# CHAPTER 10.

# Evaluation of Sugar Maple Dieback Trends in the Upper Great Lakes Region

## (Project NC–EM–B–10–02)


Tara L. Bal

Andrew J. Storer


## INTRODUCTION

Crown dieback and declines in tree health of sugar maple (*Acer saccharum*) have been reported on various land ownerships in the western Upper Great Lakes region in recent years (MDNR 2009, 2010, 2012). In some areas, the crown dieback has affected high-value crop trees. Historically, sugar maple dieback (fig. 10.1) has been reported more frequently in the eastern part of its range and has not been described on the same scale in the Great Lakes region since the 1950s and 1960s (Bal and others 2015, Millers and others 1989). As a result, fewer studies of canopy health of sugar maple exist in the Midwest than in the Eastern United States. Dieback and decline episodes of sugar maple often appear to be driven by local conditions, mainly predisposed or incited by poor soil nutrient status and further exacerbated by severe drought or other weather extremes, local insect or disease damage, or management activities (Horsley and Long 1999, St. Clair and others 2008).

Reports of current sugar maple dieback in the Great Lakes region came recently from both public and private land managers across various locations. The extent to which the recent sugar maple dieback was related to management activities and to biotic or abiotic factors was unclear. Furthermore, the severity and geographic scope of the dieback across the region was unknown. This project established long-term monitoring plots in the Upper Great Lakes region to characterize changes in dieback symptoms in sugar maple and characterize

*Figure 10.1—Severe canopy dieback and tree mortality in a sugar maple stand in Upper Michigan. (Photo by Tara Bal, Michigan Technological University)*

relationships between dieback and ownership. These plots were located on a range of soil types and encompassed areas both with and without differing amounts of dieback. Other factors related to the dieback etiology continue to be examined, including climate variables, soil and foliar nutrients, and other biotic and abiotic plot variables.

## METHODS

A network of permanent sugar maple health evaluation plots (0.04 ha, fixed radial) was established across Upper Michigan, northern Wisconsin, and eastern Minnesota, with variable mean dieback levels on public (State and federally owned, 59 plots established in 2010) and private (industry owned, 61 plots established in 2009) lands (fig. 10.2). The private lands have been managed by industry since stand initiation. Plots were not random, but were identified by industrial and agency foresters as having varying degrees of sugar maple dieback (from none to severe). Sugar maple dieback symptoms were evaluated annually from the plot establishment year through 2012. Plots were located on multiple soil types, and stand basal areas varied from 12 to 61 $m^2$/ha with a mean basal area of 30.6 $m^2$/ha. Plots were located at least 40 m away

