CHAPTER 9

Ice Storm Impacts on Forest Health: Monitoring and Predicting the Growth and Mortality of Ice-Damaged Trees in Southern Forests

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INTRODUCTION

Ice storms are among the most frequent and injurious disturbances in temperate forests (Irland 2000), but they are less studied compared with other major disturbances such as fire or drought. On a global scale, forests in the Eastern United States witness the most ice storms because the region's terrain and coastline configurations encourage freezing rains (Changnon and Karl 2003). There exists a "glaze belt" extending from north Texas to southern New England, where major ice storms are expected once every 3 years (Bennett 1959). Although less frequent, major ice storms also periodically strike the South beyond the "glaze belt" (Bragg and others 2003, Changnon and Karl 2003), causing significant damage to southern forests. For example, the February 2014 ice storm in South Carolina impacted 1.5 million acres of timberland and resulted in a loss of $360 million, second only to damages from Hurricane Hugo (South Carolina Forestry Commission 2014). Following this severe ice storm, the National Science Foundation funded a rapid response study aimed at characterizing and modeling species-specific damage and mortality by assessing the immediate responses of different species (Lu and others 2020). The objective of the study was to monitor the long-term growth and mortality of trees in Beidler Forest after the initial ice damage in 2014.

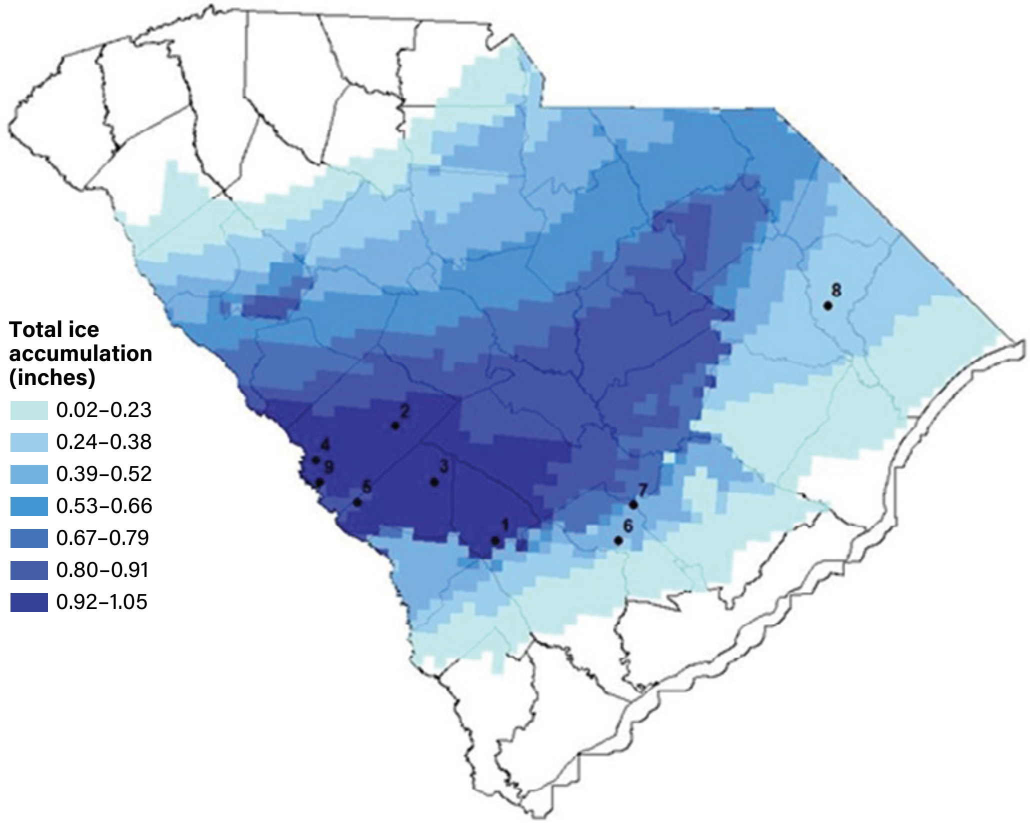
METHODS

This study was conducted at Beidler Forest in southeastern South Carolina. Beidler Forest experienced between 9.9 and 19.6 mm (between 0.39 and 0.77 inches) of ice accumulation during the February 2014 ice storm (fig. 9.1).

Three forest types were identified along a decreasing moisture gradient: cypress-tupelo swamp, bottomland hardwood, and upland forest. Post-ice storm measurement was conducted during the growing season after the 2014 ice storm on 11 permanent plots that were established after Hurricane Hugo in 1989. A detailed description of the initial assessment method is given in Lu and others (2020). On each plot, trees were remeasured in 2016 and 2018 to record diameter at breast height (d.b.h.) growth and status changes (dead, alive, or missing). Additional data were collected in 2018 to assess individual tree health through the visual description and to determine diameter growth by taking an increment core at breast height. Cored species include bald cypress (*Taxodium distichum* [L.] Rich.), blackgum (*Nyssa sylvatica* Marshall), green ash (*Fraxinus pennsylvanica* Marshall), scarlet oak (*Quercus coccinea* Münchh), red maple (*Acer rubrum* L.), white oak (*Quercus alba* L.), laurel oak (*Quercus laurifolia* Michx.), and water tupelo (*Nyssa aquatica* L.).

