CHAPTER 14

Tree Species "Declines" that May Be Associated with Large-scale Mortality

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Many of the Evaluation Monitoring (EM) projects funded by the national Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, have been motivated by perceived regional declines in specific tree species (or groups of species). Sometimes data collected from the FHM program's former Detection Monitoring (DM) plots [now Forest Inventory and Analysis (FIA) Program (Forest Service) phase 3 plots] have suggested that a species or group of species were experiencing decline. Sometimes concern developed based primarily on observations by foresters and researchers working in a particular region. Such projects have focused on determining the extent of these declines, the causal agents responsible, and whether the decline truly represents a serious forest health concern. Often the focus was also on determining if decline symptoms (such as crown dieback) were related to tree mortality. Some projects also considered the potential for forest management or land-use actions to mitigate the problems.

One of these studies focused on eastern white pine in Vermont. A number of other EM projects have focused on decline in hardwood species in the Midwest. Some EM projects have focused on declines leading to loss of forest. Concern over loss of coastal wetlands prompted a study of the health of forested wetlands in Louisiana.

Project NE-EM-01-01: Evaluation of the Condition of Eastern White Pine

Burns and others (2003a, 2003b) evaluated the health of eastern white pine (*Pinus strobus*) in Vermont. Their study was prompted by observations of unexplained white pine mortality, scattered occurrences of heavy Caliciopsis canker, and widespread needlecast. Similar observations in nearby States heightened concern that there might be a serious health problem affecting white pine. Also, there was an interest in currant and gooseberry (*Ribes* spp.) cultivation in Vermont, but a fear of the impact that increased numbers of these plants, which are the alternate host required for the spread of white pine blister rust, might have on the white pine health.

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In this project, mature stands of white pine were located on randomly selected aerial photos from a statewide coverage obtained in 2000. In the summer of 2001, 21 stands were surveyed. Trees were evaluated on four 1/24th acre subplots in each stand [including symptoms of decline (branch mortality, twig dieback, and foliar discoloration)] and site conditions were rated (Vermont Department of Forests, Parks, and Recreation 2001). In addition, 10 young pines were evaluated in regenerating stands near each mature stand.

This study found that the most common pests and pathogens on white pine were not strongly associated with the observed poor condition of the trees. While white pine weevil was found on about two-thirds of trees sampled in mature stands, 91 percent of those trees were healthy. White pine adelgid was found on 16 percent of the sampled trees in mature stands, again with 91 percent of those affected trees healthy. White pine blister rust was found on only 3 percent of the trees, and 73 percent of the affected trees were healthy. Instead, unhealthy pine stands seemed to be associated with difficult site conditions (e.g., shallow soils, wet sites) or recent disturbance (e.g., logging). Overall, white pine decline was not found to be widespread in Vermont. Most trees (89 percent of the trees sampled in mature stands and 93 percent of the trees sampled in regenerating stands) had healthy crowns (Burns and others 2003a, 2003b, 2003c).

Project NC-EM-05-02: Evaluating Black Ash (*Fraxinus nigra*) Decline in the Upper Midwest

Palik and Ostry (2005) studied black ash (*Fraxinus nigra*) decline in the upper Midwest. Black ash decline had been noted with increasing frequency in the region from the mid-1990s. There was particular concern about the status of black ash because the tree species occupied many sites that had once supported American elm (*Ulmus americana*), and the loss of black ash as well could be ecologically significant. Also, the emerald ash borer, as it spreads, poses a threat, and there was a desire to better understand the status of black ash prior to any effects of emerald ash borer in order to better evaluate the risk to black ash associated with that pest.

The project aimed to quantify black ash decline and mortality in stands across northeastern Minnesota. Another aim of the project was to relate decline and mortality pattern to factors affecting tree health, including tree and stand age, insects and diseases, and site hydrology, as well as mapped climatic, physiographic, and edaphic data. The project also aimed to quantify black ash regeneration patterns in both declining and healthy stands.