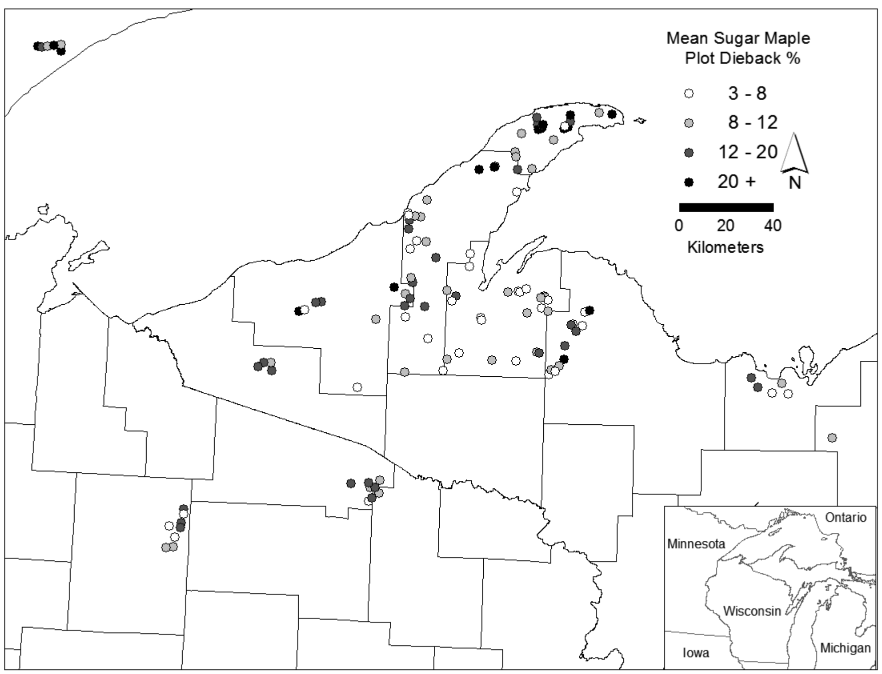


*Figure 10.2—Sugar maple health evaluation plot distribution on public and private land across Michigan, northern Wisconsin, and eastern Minnesota (circles), and mean plot sugar maple dieback from year of establishment (2009–10) through 2012, excluding initially 100-percent dead trees (shading of circles).*

from established roadways and in most cases included at least 10 sugar maple trees.

All trees with at least a 10-cm diameter at breast height (d.b.h.) (merchantable size) were measured, permanently tagged, and had canopies assessed using Forest Health Monitoring protocols[1] to determine canopy dieback, transparency, density, and other measureable factors. Crown dieback was estimated as percentage of the whole crown that had dieback present (0 to 99 percent, estimated to 1- to 5-percent intervals), including recently dead branches, peeling branches, or fine twigs lacking foliage or live buds in the upper and outer portions of the crown. In order to calculate the mean sugar maple dieback for plots in each year, harvested trees were not included (11 of 120 plots had at least one tree removed during the 4-year period). Saplings that reached the minimum 10 cm d.b.h. were added into the plot measurements after the plot establishment year. Trees that were 100-percent dead during the plot establishment year were not included in the plot mean canopy dieback for that year, but subsequent mortality was included in annual dieback estimations to capture dead and dying trees. Other tree and plot variables were also assessed for use in future studies, including tree bole conditions, foliage and soil nutrients in plots, soil density, canopy density, regeneration and herbaceous density, growth rates from increment cores, and forest floor disturbance.

[1] U.S. Department of Agriculture Forest Service. 1999. Forest health monitoring 1999 field methods guide. Research Triangle Park, NC: U.S. Department of Agriculture Forest Service, Forest Health Monitoring Program. 480 p. On file with: Forest Health Monitoring Program, 3041 Cornwallis Road, Research Triangle Park, NC 27709.

## RESULTS AND DISCUSSION

On 120 sites, a total of 2,763 trees were evaluated (the majority annually), with 2,065 being sugar maple. The overall mean plot sugar maple dieback level on industry land decreased from 14 to 9 percent from 2009–12 across the region; on public land, dieback decreased from 10 to 9 percent from 2010–12 (fig. 10.3). There were significant differences in mean plot dieback between years ($p < 0.001$), with a general increase until 2011 and decline in

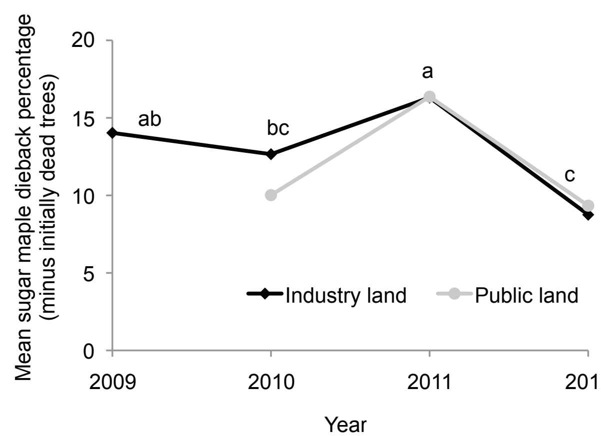


*Figure 10.3—Mean sugar maple crown dieback percentage (excluding initially dead trees) from 2009–12 on industry (61 plots) and public (59 plots) lands in the western Upper Great Lakes region (Bal 2013). Letters indicate significant differences (repeated-measures analysis of variance, α = 0.05) between years of means, independent of ownership.*

dieback symptoms in 2012. Mean dieback values ranged considerably across the study area, with individual plots having from 0.8-percent (apparently healthy) to 75.5-percent (severely unhealthy) mean sugar maple dieback. A similar evaluation of more than 1,000 sugar maples across a wider regional gradient (the North American Sugar Maple Project) reported an average dieback percentage between 6 and 9 percent during 1988–90, which is lower than those found here (Allen and others 1992). The stresses currently impacting trees in the Upper Great Lakes region are likely ongoing or may be more severe than those that have occurred historically.

