Chapter 16. Evaluating Elevated Levels of Crown Dieback among Northern White-cedar (*Thuja occidentalis* L.) Trees in Maine and Michigan: A Summary of Evaluation Monitoring

(Project NE-EM-07-01)

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Introduction

Analysis of crown condition data for the 2006 national technical report of the Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, exposed clusters of phase 3 plots (by the Forest Inventory and Analysis [FIA] Program of the Forest Service) with northern white-cedar (*Thuja occidentalis* L.) crown dieback averages of 10 percent or more in Maine and northern Michigan (Randolph 2009). Such elevated levels of dieback were of concern because unlike hardwood trees, conifers often do not exhibit crown dieback unless the tree, and in particular its root system, is under serious stress (Millers and others 1992). An examination of the plots with elevated dieback showed that the high dieback averages for northern white-cedar (NWC) were not necessarily accompanied by elevated average dieback levels among the other tree species on the same plots. Plot-level condition and disturbance information, the NWC literature, and local experts were consulted to ascertain potential causes of the elevated levels of crown dieback. When no specific causes were evident, we initiated an Evaluation Monitoring (EM) project in order to verify the apparently elevated levels of crown dieback (Randolph 2008). Through additional ground work and more in-depth data analyses, we proposed to answer three primary questions:

(1) Was the crown dieback level of NWC significantly higher than that of other species?

(2) Was there a change in the average level of NWC crown dieback over an approximately 10-year period?

(3) What, if any, stand conditions were associated with elevated plot-level NWC crown dieback averages?

Methods

The EM project was completed in two phases. The first phase entailed field work to verify the original FIA field crew assessments and search for evidence of disturbances not recorded by the field crews. For this, 13 plots with average NWC crown dieback of at least 10 percent ("poor" plots) and 5 comparison plots with an average NWC crown dieback of < 10 percent (based on the 2000–2004 FIA surveys) were visited. Plot visits were made in the summer of 2007 and occurred 4 to 7 years after the FIA assessments

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on which the study was based. Tree status (live or dead), crown conditions, and diameter at breast height (d.b.h.) were recorded for NWC trees with d.b.h. at least 5.0 inches (12.7 cm) on each plot. Observations about individual-tree damages, e.g. broken tops, and stand-level growing conditions, e.g., soil drainage and disturbances, were made as well. Plant pathologists and forest health specialists from the Forest Service, the Maine Forest Service, and the Michigan Department of Natural Resources provided assistance in looking for insect and disease problems during the plot visits.

In the second phase of the project, we analyzed the forest health monitoring data collected by FHM during the 1990s and by the FIA program between 2000 and 2005. During both time periods, crown dieback, defined as recent mortality of branches with fine twigs that begins at the terminal portion of a branch and proceeds toward the trunk, was recorded in 5 percent classes (Schomaker and others 2007). Randolph and others (2009) describe the analytical procedures for questions (1) and (2). Briefly, an analysis of variance model, with plot-level average crown dieback as the response variable and taxa (hardwoods, NWC, and other softwoods), measurement year, and the taxa * measurement year interaction as the explanatory factors, was applied to answer question (1). This was done separately by State for the time periods 1990–1999 and 2000–2005 in Maine and 1994–99 and 2000–2005 in Michigan. For question (2), individual tree crown dieback for a subset of NWC survivor trees with observations spanning the 1990–2005 time period was modeled as a linear function of measurement year, by State. For question (3), data from all FIA Phase 3 plots measured in Maine and Michigan between 2000 and 2005 were used to relate plot-level average crown dieback for NWC to the following seven plot-level stand condition variables:

1. plot-level quadratic mean diameter of all live trees at least 5 inches (12.7 cm) d.b.h.
2. plot-level quadratic mean diameter of all live NWC trees at least 5 inches (12.7 cm) d.b.h.
3. latitude
4. longitude
5. total precipitation (cm) accumulated December–February prior to the FIA assessment
6. average minimum temperature (^{o}C) December–February prior to the FIA assessment
7. soil drainage index, an index of the relative amount of water that a soil contains on a long-term basis that is available to plants under normal climatic conditions (Schaetzl 1986).

An analysis of variance model with an autoregressive order 1 covariance structure was used to test for significant relationships between plot-level average NWC crown dieback and the seven stand condition variables all together. To accommodate the repeated measures, the SAS software procedure MIXED (Littell and others 1996) with a REPEATED statement was used to analyze the data for all three questions.