The researchers first used FIA and FHM data to assess the distribution of decline in Minnesota and relate decline occurrence and variation to mapped landscape-scale climatic, physiographic, and edaphic data (Ward and others 2007, 2008). Using FHM aerial sketchmapping data for Minnesota in 2004, they found that black ash decline was spatially concentrated and that declining stands were significantly closer to city, county, and State roads. Data from the FIA public database (1977-2005) were analyzed together with hydrology, wetlands, soils, climate, and roads data. The researchers found that ash survival and mean diameter at breast height (d.b.h.) both decreased over time and that survival varied greatly among counties. Both mean d.b.h. and survival were found to be greater on moist slopes than on flat, wet sites.

Analyses using FIA data with true geographic coordinates (1990-2003) were also performed to determine if the more accurate plot locations provided more information. From these analyses they found that the decline in mean d.b.h. was greater on drier than on wetter sites, that mortality levels differed among counties, climate divisions, and ecological subsections, and that soils, temperature, and precipitation data were associated with mortality and change in d.b.h., but they explained little of the variation.

Field evaluations confirmed some of the findings from the FIA data analyses and provided additional results. Trees growing on wetter plots were found to have greater decline symptoms than trees growing on drier plots. Trees growing closer to roads had more decline symptoms than those farther from roads. No biotic agent was found to be responsible for the decline. Black ash regeneration (seedling and sapling size classes) varied widely across sites but was generally greater on better drained plots. Amount of black ash regeneration was not related to degree of decline in a stand (Palik and others 2008; Palik and others, in press; Ward and others 2007).

Work on this project has continued. In 2007, an additional 31 stands were sampled in Lake, St. Louis, Carlton, Aitkin, and Itasca counties in Minnesota. Analysis is ongoing to verify the preliminary findings reported to date. Additional work also focuses on successional trends in declining ash stands.

Project NE-EM-98-01: Lake State Basswood Decline Evaluation

Werner and others (2001) studied basswood (*Tilia americana*) decline in the Midwest. Detection Monitoring projects in the Great Lakes Region recorded increases in crown dieback, foliage transparency, and mortality of American basswood in the 1990s. An EM project was initiated in 1998 to assess basswood condition and determine causal agents related to this problem.

Twenty-two sites were established in 1998 to monitor basswood condition, insects, soil, and other site factors. Sites and plots were chosen to maximize overlap with previously established monitoring networks. Basswood condition was monitored using the then-current FHM protocols to measure branch dieback, foliage transparency, and crown density in June and August from 1998 to 2000. In addition, insects were sampled from foliage and tree boles at each site in 1998, 1999, and 2000. Soil cores were collected from five random points per site in 1999. Samples were analyzed for relative site pH, organic matter, P, K, Ca, Mg, nitrate, and ammonium. Increment cores were taken from five basswood trees per site in 2000 (Werner and others 2001, 2005).

Both crown dieback and foliar transparency increased from 1998 to 2000. High variability in crown conditions and soil type was observed among sites. Disease symptoms were relatively rare. Nine species of Thysanoptera (thrips) were collected from foliage samples from 1998 through 1999. The introduced basswood thrips (*Thrips calcaratus*) dominated insect abundance, accounting for over 99 percent of total Thysanoptera, and introduced thrips species far outnumbered the native thrips, *Neohydatothrips tiliae* (Werner and others 2001). Weak associations between basswood dieback and *T. calcaratus* abundance suggest that it is a major component of basswood decline in the Great Lakes region, but that other factors, including lepidopteran herbivores and diseases, may also be contributing factors (Werner and others 2001, 2005).

