuable information that can be applied to pathogens that are newly introduced or may be introduced in the future.

Project NE-EM-02-01: Forest Health Conditions and Analysis of the Allegheny National Forest

The study was initiated on the Allegheny National Forest in response to concerns regarding forest condition following 15 to 20 years of damage associated with drought, insect defoliation by the gypsy moth and various native pests, and the progression of beech bark disease. Comparisons were made between disturbed and undisturbed sites, including the effects of beech bark disease within and outside the “killing front.”

The FHM plot grid was intensified across the Forest in 1998 to 168 plots, to facilitate forest health monitoring and implement forest management practices based on plot data analysis. This approach serves as a model for implementing monitoring systems on other national forests to support forest management planning, monitoring, and plan revision. The analysis of the initial data was conducted in 2000. This EM project provided an opportunity to continue the analysis to provide a more extensive look at the various damage factors

affecting the forest including beech bark disease. Beech bark disease was first detected in northeastern Pennsylvania in 1958, a half-century after it was introduced into Nova Scotia on European beech. The “killing front” was determined to be moving across the northeast section of the Forest. The intensified FHM grid provided a network to evaluate the impact of the disease. A map of the forest was developed to show the area where the front was located, indicating that 58 monitoring plots were within the “killing front” zone and 64 plots outside.

Results indicated that, by 2001, 9.9 percent of basal area of American beech within the “killing front” zone were standing dead, in contrast to only 4 percent of the basal area of standing dead outside of that zone (Morin and others 2006). The percentage of standing dead beech was more than twice as great inside the “killing front” as opposed to outside the front. It is probable that the beech mortality has been even higher since dead beech trees often quickly decay and snap off. Eastern hemlock showed the greatest increase in relative dominance following the loss of beech to the disease.

Project NE-EM-02-03: Health and Sustainability of the New York Forest in Relation to the Destructive Exotic Beech Bark Disease System

The overall objective was to examine variation in disease severity in relation to forest health and sustainability of northern hardwood forest systems. It was hypothesized that in the “aftermath zone” where the disease has already been established for some time, the system would have reached equilibrium and the disease would no longer be a threat to sustainability of the forest. The study incorporated data from established plots to study the disease on a landscape scale in New York.

Since the sustainable equilibrium may not have been reached on all sites, researchers hoped to look at the parameters that defined sustainability, along with determining the influence of site factors and forest composition. The State University of New York College of Environmental Science and Forestry conducted the survey using data from 286 plots throughout the State, to obtain a wide range of variation in beech and site conditions (Manion and Griffin 2001). To assess forest health on State-owned lands, a portion of the plots were established in the Adirondacks after the 1998 ice storm and other storms in 2000 and 2001.

The dataset was used to assess effects of slope and aspect, stand composition, disease incidence, and mortality on forest composition. Beech bark disease was present in all sampled sites and was the leading cause of beech mortality. Beech scale

was present across all diameter classes; however, most of the smaller diameter beech trees were disease-free, as were some larger trees, suggesting that these individuals may be resistant to the scale or disease. Fewer trees were infested with the scale on eastern and southeastern eastern slopes; however, a larger proportion of trees on eastern slopes > 16 percent were infested with *Neonectria* spp. (Munck and Manion 2006).

Within the forest stands in these “aftermath zones” the impact of beech bark disease mortality and beech snap resulted in a shift in size classes with a larger number of small diameter stems and low numbers of large stems, due to the ongoing impact from the disease. Although the host species will take a long time to reestablish, the extirpation and extinction of beech is not likely, as a certain portion of the population is retained to sustain forest structure in the aftermath of the disease. This model may be useful to assess other introduced diseases and their expected impacts on forest sustainability and resiliency.