Results

Through the observations made during the field visits we were able to verify the elevated levels of NWC crown dieback (fig. 16.1) and identify the likely causes of the high crown dieback averages for some of the poor plots. Of the five poor plots visited in Michigan, three were impacted by high water levels and one by wind damage. Detrimental stand conditions on the remaining plot were not clearly identifiable, though water stress seemed to be a possibility. Of the eight poor plots visited in Maine, one was visibly impacted by high water and two were damaged by wind. Besides the plot-level disturbances, poor tree conditions consistent with those noted in the NWC literature (Hofmeyer and others 2007) were observed during the plot visits (Randolph and others 2008). Pistol-butted trees, particularly in northern Maine, and leaning or fallen

Figure 16.1—Northern white-cedar trees with poor crown conditions observed during the 2001 summer assessment. (Photos by KaDonna Randolph)

boles were prominent. Wind events were the apparent cause of many of the leaning and fallen trees; however, leaners were common even in areas not obviously disturbed by wind. Such conditions may be attributed to shallow root systems (Johnston and Hyvarinen 1979) and perhaps heavy snow loads (Curtis 1941[5]). Many trees also had exposed roots, either due to windthrow or microsite growing conditions such as hummocks.

Results of the data analysis showed that between 1990 and 2005, there was not a significant increase in average NWC crown dieback in either State (p-values greater than 0.1900) (question 2), but there were significant differences among the average crown dieback levels of the NWC, hardwoods, and other softwoods (question 1) (Randolph and others 2009). When significant differences among the taxa means existed, NWC crown dieback levels were higher than the dieback levels of other softwoods and lower than the dieback levels of hardwoods, though these differences were sometimes dependent upon measurement year. None of the seven plot-level stand condition variables were significantly related ($\alpha = 0.05$) to average NWC plot-level dieback between 2000 and 2005 (question 3).

[5] Curtis, J.D. 1941. Report of northern white cedar research in Maine. 23 p. Unpublished manuscript. On file with: K. Randoph, 4700 Old Kingston Pike, Knoxville, TN 37919.

Conclusions

Through the follow-up EM project, the causes of the relatively high NWC crown dieback plot averages observed in Maine and Michigan were determined to be associated with local factors such as disturbances and water levels rather than broader climatic variables such as temperature and precipitation. Though some causes were indeterminable, there did not appear to be an insect or disease problem. Overall, this project demonstrated the effectiveness of the tiered forest health monitoring strategy implemented by the Forest Service to identify, investigate, and in this particular case, nullify a suspected forest health problem.

Literature Cited

Hofmeyer, P.V.; Kenefic, L.S.; Seymour, R.S. 2007. Northern white-cedar (*Thuja occidentalis* L.) an annotated bibliography. CFRU RR 07-01. Orono, ME: University of Maine Cooperative Forestry Research Unit. 30 p. http://www.treesearch.fs.fed.us/pubs/14234. [Date accessed: April 15, 2009].

Johnston, W.F.; Hyvarinen, M.J. 1979. Northern white-cedar: an American wood. Misc. Res. Rep. FS-227. Washington, DC: United States Department of Agriculture Forest Service. 4 p.

Littell, R.C.; Milliken, G.A.; Stroup, W.W.; Wolfinger, R.D. 1996. SAS® system for mixed models. Cary, NC: SAS Institute, Inc. 633 p.

Millers, I.; Anderson, R.; Burkman, W.; Hoffard, W. 1992. Crown condition rating guide. Newtown Square, PA: U.S. Department of Agriculture Forest Service. Northeastern Area State and Private Forestry. 26 p.

Randolph, K. 2008. Evaluating elevated levels of crown dieback among northern white-cedar (*Thuja occidentalis*) trees in Maine and Michigan. U.S. Department of Agriculture Forest Service. Forest Health Monitoring Program evaluation monitoring project NE-EM-07-01. 4 p. http://fhm.fs.fed.us/em/funded/08/ne_em_07_01.pdf. [Date accessed: January 27, 2009].

Randolph, K.C. 2009. Crown condition. In: Ambrose, M.J.; Conkling, B.L., eds. 2009. Forest health monitoring: 2006 national technical report. Gen. Tech. Rep. SRS-117. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 65–110.

Randolph, K.; Bechtold, W.A.; Morin, R. S.; Zarnoch, S.J. 2009. From detection monitoring to evaluation monitoring—a case study involving crown dieback in northern white-cedar. [1 CD]. In: Proceedings, 2008 Forest Inventory and Analysis (FIA) Symposium: climate change, fire, and other hot topics. McWilliams, W.; Moisen, G.; Czaplewski, R., comps. RMRS-P-56CD. Fort Collins, CO: U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station.

Randolph, K.; Ostrofsky, B.; Steinman, J. [and others]. 2008. Field observations of northern white-cedar (*Thuja occidentalis*) crown dieback in Maine and Michigan (NE-EM-07-01). http://fhm.fs.fed.us/posters/posters08/northern_white_cedar.pdf. [Date Accessed: August 22, 2008].

Schaetzl, R.J. 1986. A soilscape analysis of contrasting glacial terrains in Wisconsin. Annals of the Association of American Geographers. 76(3): 414–425.

Schomaker, M.E.; Zarnoch, S.J.; Bechtold, W.A. [and others]. 2007. Crown-condition classification: a guide to data collection and analysis. Gen. Tech. Rep. SRS-102. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 78 p.