Project NC-EM-07-01: Assessment and Etiology of Hickory (*Carya* spp.) Decline in the Midwest and the Northeastern Regions

Hickory (*Carya* sp.) decline, particularly the decline of smoothbark hickories, had been reported in several Midwestern States and in New York. Widespread hickory mortality had been linked to outbreaks of the hickory bark beetle (*Scolytus quadrospinosus*) during or immediately after periods of drought, and, in the early 1990s, a fungus (*Ceratocystis* sp.) was linked to stem-discoloring and sunken cankers associated with beetle outbreaks. Site factors such as soil fertility and land use, as well as the flatheaded woodborer

(*A. tiosus*), also have been associated with hickory decline. Juzwik and Haugen (2007) studied hickory decline in the Midwest to determine the extent of hickory decline and mortality and quantify the relationships between decline incidence and severity and pathogen and/or insect presence, stand basal area, soil type, elevation, land use, and drought history.

Fourteen sites in thirteen counties across three States (Iowa, Minnesota, and Wisconsin) were surveyed and sampled in the summer of 2007. At each site, total live stand basal area and number of hickory stems across four size classes were recorded on nine fixed-radius, 1/15th acre plots. The frequencies of hickory decline and mortality (decline was defined as >20 percent crown dieback), decline severity based on crown ratings, and evidence of damage on trees from fungi, insects, fire, or mechanical damage were gathered at 30 point plots per site. Soil, topographical, and elevation data were gathered through use of GIS. At each site, four 2-foot long log sections also were taken from each of three declining trees for insect and pathogen evaluation. Two log sections from each declining tree were placed in insect emergence chambers. Total number and type of insects that emerged were recorded weekly over 6 weeks. After 6 weeks, the bark on each log was removed and presence and type of galleries recorded. Small cubes of discolored wood underneath cankers were taken from each 2-foot log section and used to isolate suspected pathogens. Additional sites were surveyed and sampled in 2008, including two new sites each in Wisconsin and Iowa, three sites in Indiana and Ohio, and six sites in New York (Juzwik and others 2008c).

Hickory decline and mortality were found to be widely distributed in the Central and Northeastern United States, but only in portions of affected States. For example, in New York, the problem was most severe in the Finger Lakes region. Also, decline and mortality were often localized within larger stands, and stands within a few miles of severely affected stands could have low incidence of the problem.

Preliminary results were presented in 2008 (Juzwik and others 2008c). Several different types of damage were found on declining hickories (from most to least common): insect holes (associated with hickory bark borer, flatheaded woodborer, and ambrosia beetles), sunken annual and diffuse cankers, galls, black leaf spotting, sapsucker and woodpecker damage, decay fungi, mechanical and fire damage, broken tops, and human-induced girdling.

Further analyses identified three major patterns of damage/decline and associated damage-causing agents (Juzwik and others 2009; Park and others 2009). Globose galls, caused by *Phomopsis* sp., occurred on branches in tree crowns and/or main stems. Mortality can result from heavy infections. This was the least common of the three damage types (USDA Forest Service 2009).

The second major damage pattern identified was top dieback. Affected bitternut hickories have numerous annual cankers on the upper main stem or on a major branch resulting in dieback. The fungus, *Fusarium solani*, was most commonly isolated from the cankered tissues. *Ceratocystis smalleyi*, a recently discovered fungus, was also commonly isolated. Field inoculation studies showed both fungi can cause annual cankers on bitternut hickory (Juzwik and others 2008b, USDA Forest Service 2009).

The third damage/decline pattern observed was a relatively rapid crown decline followed by mortality. This was characterized by progressive deterioration of crown (e.g., small, chlorotic leaves, thin crowns, usually dying from top down, diffuse cankers sometimes with obvious bleeding spots, insect attacks). Hickory bark beetles (*Scolytus quadrispinnosus*) and hickory timber beetles (*Xyleborus celsus*) accounted for 91 percent and 8 percent, respectively, of the insects attacking trees with crown decline in the 2008 survey (Juzwik and others 2009). *Ceratocystis smalleyi*, a canker pathogen of bitternut hickory, was commonly isolated from diffuse cankers (Park and others 2009, Park and others 2010, USDA Forest Service 2009). Hundreds of such cankers may be associated with an affected tree (Juzwik and others 2010).