Project NE-EM-04-02: Historical and Regional Analysis of Beech Bark Disease Impacts

The intent of this study was to predict spread to estimate the expected geographical distribution of the disease through 2025 and develop a mortality model to determine which areas would be most at risk. This study looked at historical information describing the progress of the disease since it was introduced in the Canadian Maritimes and mapped the geographical distribution of the suitable habitat based on 93,611 forest inventory plots in the Eastern United States. A forest susceptibility map was then developed based on the basal area/ha of American beech and adjusted for percent cover type.

The future range of expansion of beech bark disease was predicted by applying estimates of past spread rates derived from historical records. These records consisted of the year each county became infested and the distance of each county from the area initially infested to determine the rate of infection. Then a predicted spread map representing years of expected presence from 2001 to 2025 was generated on a 1- by 1-km grid based on the estimated rate of spread. This map was overlaid with the forest susceptibility map to create the disease risk map through 2025.

The results indicated that the beech bark disease has spread through much of the range of American beech, the host tree is most abundant in the Adirondack and Southern Appalachian Mountains, and that Kentucky is the highest risk area that is currently uninfested. Over the next 50 years, it is likely that the disease will continue to expand its range in the United States. Analysis of current inventory data suggests that the

disease has already invaded most of the areas with high densities of beech and caused a temporary decrease in the dominance of American beech regionally. It has not caused the elimination of the species, although in the aftermath forests beech stems are smaller and have a reduced quality.

This study is important in that it addressed the possible future impact from the disease. It serves as a model for risk assessment for management of exotic invasive species before and after their arrival in new habitats. For beech bark disease this includes further spread in the Lake States and also the Southern States, where beech is a component of the hardwood forest and where the disease is likely to occur in the future.

Project NE-EM-04-01: Development of a Challenge Protocol to Identify Young American Beech Trees that are Resistant to the Beech Scale Insect

A percentage of American beech trees remain disease-free in stands long affected by beech bark disease, and challenge trials have shown that they are resistant to the scale insect. It is thought that the best management approach to reduce the impact from the disease is to increase the number of resistant beech trees, while reducing the proportion of susceptible trees. David Houston conducted years of research on this disease and developed a technique to artificially inoculate trees to test resistance (Houston 1982).

This study was designed to determine if this technique was effective in distinguishing resistant from susceptible American beech trees (Koch and Carey 2004). Three different tree sources were employed: natural and artificial root grafts; grafted material; and seedlings from pollinated sources (either open or controlled cross-pollination). It is hoped that eventually superior resistant progeny can be selected and used to develop seed orchards to provide an enriched source of resistant beech for plantings. These trees would be planted ahead of the “advancing front” to minimize the impact of beech scale and beech bark disease, to introduce resistant genetic material for restoration of beech across the forest landscape where this species is prevalent.

Traps were set for egg collection in Ohio, Michigan, and Pennsylvania for use in scale insect challenge experiments. Putative resistant root sprouts were identified with control susceptible areas nearby. Eggs were placed in 2003, and colonization was scored in 2004. Scion material from resistant and susceptible trees was collected in Maine and Michigan for grafting onto seedling root stock. Controlled cross-pollinations were successfully performed and 1,200 seeds collected, along with 5,000 open pollinated seeds.

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Inoculations were conducted by wrapping insect eggs around seedlings to determine hereditary resistance.

The tests were successful to distinguish between resistance and susceptible seedlings, with a higher proportion of resistance from the resistant X resistant crosses, suggesting that the trait is heritable and not a single gene trait. This test also appears to be successful in a variety of age classes, as demonstrated by test sites on the Allegheny National Forest.

Project Number NE-EM-01-03, NC-EM-02-01: Evaluation of the Viability of the Butternut Resource

Butternut distribution was evaluated using the Eastwide database of the Forest Inventory and Analysis (FIA) Program of the Forest Service, and a hierarchical ecological classification system of ecoregion provinces and sections. Although relatively few butternut occur on FIA phase 3 plots, this technique enabled construction of a map of the probability of butternut occurrence that can be used for intensive surveys of butternut to identify candidate trees with possible canker resistance and to locate suitable sites for future reintroduction of the species.

