HURRICANES STIMULATE CONE PRODUCTION IN LONGLEAF PINE WOODLANDS

Jeffery B. Cannon, Brandon T. Rutledge, Joshua J. Puhlick, John L. Willis, and Dale G. Brockway

EXTENDED ABSTRACT

Many trees exhibit a reproductive strategy known as masting where seed production is highly variable in time (Janzen 1971, Koenig 2021, Koenig and Knops 2005). Variability in weather patterns can trigger seed production leading to synchrony over large geographic areas (Pearse and others 2014). Disturbances such as drought and fire are known to stimulate masting, but little is known about whether hurricanes also stimulate seed production (Vacchiano and others 2021). Hurricanes may trigger cone production through multiple environmental stimuli associated with windstorms such as additional precipitation, neighbor removal, and sublethal mechanical damage (fig. 1).

Figure 1—Hurricane damage to a longleaf pine forest in Newton, GA, following 2018 Hurricane Michael. (Photo courtesy of The Jones Center at Ichauway)

Jeffery B. Cannon, Landscape Ecologist, The Jones Center at Ichauway, Newton, GA 39870

Brandon T. Rutledge, Conservation Coordinator, The Jones Center at Ichauway, Newton, GA 39870

Joshua J. Puhlick, Ecological Silviculturist, The Jones Center at Ichauway, Newton, GA 39870

John L. Willis, Research Forester, U.S. Department of Agriculture, Forest Service, Southern Research Station, Auburn, AL 36849

Dale G. Brockway, Research Ecologist, U.S. Department of Agriculture, Forest Service, Southern Research Station, Auburn, AL 36849

Longleaf pine (*Pinus palustris*) is considered a weakly masting species with sporadic seed production and is concentrated in the hurricane-prone Southeastern United States (Chen and Willis 2023, Guo and others 2016), making it suitable for testing whether intense winds stimulate seed production. In addition, longleaf pine is a primary focus for restoration efforts, as the species is expected to be resilient to future climate changes such as increased drought and hurricane intensity (Bigelow and others 2021, McLaughlin and others 2013, Noss and others 1995, Qi and others 2022, Rutledge and others 2021).

Due to widespread interest in restoration and management of longleaf pine, long-term records of cone production are available that can provide valuable insights into the dynamics of cone production (Willis and Brockway 2022). We combined these cone records with hurricane records to test the hypothesis that hurricanes stimulate cone production in longleaf pine. A record of cone production is available for 12 mature longleaf pine sites throughout the Southeastern United States with record lengths ranging from 8 to 67 years (1958 to 2022). At each of these sites, scientists with the U.S. Department of Agriculture, Forest Service conducted annual cone counts using 8- to 10-power binoculars between April and May each year (Willis and Brockway 2022). Annual information on cone production is available for each site as the mean number of cones per tree based on the averaged counts from a set of 10 to 17 trees per site for most sites, and 50 trees at one site. Initially, trees were selected as dominant healthy trees after a shelterwood cut, and consistently sampled each year. The death of a sampled tree was replaced with a nearby healthy tree in a dominant canopy position.

Using the hurricane tracks available from the National Oceanic and Atmospheric Administration [Best Track Data (HURDAT2)] (Landsea and Franklin 2013, NOAA 2022), we identified 96 instances where hurricane winds approached monitored sites, and 34 cases where cone count data was available 1 year before and each of 3 years after a hurricane. To test the hypothesis that hurricanes influence cone production, we assessed changes in cone production based on lag time since a recent hurricane ranging from 1 year before to 3 years after a hurricane. This sampling provided a means to compare the years after a hurricane to the baseline 1 year prior. Over the 4 years, repeated measures analysis of variance was used to test whether time since hurricane had a significant impact on cone production.

Preliminary results reveal that cone production increased by 31 percent in the first year after a hurricane, and 71 percent higher in the second year, before returning to prestorm levels in year three ($P = 0.028$). This suggests that hurricanes may stimulate reproduction in longleaf pine, and more generally provides evidence that intense winds may trigger masting in some tree species. Longleaf pine was once a dominant tree in forests of the hurricane-prone Gulf Coastal Plain (Cannon and others 2023; Dahal and others 2014; Keim and others 2007). Thus, it should not be surprising that the species exhibits a reproductive response to hurricane winds. The posthurricane environment provides opportunities for successful longleaf pine germination, such as bare mineral soil within tip-up mounds

(Beatty1984, Sobhani and others 2014, Ulanova 2000). Large downed logs from wind storms may also temporarily reduce fire continuity (Cannon and others 2017) and provide a fire-free period needed for successful longleaf pine establishment (Robertson and others 2019).