It is hypothesized that stressed (due to drought, overstocking, flooding, or other causes) hickories are attacked by beetles carrying fungal spores on their bodies. The fungal spores are dislodged, germinate, and infect the attacked host. Diffuse cankers and sapwood infections resulting from the fungal colonization further stress the tree, leading to more beetle attacks (Juzwik and others 2009, USDA Forest Service 2009). The role of the fungus *C. smalleyi* in the decline is the subject of ongoing research.

Juzwik and Haugen (2007) developed management guidelines for dealing with hickory decline. These included management of stand density to reduce stress on trees, management of the abundance of hickory in mixed stands to lessen susceptibility to bark beetle attacks, and phytosanitary practices to control bark beetle levels.[2]

[2] These guidelines were presented at a meeting of the Wisconsin DNR (DNR Forest Health Protection Work Planning Meeting—January 30, 2009; 3911 Fish Hatchery Rd. SCR Headquarters, Fitchburg, WI) and were also provided in a letter to the landowners who participated in the 2008 landowner survey. Personal communication. 2009. Jennifer Juzwik, Research Plant Pathologist, U.S. Department of Agriculture Forest Service, Northern Research Station, 1561 Lindig St., St. Paul, MN 55108, and Adjunct Associate Professor, Department of Plant Pathology, University of Minnesota.

Decline mostly affected trees larger than 5 inches d.b.h. Incidence and severity of decline were positively correlated with basal area in sampled stands on all but one site. Hickory bark beetles and/or their galleries were found at all sites, exceeding occurrences of other damage on declining trees. *Ceratocystis* and *Fusarium* fungi were both obtained from log sections from declining trees with hickory bark beetles and/or galleries (Juzwik and others 2008a, 2008b, 2008c). Work continues on this project.

Project NC-EM-04-01: Forest Health Evaluation of Reported Yellow-poplar, Ash, and Bitternut Hickory Decline

This project aimed to link off-plot and on-plot monitoring of forest health. In particular, the project focused on explaining the extent and severity of tree mortality and decline (as expressed through crown conditions) of drought-sensitive species in Indiana following the 1999 and 2002 droughts (Fischer and Marshall 2004).

The project results focused on observed yellow-poplar (*Liriodendron tulipifera*) decline. Yellow-poplar is an important component of Indiana's hardwood forests. The species grows best on rich, mesic sites and has been long regarded as a drought-sensitive forest species. Indiana foresters reported pockets of declining yellow-poplar in southeastern parts of the State following substantial, prolonged droughts in 1999 and 2002. Decline symptoms include chlorosis of leaves, sparse crown, dieback, trunk and branch cankers, and root sprouts, as well as epicormic sprouting.

Field observations were made in 2004 on yellow-poplar trees at 12 locations in southeastern Indiana in order to identify factors associated with yellow-poplar decline and evaluate the effectiveness of FHM/FIA data and methods in detecting yellow-poplar decline (Krecik and Marshall 2006).

Yellow-poplar decline was found to be strongly associated with prolonged drought events. Decline symptoms were most pronounced on exposed slopes, and first appeared after the 1999 and 2002 droughts. Several FHM crown condition parameters were strongly correlated with yellow-poplar decline. However, insufficient Indiana phase 3 crown condition data restricted use of the then-current on-plot data set to extrapolate the extent of yellow-poplar decline statewide. Plotting of FIA mortality data (1985-2005) showed that yellow-poplar mortality followed both the distribution of drought-vulnerable soils and areas of the State with reported decline, further indicating yellow-poplar decline to be drought-associated. Mortality was also significantly correlated with smaller diameter classes (Krecik and Marshall 2006). Being a more drought-sensitive species, yellow-poplar trees reduced incremental growth during the drought years of 1999 and 2002, while less drought-sensitive species, such as oaks, did not significantly vary in incremental growth (Krecik and Marshall 2006).

Project SO-EM-99-01: Factors Affecting Tree Health in Forested Wetlands of Louisiana

The main focus of this project was to determine the extent of previously observed decline in the health of trees in forested wetlands in southern Louisiana as well as to determine the causal agents responsible for the decline. The study area was the oak-gum-cypress bottomland forest of the Mississippi River delta. Existing historical data were used together with new air and ground surveys to document the extent and severity of the problem.