An investigation of silvicultural options for retention and recruitment of butternut to maintain viable populations revealed several critical requirements for natural or artificial regeneration systems. Most important is opening stands to promote regeneration but not to the extent that it will be to the detriment of the residual butternut seed source trees (Ostry and others 2003). Continued loss of butternut regeneration was attributed as much to competing vegetation and damage from deer as was caused by canker. A large proportion of the marked, healthy butternut that was retained in the stand at the start of the study was still healthy after 13 years. Grafted copies of these source trees have been placed into archive plantings and breeding orchards and the trees are being tested for canker resistance.

Project NE-EM-02-02: Assessment of the Rate of Progression of Butternut Canker Disease

This study of butternut canker progression in Vermont based on a small number of plots revealed that disease incidence and tree mortality was 94 percent and 12 percent, respectively, in 1996. In 2002, disease incidence increased to 96 percent and tree mortality to 41 percent. A larger sample size from additional plots throughout Vermont in 2004 resulted in finding 86 percent of trees diseased and 45 percent killed by butternut canker. Based on these data, it was projected that 85 percent of all butternut in Vermont would be dead by 2011.

Project NE-EM-06-03: Assessment of the Butternut Canker on Public and Private Lands in the Eastern U.S.

An assessment of butternut health on public and private lands in the Eastern United States revealed that butternut mortality in Maine and New Hampshire was 28 percent in 2007. Butternut inventories are continuing in many States, and a GPS/GIS database is being compiled. Surveys have shown that butternut crown dieback from disease and shading is reducing seed production, and butternut regeneration is either lacking or sparse. Diseased and suppressed trees are often affected by decay fungi and killed by *Armillaria* root rot. Stump sprouts are not common and often are diseased or have been killed by butternut canker. A GIS-based predictive model was developed and is being used to locate healthy butternut trees and to delineate sites that are optimum for butternut growth.

Utilization of Project Results

The beech bark disease and butternut EM projects have provided information that has heightened the general public's awareness of the plight of the American beech and butternut resource in North America. Results of the various studies have been developed into guidelines for the assessment, management, and conservation of beech and butternut, which are being used by land management agencies in the United States and Canada.

Suggestions for Further Investigation

In 2008 a working group was formed to address research needs related to beech bark disease in the Eastern United States. This effort followed a 2004 symposium of research, pest management specialists, and forest managers. Based on the overall importance of American beech as a component of the extensive hardwood forest, it was prudent to readdress the research needs related to the impact from this forest disease by forming the Beech Bark Disease Initiative.

The major focus of the Initiative is to consolidate information, provide spatial analysis, identify putative resistance, and then enhance this through management. As a result of the group discussions, several research proposals were developed in regards to:

- Ecological factors that influence incidence and severity
- DNA-based markers to screen for resistance
- Enhanced propagation methods to develop seed orchard
- Silvicultural treatments to enhance resistance
- Spread rates

- Abundance and distribution of resistant trees following harvesting
- Scale intensity related to biogeoclimatic zones
- Locating and mapping resistance

Future research that would address reducing susceptibility of beech trees in advance of the scale, identifying and managing for scale resistant trees, and restoring affected forests would be appropriate.

EM-funded projects have increased understanding of the extent that butternut canker has impacted the butternut resource, revealed habitat requirements critical for butternut conservation and restoration, and resulted in locating potentially canker resistant trees for breeding and restoration efforts. These projects have also revealed several important gaps in our knowledge that require further investigation.

Critical information needs include determining the level of genetic diversity remaining among populations of butternut to guide future germplasm collection. This information will result in conserving an adequate level of genetic diversity across the species range.

Evidence from current collections of butternut has revealed the presence of butternut hybrids that complicate the identification of potentially resistant pure butternut. This will require the investigation of the extent of hybridization with Japanese walnut (*Juglans ailantifolia*) within the range of butternut and the development of techniques to accurately distinguish pure species.