Mean plot values over 10 percent are usually indicative of an unhealthy stand, and values over 20 percent are typically considered moderate to severe (e.g., Allen and others 1992, Horsley and Long 1999). Although overall mean dieback decreased during the 4 years of this study, some individual trees and stands continued to decline rapidly. Four years of data collection may establish a good baseline for long-term monitoring, though interannual variation in precipitation and data collection timing may influence the amount of crown foliage and dead twigs seen and thereby limit the interpretation of long-term trends. In cases where the cause of the dieback is occurring gradually, such as a nutrient deficiency that weakens trees over decades, dead branches will snap off, reducing measured dieback levels (Watmough and others 1999). In addition, harvesting removed some trees present with heavy dieback. Examination of basal area indices and growth rates are needed in some cases to determine evidence of decline that is not necessarily evident from mean dieback values. Crown conditions for sugar maple varied between plots, with mean crown transparency following a similar pattern as dieback over time, and mean crown density followed an inverse pattern over time, as would be expected given the relationships between these variables (fig. 10.4). Mean foliage density and canopy transparency plot values for each year have significant linear correlations with mean dieback plot values except for crown density in 2009 and

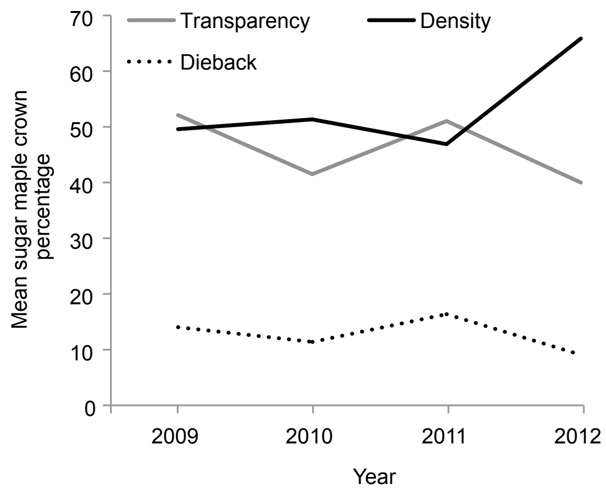


*Figure 10.4—Mean sugar maple plot percentages of foliage transparency, crown density, and crown dieback during study period across the western Upper Great Lakes region (Bal 2013). Note: transparency in 2012 from only a subset of plots.*

foliage transparency in 2011 (all others, $p < 0.05$). The increase in foliage density in 2012 could be masking dieback from surveyors, causing them to underestimate signs of stress in the canopies.

There was no significant difference in mean dieback between ownership types, public or industry (fig.10.3). Some difficulties exist in separating the effects of management and ownership type due to the industry land plots being primarily located in Houghton, Keweenaw, Baraga, and Marquette Counties, Michigan (in the northwestern Upper Peninsula of Michigan), while the public lands evaluated during the study had a much wider regional distribution (fig. 10.2). Regional differences in forest composition and biotic and abiotic stress may also be influencing sugar maple health. For example, eastern Upper Michigan stands have beech bark disease (*Fagus grandifolia, Cryptococcus fagisuga* and *Neonectria* spp.) present, which can influence sugar maple growth (DiGregorio and others 1999), but this was not the focus of this study.

## CONCLUSIONS

The specific etiology of the current sugar maple dieback is still unclear but likely varies across more local rather than regional scales. Sapstreak (*Ceratocystis virescens*) was present in some stands but was ruled out as responsible for the extent of dieback seen across the region (Bal and others 2013). Further analysis of data indicates factors impacting trees may continue to persist, including climate extremes, poor soil nutrients, and invasive earthworms impacting the forest floor condition (Bal 2013, Larson and others 2010).