The study found that a variety of forest health issues are affecting the forested wetlands of southern Louisiana. The most significant factor appears to be saltwater intrusion. The increased salinity makes wetlands unsuitable for the tree species of the oak-gum-cypress forest type, leading ultimately to a loss in forested wetlands. The saltwater intrusion is related to reduced flows of freshwater, which also carry nutrients and sediments necessary to sustain these wetland systems. The reduced freshwater flows are often due to human impacts on the landscape. Navigation channels have allowed saltwater to reach farther inland. Spoil banks from dredging channels have created impoundments that permanently flood some areas while cutting off freshwater to others. Levees and elevated roadways have also affected hydrology (Goyer 2002, Goyer and Lenhard, no date).

Other factors have added stress to these forests, sometimes killing trees that cannot regenerate under the altered hydrology. These include herbivory from mammals (e.g., nutria and beaver) and insects (e.g., forest tent caterpillar and cypress leaf roller) (Goyer 2002, Goyer and Lenhard, no date).

Goyer (2002) recommends several actions to restore degraded wetlands and stop the further loss of forested wetlands. The most important action is to engineer changes to the hydrology to provide or restore freshwater inputs and reduce or stop saltwater encroachment.[3] Goyer also suggests addressing some of the biological stressors affecting these forested wetlands. Suggested actions include controlling the exotic

[3] The closing of the Mississippi River Gulf Outlet (MRGO), which began in early 2009, is one major project that may ameliorate the hydrological conditions.

nutria, use of biological insecticides on high-value cypress stands, and selection of salt tolerant genotypes of baldcypress for regenerating stands.

Summary of Key Findings

Most of the findings of these various EM projects are unique to particular regions or forest types. Nevertheless, some general trends can be found. Key findings include:

- Unhealthy white pine stands in Vermont were associated with difficult site conditions (such as shallow soils or wet sites).
- The most common pests and pathogens on white pine were not strongly associated with the observed poor condition of the trees.
- Black ash trees growing on wetter plots were found to have greater decline symptoms than trees growing on drier plots, and trees growing closer to roads had more decline symptoms than those farther from roads.
- No biotic agent was found to be responsible for the black ash decline.
- An introduced insect pest, *Thrips calcaratus*, appears to be a major cause of basswood decline in the Lake States.
- A number of pathogens, including the fungus *Ceratocystis smalleyi,* have been identified as being related to hickory decline. It is hypothesized that the hickory bark beetle (*Scolytus quadrospinosus*) helps to spread the spores of these organisms.
- Yellow-poplar decline was found to be strongly associated with prolonged drought events.
- Altered hydrology, which reduced freshwater inputs to forested wetlands in southern Louisiana, is the major factor leading to decline and loss of those forests.
- Both native and exotic insects and mammal species contribute to the loss of forested wetlands in southern Louisiana.

Several of these studies indicate that maintaining site quality and, in particular, the original hydrology of forested sites is important for maintaining the forest health. Disturbances at a variety of scales may affect forest hydrology and have negative impact on the forest. White pine decline was associated with site conditions and site disturbance. Black ash decline was related to site hydrology and, possibly, to alteration of that hydrology from road construction. Yellow-poplar decline was found to be related to drought, but site factors affected the severity of drought impact. Large-scale changes to the hydrology of wetland forests in Louisiana are leading to loss of those forests.

Biotic factors played a relatively small role in several decline situations studied in these projects. The most common pests and pathogens on white pine were not strongly associated with the observed poor condition of the trees. No biotic agent was found to be responsible for the black ash decline. However, hickory bark beetle (*Scolytus quadrospinosus*) as well as several fungi seem to play a role in hickory decline. An introduced insect pest, *Thrips calcaratus*, appears to be a major cause of basswood decline in the Lake States. Also, both native and exotic insects and mammal species contribute to the loss of forested wetlands in southern Louisiana.