Our results demonstrate that hurricanes can increase reproduction, but the mechanism of this effect remains unknown. Hurricanes may increase cone production by increasing precipitation, freeing up resources from competing vegetation, or by stimulating reproduction via stress mechanisms. For example, anomalous precipitation typically accompanies hurricanes, and can be significant especially in the late summer and early fall (August through September) when precipitation is low in the region (Schwarz 1970). Severe winds can topple trees, thinning forests and providing greater access to resources for surviving mature trees (Brockway and others 2006, Croker and Boyer 1975). Intense winds cause sublethal mechanical damage to trees such as leaf stripping, broken branches, or stem torsion (Doyle and others 1995, Rutledge and others 2021). These disturbances may elicit a physiological response that increases reproduction—similar to what is sometimes observed after other disturbances such as wildfire and drought (Lauder and others 2019). Further research into how cone production may vary with each of these factors is underway and may shed light on the specific mechanism responsible for hurricane-triggered masting events.

There is widespread interest in promoting conservation, management, and restoration of longleaf pine forests and woodlands (McIntyre and others 2018). Highly variable cone and seed production make it challenging for managers of longleaf pine to regenerate the species naturally. Often, prescribed burns must be timed with masting events for successful seedling establishment. Increasing the understanding of the factors driving seed production at stand and regional scales can promote natural regeneration of the species. Further, understanding population dynamics in the face of threats from increasing climate-related disturbances will be critical for formulating silvicultural prescriptions for adapting to anticipated changes.

REFERENCES

Beatty, S.W. 1984. Influence of microtopography and canopy species on spatial patterns of forest understory plants. Ecology. 65: 1406–1419. https://doi.org/10.2307/1939121.

Bigelow, S.W.; Looney, C.E.; Cannon, J.B. 2021. Hurricane effects on climate-adaptive silviculture treatments to longleaf pine woodland in southwestern Georgia, USA. Forestry. 94: 395–406. https://doi.org/10.1093/forestry/cpaa042.

Brockway, D.G.; Outcalt, K.W.; Boyer, W.D. 2006. Longleaf pine regeneration ecology and methods. In: Jose, S.; Jokela, E.J.; Miller, D.L., eds. The longleaf pine ecosystem: ecology, silviculture, and restoration. New York, NY: Springer: 95–133.

Cannon, J.B.; Peterson, C.J.; Godfrey, C.M.; Whelan, A.W. 2023. Hurricane wind regimes for forests of North America. Proceedings of the National Academy of Sciences. 120(42): e2309076120. https://doi.org/10.1073/pnas.2309076120.

Cannon, J.B.; Peterson, C.J.; O'Brien, J.J.; Brewer, J.S. 2017. A review and classification of interactions between forest disturbance from wind and fire. Forest Ecology Management. 406: 381–390. https://doi.org/10.1016/j.foreco.2017.07.035.

Chen, X.; Willis, J.L. 2023. Individuals' behaviors of cone production in longleaf pine trees. Forests. 14: 494. 10 p. https://doi.org/10.3390/f14030494.

Croker, T.C., Jr.; Boyer, W.D. 1975. Regenerating longleaf pine naturally. Res. Pap. SO-105. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 21 p.

Dahal, D.; Liu, S.; Oeding, J. 2014. The carbon cycle and hurricanes in the United States between 1900 and 2011. Scientific Reports. 4: 5197. 10 p. https://doi.org/10.1038/srep05197.

Doyle, T.W.; Smith, T.J. III; Robblee, M.B. 1995. Wind damage effects of Hurricane Andrew on mangrove communities along the southwest coast of Florida, USA. Journal of Coastal Research. 21: 159–168.

Guo, Q.; Zarnoch, S.J.; Chen, X.; Brockway, D.G. 2016. Life cycle and masting of a recovering keystone indicator species under climate fluctuation. Ecosystem Health and Sustainability. 2(6): e01226. 11 p. https://doi.org/10.1002/ehs2.1226.

Janzen, D.H. 1971. Seed predation by animals. Annual Review of Ecology and Systematics. 2: 465–492. https://doi.org/10.1146/annurev.es.02.110171.002341.