This study provides a baseline for monitoring sugar maple health in the Upper Great Lakes region. Occurrence and severity of sugar maple dieback in the Upper Great Lakes region was variable and may be more prevalent than historically reported in the area. No differences in dieback amounts were detected between forest ownership. Forest managers should adopt practices that alleviate additional stresses such as increased soil disturbance and exposure in northern hardwood systems. In some cases, it may be appropriate to promote other species in anticipation of sugar maple dieback or reduced growth that may occur from stressors that will continue to impact forests such as climate change, invasive exotic species, defoliator outbreaks, and soil biogeochemistry perturbation.



## CONTACT INFORMATION

Tara Bal: tlbal@mtu.edu.

## ACKNOWLEDGMENTS

We thank the USDA Forest Service and GMO Renewable Resources, LLC, for financial support and access to field sites. Additional assistance was provided by foresters and field technicians from Michigan Department of Natural Resources; American Forest Management, Inc.; and Michigan Technological University. We also

thank Bob Heyd, Michigan Department of Natural Resources, and Kurt Gottschalk at the Northern Research Station of the USDA Forest Service for comments on this report.

## LITERATURE CITED

Allen, D.C.; Barnett, C.J.; Millers, I.; Lachance, D. 1992. Temporal change (1988–1990) in sugar maple health, and factors associated with crown condition. Canadian Journal of Forest Research. 22: 1776-1784.

Bal, T.L.; Richter, D.L.; Storer, A.J.; Jurgensen, M.F. 2013. The relationship of the sapstreak fungus, *Ceratocystis virescens*, to sugar maple dieback and decay in northern Michigan. American Journal of Plant Sciences. 4: 436-443.

Bal, T.L.; Storer, A.J.; Jurgensen, M.F. [and others]. 2015. Nutrient stress predisposes and contributes to sugar maple dieback across its northern range: a review. Forestry. 88: 64-83.

Bal, T.L. 2013. Evaluation of sugar maple dieback in the Upper Great Lakes region and development of a forest health youth education program. Houghton, MI: Michigan Technological University. 176 p. Ph.D. dissertation.

DiGregorio, L.M.; Krazny, M.E.; Fahey, T.J. 1999. Radial growth trends of sugar maple *(Acer saccharum*) in an Allegheny northern hardwood forest affected by beech bark disease. Journal of Torrey Botanical Society. 126: 245-254.

Horsley, S.B.; Long, R.P., eds. 1999. Sugar maple ecology and health: proceedings of an international symposium. Gen. Tech. Rep. NE–261. Radnor, PA: U.S. Department of Agriculture Forest Service, Northeastern Research Station. 120 p.

Larson, E.R.; Kipfmueller, K.F.; Hale, C.M. [and others]. 2010. Tree rings detect earthworm invasions and their effects in northern hardwood forests. Biological Invasions. 12: 1053-1066.

Michigan Department of Natural Resources and Environment (MDNR). 2009. Michigan forest health highlights 2009. Michigan Department of Natural Resources and Environment, Forest Management Division. http://fhm.fs.fed.us/fhh/fhh_09/mi_fhh_09.pdf. [Date accessed: April 1, 2014].

Michigan Department of Natural Resources and Environment (MDNR). 2010. Michigan forest health highlights 2010. Michigan Department of Natural Resources and Environment, Forest Management Division. http://fhm.fs.fed.us/fhh/fhh_10/mi_fhh_10.pdf. [Date accessed: April 1, 2014].

Michigan Department of Natural Resources (MDNR). 2012. 2012 Michigan forest health highlights. Michigan Department of Natural Resources, Forest Management Division. http://www.midnr.com/Publications/pdfs/ForestsLandWater/ForestHealth/FHH.pdf. [Date accessed: April 1, 2014].

Millers, I.; Shriner, D.S.; Rizzo, D. 1989. History of hardwood decline in the Eastern United States. Gen. Tech. Rep. NE–126. Broomall, PA: U.S. Department of Agriculture Forest Service, Northeastern Forest Experiment Station. 75 p.

St. Clair, S.; Sharpe, W.E.; Lynch, J.P. 2008. Key interactions between nutrient limitation and climatic factors in temperate forests: a synthesis of the sugar maple literature. Canadian Journal of Forest Research. 38: 401-414.

Watmough, S.; Brydges, T.; Hutchison, T. 1999. The tree-ring chemistry of declining sugar maple in central Ontario, Canada. Ambio. 28: 613-618.