Finally, evaluating the extent of site and environmental influences on disease severity and on the success of natural and artificial butternut regeneration will greatly contribute to the success of future butternut conservation and restoration projects.

Literature Cited

- Ehrlich, J.** 1934. The beech bark disease, a Nectria disease of Fagus following *Cryptococcus fagi* (Baer.). Canadian Journal of Forest Research. 10: 593-692.
- Heyd, R.L.** 2005. Managing beech bark disease in Michigan. In: Evans, C.A.; Lucas, J.A.; Twery, M.J. Beech Bark Disease: Proceedings of the Beech Bark Disease Symposium. Gen. Tech. Rep. NE-331. U.S. Department of Agriculture Forest Service, Northern Research Station: 128-132.
- Houston, D.R.** 1982. A technique to artificially infest beech bark with the beech scale, *Cryptococcus fagisuga* (Lindinger). Res. Pap. NE-507. Broomall, PA: U.S. Department of Agriculture Forest Service, Northeast Forest Experiment Station. 8 p.
- Houston, D.R.** 1994a. Temporal and spatial shift within the Nectria pathogen complex associated with beech bark disease of *Fagus grandifolia*. Canadian Journal of Forest Research. 24: 960-968.
- Houston, D.R.** 1994b. Major new tree disease epidemics: beech bark disease. Annual Review of Phytopathology. 32: 75-87.
- Koch, J.L.; Carey, D.W.** 2004. Identifying and enriching for American beech trees that are resistant for beech bark disease. In: Proceedings, New England Society of American Foresters 84th Winter Meeting. Gen. Tech. Rep. NE-314. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northeastern Research Station. 44 p.
- Lohman, M.L.; Watson, A.J.** 1943. Identity and host relations of Nectria species associated with disease of hardwoods in the eastern states. Lloydia. 6: 77-108.
- Manion, P.D.; Griffin, D.H.** 2001. Large landscape scale analysis of tree death in the Adirondack Park, New York. Forest Science. 47(4): 542-549.
- Miller-Weeks, M.** 1983. Current status of beech bark disease in New England and New York. In: Proceedings, IUFRO beech bark disease working party conference. Gen. Tech. Rep. WO-37. Washington, DC: U.S. Department of Agriculture Forest Service: 21-23.
- Morin, R.S.; Liebhold, A.M.; Gottschalk, K.W. [and others].** 2006. Analysis of forest health monitoring surveys on the Allegheny National Forest (1998-2001). Gen. Tech. Rep. NE-339. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northeastern Research Station. 102 p.
- Munck, L.A.; Manion P.D.** 2006. Landscape-level impact of beech bark disease in relation to slope and aspect in New York State. Forest Science. 52(5): 503-510.
- Nair, V.M.G.; Kostichka, C.J.; Kuntz, J.E.** 1979. *Sirococcus clavignenti-juglandacearum*: an undescribed species causing canker on butternut. Mycologia. 71: 641-646.
- Ostry, M.E.; Ellingson, B.; Seekins, D.; Ruckheim, W.** 2003. The need for silvicultural practices and collection of butternut germplasm for species conservation. In: Van Sambeek, J.W.; Dawson, J.O.; Ponder, F., Jr. [and others]. 13th central hardwoods forest conference. Gen. Tech. Rep. NC-234. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Research Station: 551-555.
- Ostry, M.E.; Mielke, M.E.; Skilling, D.D.** 1994. Butternut- strategies for managing a threatened tree. Gen. Tech. Rep. NC-165. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Research Station. 7 p.
- Schultz, J.** 2003. Conservation assessment for butternut or white walnut (*Juglans cinerea* L.). Milwaukee, WI: U.S. Department of Agriculture Forest Service. Eastern Region. 76 p.
- Shigo, A.L.** 1972. The beech bark disease today in the Northeastern United States. Journal of Forestry. 70: 286-289.
- Woeste, K.; Farlee, L.; Ostry, M. [and others].** 2009. A forest manager's guide to butternut. Northern Journal of Applied Forestry. 26: 9-14.