Keim, B.D.; Muller, R.A.; Stone, G.W. 2007. Spatiotemporal patterns and return periods of tropical storm and hurricane strikes from Texas to Maine. Journal of Climate. 20(14): 3498–3509. https://doi.org/10.1175/JCLI4187.1.

Koenig, W.D. 2021. A brief history of masting research. Philosophical Transactions of the Royal Society B. 376: 20200423. 7 p. https://doi.org/10.1098/rstb.2020.0423.

Koenig, W.D.; Knops, J.M.H. 2005. The mystery of masting in trees. American Scientist. 93: 340–347.

Landsea, C.W.; Franklin, J.L. 2013. Atlantic hurricane database uncertainty and presentation of a new database format. Monthly Weather Review. 141(10): 3576–3592. https://doi.org/10.1175/MWR-D-12-00254.1.

Lauder, J.D.; Moran, E.V.; Hart, S.C. 2019. Fight or flight? Potential tradeoffs between drought defense and reproduction in conifers. Tree Physiology. 39: 1071–1085. https://doi.org/10.1093/treephys/tpz031.

McIntyre, R.K.; Guldin, J.M.; Ettel, T. [and others]. 2018. Restoration of longleaf pine in the southern United States: a status report. In: Kirschman, J.E., comp. Proceedings of the 19th biennial southern silvicultural research conference. e-Gen. Tech. Rep. SRS-234. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 297–302.

McLaughlin, D.L.; Kaplan, D.A.; Cohen, M.J. 2013. Managing forests for increased regional water yield in the southeastern U.S. coastal plain. Journal of the American Water Resources Association. 49: 953–965. https://doi.org/10.1111/jawr.12073.

National Oceanic and Atmospheric Administration [NOAA]. 2022. NHC data archive. National Hurricane Center. https://www.nhc.noaa.gov/data/#hurdat. [Date accessed: August 20, 2022].

Noss, R.F.; LaRoe, E.T. III; Scott, J.M. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. Biological Report 28. Washington, DC: U.S. Department of the Interior National Biological Service. 58 p.

Pearse, I.S.; Koenig, W.D.; Knops, J.M.H. 2014. Cues versus proximate drivers: testing the mechanism behind masting behavior. Oikos. 123: 179–184. https://doi.org/10.1111/j.1600-0706.2013.00608.x

Qi, J.; Brantley, S.T.; Golladay, S.W. 2022. Simulated longleaf pine (*Pinus palustris* Mill.) restoration increased streamflow—a case study in the Lower Flint River Basin. Ecohydrology. 15: e2365. 15 p. https://doi.org/10.1002/eco.2365.

Robertson, K.M.; Platt, W.J.; Faires, C.E. 2019. Patchy fires promote regeneration of longleaf pine (*Pinus palustris* Mill.) in pine savannas. Forests. 10: 367. 16 p. https://doi.org/10.3390/f10050367.

Rutledge, B.T.; Cannon, J.B.; McIntyre, R.K. [and others]. 2021. Tree, stand, and landscape factors contributing to hurricane damage in a coastal plain forest: post-hurricane assessment in a longleaf pine landscape. Forest Ecology Management. 481: 118724. 13 p. https://doi.org/10.1016/j.foreco.2020.118724.

Schwarz, F.K. 1970. The unprecedented rains in Virginia associated with the remnants of Hurricane Camille. Monthly Weather Review. 98(11): 851–859. https://doi.org/10.1175/1520-0493(1970)098<0851:TURIVA>2.3.CO;2.

Sobhani, V.M.; Barrett, M.; Peterson, C.J. 2014. Robust prediction of treefall pit and mound sizes from tree size across 10 forest blowdowns in eastern North America. Ecosystems. 17: 837–850. https://doi.org/10.1007/s10021-014-9762-8.

Ulanova, N.G. 2000. The effects of windthrow on forests at different spatial scales: a review. Forest Ecology and Management. 135: 155–167. https://doi.org/10.1016/S0378-1127(00)00307-8.

Vacchiano, G.; Pesendorfer, M.B.; Conedera, M. [and others]. 2021. Natural disturbances and masting: from mechanisms to fitness consequences. Philosophical Transactions of the Royal Society B. 376: 20200384. 13 p. https://doi.org/10.1098/rstb.2020.0384.

Willis, J.L.; Brockway, D.G. 2022. Longleaf pine cone prospects. 22 p. Unpublished report. On file with: U.S. Department of Agriculture Forest Service, Southern Research Station, 521 Devall Drive, Auburn, AL 36849.