We tested the effects of forest type, lifeform, damage category, damage severity, and diameter size on tree mortality, mean annual basal area growth after the storm, and recovery using analysis of variance (ANOVA). Based on changes in basal area growth from d.b.h. measurements between 2014 and 2018, the recovery status of each live tree was classified as in recovery (increase in growth), no change, or decline (decrease in growth). Using ANOVA, we also tested the effect of percentage of crown damage on the

Figure 9.1—Levels of ice accumulation in South Carolina from the 2014 ice storm denoted by different colors (Data source: South Carolina Forestry Commission). Nine sites (1–9) were sampled immediately after the ice storm (Lu and others 2020). Study site 7 is Beidler Forest, where permanent plots were set up for long-term monitoring.



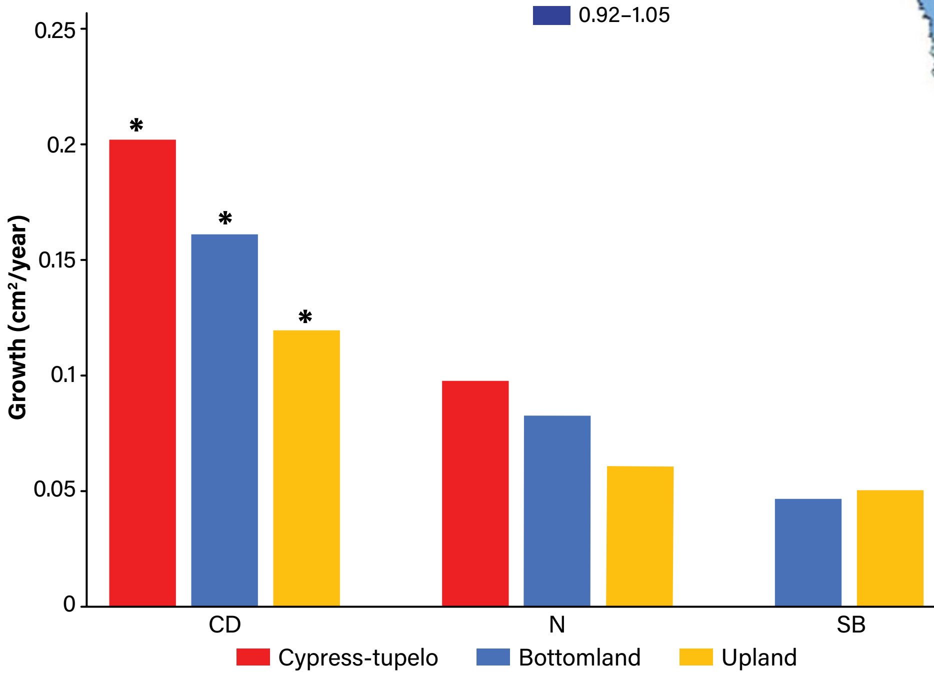


Figure 9.2—Mean annual basal area growth among forest types and damage categories are compared at Beidler Forest in 2018. CD = crown damage; N = no damage; SB = snapped bole. An asterisk indicates mean annual growth is significantly different between the damage categories at α *= 0.05.*

radial growth index, which was calculated as the annualized mean increment for the 4 years after storm injury (2014–2017) divided by the annualized mean increment for the 4 years before the storm injury (2010–2013) determined through tree core analyses. Tree health was analyzed using only descriptive statistics because of the low frequency of observations.

RESULTS AND DISCUSSION

Damage and Mortality

Ice storm damage can have lasting effects on the mortality of southern forests, with an increase from 3.4 percent immediately after the storm to 13.1 percent 4 years later. The mortality rate was much higher than the mean annual mortality of <1 percent in the Southeastern United States (Klos and others 2009). For trees >5 cm d.b.h., mortality from damage was dependent upon the category of damage sustained from the ice storm and the forest type. Root-sprung trees and snapped trees were more likely to perish over time than those with crown damage. Crown damage, the most common type of damage sustained from an ice storm, does not impact the probability of mortality, suggesting that trees with crown damage recovered during the 4 years after the ice storm. The cypress-tupelo community was the most resistant to ice storm damage because of dominant species such as bald cypress showing storm-resistant traits, including narrow, symmetrical crowns, deciduous leaves, and strong buttressed stems. The dominant species in the bottomland and upland forest types, such as laurel oak, had qualities associated with higher susceptibility to ice damage such as asymmetry, winter phenology with larger surface area (marcescent and evergreen broadleaf trees), and sprawling crowns. A positive correlation with diameter size and damage was found, which is consistent with Lafon (2004). Smaller trees are more likely to die from severe damage as these trees may face more competition from other larger trees. Future research could include tree height as an additional measure of size to study the impact of ice storms.