Utilization of Project Results

The researchers working on several of these EM projects have used various means to disseminate their results to landowners and forest managers. Sometimes the project results enabled the researchers to develop specific guidelines for forest management. In other cases, the project results enabled landowners to make more informed management decisions relating to particular species on difficult sites.

- Results of the white pine study were shared with over 200 forest managers at the New England Society of American Foresters meeting and over 100 foresters at the 2003 Forest Health Information Meeting. Forest managers were made aware that managing white pine on marginal sites is risky, but that otherwise, there was not widespread decline on white pine. This information allowed forest managers to continue to manage it for maximum growth and timber yield.[4]
- Results from black ash study have increased awareness of the extent of black ash decline among landowners and managers of the region. Landowners have been made aware of possible linkages between ash decline and site factors related to soil moisture. Results also allow managers to place the anticipated invasion of the black ash forest by emerald ash borer in proper perspective, since many of these forests are already experiencing significant decline and mortality.[5]

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[4] Personal communication. 2009. Barbara Burns, Forest Health Program Manager, Vermont Department of Forests, Parks, & Recreation, 100 Mineral Street, Suite 304, Springfield, VT 05156.

[5] Personal communication. 2009. Brian Palik, Research Ecologist, U.S. Department of Agriculture Forest Service, Northern Research Station, 1831 Hwy. 169 E, Grand Rapids, MN 55744.

- Information about the extent and causes of hickory decline were communicated to forest landowners and managers (Allen and others 2009; USDA Forest Service 2009; Wisconsin Department of Natural Resources 2006, 2007), and management guidelines for hickory based on the hickory decline research have been published (see footnote 2).

The results of some projects helped form the basis for further research or have led to tree breeding programs to obtain better survival in the face of particular insects, pathogens, or other stressors.

- Based on the black ash study, the researchers are now examining field plots across northern Minnesota to investigate the influence of finer scale site (soil moisture-drainage), tree age, and road influences on incidence and severity of decline.

- The black ash project provides a starting point for future studies on the potential impact of emerald ash borer on black ash in Minnesota. Researchers plan to use some of the same study sites and will use their previous assessments of black ash health as a baseline. The future research effort will involve an expanded team of hydrologists, plant ecologists, entomologists, and foresters from the University of Minnesota, the Northern Research Station of the Forest Service, and the Minnesota Department of Natural Resources.[6]

- The Louisiana Department of Agriculture and Forestry has established a baldcypress tree improvement program, has acres of genetic material being cultured for salt tolerance and insect tolerance as well, and uses progeny of cypress trees shown to survive better in saline/insect environments for much of the department's coastal reforestation efforts after hurricanes.[7]

Suggestions for Further Investigation

Future research should continue to look at the relationships of decline to tree mortality and try to determine the causal relationships. Useful research may aim to determine the factors related to decline and mortality that can be affected by human management of forest systems in order to prevent or reduce the severity of forest decline. Another goal of future research may be to determine which decline symptoms indicate situations so severe that radical intervention (such as harvest and replanting) is warranted.

The results of these projects suggest that future research should not only focus on biotic factors related to forest decline. Research also must consider factors relating to site quality and how humans may have altered site characteristics.

FHM must continue to conduct in depth investigations when observations suggest that there may be forest health issues that might lead to large scale mortality with a species or group of species. At the same time, it is important that data about tree species reactions to stressors be compiled over longer time periods so that we have a better idea of the natural variation that occurs both in stressors (such as climate or insects and pathogens) and in the responses of forests to those stressors. Such data will allow future researchers to better determine which phenomena truly warrant in depth investigations and which are related to natural cycles.

[6] Personal communication. 2009. Robert Venette, Research Biologist, U.S. Department of Agriculture Forest Service, Northern Research Station, 1561 Lindig Street, St. Paul, MN 55108.

[7] Personal communication. 2009. Richard Goyer. Professor (retired), Louisiana State University, Department of Entomology. 404 Life Sciences Building, Louisiana State University, Baton Rouge, LA 70803-1710.

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