Growth

Diameter size and growth rate were positively correlated, which is consistent with Bragg and others (2010). Surprisingly, the highest annual growth rates were found in trees that sustained crown damage in all forest types (fig. 9.2), which may be due to the probability of these trees being in the vicinity of other crown-damaged trees or areas with higher tree mortality due to the ice storm. The increase in light level must have been large enough to overcome the loss of photosynthetic area from crown damage. However, crown damage intensity affected neither basal area (by d.b.h. measurement) nor radial growth (by analyzing tree cores). We note that our sample size was limited by a low number of live trees with severe crown damage, which likely decreased the statistical power of the test.

Recovery

Overall, 14.2 percent of surviving trees are in growth decline, while 65.3 percent experienced no change, and 20.5 percent are in recovery since the storm in 2014. The forest type with the most trees in decline is the bottomland community at 18.9 percent. Interestingly, the bottomland community also has the highest number of recovering trees at 22.2 percent. Large trees (d.b.h. >11 cm) were the most impacted by the ice storm, with 30 percent having experienced growth changes (recovery or decline), while small trees were almost entirely unaffected due to their position in the canopy, suggesting that canopy position should also be evaluated with diameter size.

Forest Health

Overall, 6.1 percent (184 of 3,032) of surviving trees had some sort of implication to their health. However, the visual health data were skewed toward smaller (shorter) trees since visual estimations of foliar damage were difficult for taller trees.

CONCLUSIONS

Ice storms may be infrequent, but their impacts can have a lasting legacy on the remaining trees for years. The accumulated mortality increased by about 10 percent over the 4 years after the ice storm. Damage severity had a positive correlation with mortality, and trees with damage categories of uprooting and snapped bole were more likely to perish than those with crown damage. Evergreen broadleaf and marcescent trees were significantly more likely to perish than deciduous trees. Small-diameter trees were also more likely to perish than larger ones. The cypress-tupelo swamp is the community that is most resistant to ice storms, with significantly lower mortality in trees >5 cm d.b.h. than the two drier (bottomland and upland) communities. Trees with d.b.h >11 cm are the most dynamic in changes in growth after the storm, with >30 percent experiencing recovery and >30 percent experiencing decline, while most smaller trees remain steady in post-storm growth rates.

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LITERATURE CITED

Bennett, I. 1959. Glaze: its meteorology and climatology, geographical distribution, and economical effects. Tech. Rep. EP-105. Natick, MA: U.S. Army Quartermaster Research & Engineering Center, Environmental Protection Research Division. 217 p.

Bragg, D.C.; Shelton, M.G. 2010. Recovery of planted loblolly pine 5 years after severe ice storms in Arkansas. Southern Journal of Applied Forestry. 34(1): 13–20. https://doi.org/10.1093/sjaf/34.1.13.

Bragg, D.C.; Shelton, M.G.; Zeide, B. 2003. Impacts and management implications of ice storms on forests in the Southern United States. Forest Ecology and Management. 186: 99–123. https://doi.org/10.1016/S0378-1127(03)00230-5.

Changnon, S.A.; Karl, T.R. 2003. Temporal and spatial variations of freezing rain in the contiguous United States: 1948–2000. Journal of Applied Meteorology. 42: 1302–1315. https://doi.org/10.1175/1520-0450(2003)042<1302:TASVOF>2.0.CO;2.

Irland, L.C. 2000. Ice storms and forest impacts. Science of the Total Environment. 262: 231–242. https://doi.org/10.1016/S0048-9697(00)00525-8.

Klos, R.J.; Wang, G.G.; Bauerle, W.L.; Rieck, J.R. 2009. Drought impact on forest growth and mortality in Southeast USA: an analysis using Forest Health and Monitoring data. Ecological Applications. 19: 699–708. https://doi.org/10.1890/08-0330.1.

Lafon, C.W. 2004. Ice-storm disturbance and long-term forest dynamics in the Adirondack Mountains. Journal of Vegetation Science. 15: 267–276. https://doi.org/10.1111/j.1654-1103.2004.tb02261.x.

Lu, D.L.; Pile, L.S.; Yu, D. [and others]. 2020. Differential responses of tree species to a severe ice storm and their implications to forest composition in the Southeast United States. Forest Ecology and Management. 468: 118177. https://doi.org/10.1016/j.foreco.2020.118177.

South Carolina Forestry Commission. 2014. Timber damage assessment. https://www.state.sc.us/forest/2014winterstorm.htm [Date accessed: January 4, 2022].