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Bark and Woodboring Beetles in Wind-damaged Pine Stands in the Southern United States

Kamal J.K. Gandhi[a], Kier D. Klepzig[b], Brittany F. Barnes[a], Benjamin Gochnour[a], Elizabeth P. McCarty[a], Thomas N. Sheehan[b], Caterina Villari[a], and J.T. Vogt[c]

[a]University of Georgia, [b]The Jones Center at Ichauway, [c]USDA Forest Service

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Introduction

Catastrophic windstorms and southern pine beetle (*Dendroctonus frontalis* Zimmerman) outbreaks are considered primary sources of natural disturbances in the southeastern U.S.[1] Important windstorms include hurricanes, tornadoes, and derechos (straight-line winds with downbursts).[2] Tornadoes are most likely to occur in February and March, with a second peak of activity in November-December in the South.[2] Derechos are most common in September-April, although they can occur during any time of the year in southern forests.[3] Canopy tree mortality due to windstorms can occur on the scale of a few to millions of trees in a short time-span. The severity of tree mortality is based on storm size and intensity, stand characteristics (e.g., soil type, tree species, stand age, tree heights, and thinned or unthinned), and conditions prior to the event. Tree mortality occurs primarily through the snapping of boles, uprooting, and branch and canopy damage. Since most storms are associated with heavy rainfall, flooding and soil erosion can further damage tree roots and younger trees.

Fig. 1: ***Windthrow of a pine stand from Hurricane Michael.***
Image credit: Benjamin Gochnour, University of Georgia

In recent years, catastrophic and devastating hurricanes such as Irma and Michael have resulted in widespread tree mortality, especially in commercially important pine plantations. For example, Hurricane Michael had major impacts across Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia. Up to 95% of trees were impacted in many areas with an estimated $2 billion loss of marketable trees (Fig. 1).[4,5] Similarly, Hurricane Katrina resulted in damage and mortality of approximately 300 million trees and greater than 60% of trees in severely impacted areas.[6]

Typically, major hurricanes (Category 3 and greater) make landfall along the U.S. coastline at a frequency of two out of three years.[7] Models indicate that, as the climate changes, such disturbances will increase in frequency and cause greater damage.[7] How climate change may impact smaller scale events such as tornadoes is not clear, but warmer temperatures are likely to support greater development of convective systems.[2] Forest managers may, therefore, need to focus more on the impacts of catastrophic windstorms to make effective decisions for long-term forest sustainability.

Responses of Biotic Disturbance Agents

Damage to trees in areas affected by windstorms is variable and may include snapped trunks, uprooting, bent and leaning trees, and slash debris. Severity of damage can influence the amount of woody debris deposited on the landscape and the time it takes for affected trees to die. Tree mortality may occur over several years as leaning live trees and standing trees that experienced damage may take a few years to die. Thus, the input of woody material may continue for years, extending the effects of disturbance beyond the initial tree mortality. Damaged, dying, and dead trees provide excellent habitats for pests and pathogens, such as bark beetles, woodboring insects, and pitch canker (*Fusarium circinatum* Nirenberg & O'Donnell). Many species of bark and woodboring beetles are known to invade wind-disturbed forests and reproduce in the woody debris.[8,9,10] The insects may increase in population size and move into residual and surrounding live trees to cause even greater economic damage over time. Severity of wind damage, host tree species, and seasonality of the storm can all affect the suitability of trees as host material, and subsequent beetle colonization and outbreak dynamics.

Dendroctonus and *Ips* are two important types of bark beetles that are expected to colonize wind-damaged trees in the southeast. Southern pine beetle is the most damaging forest insect in the southern United States (Fig. 2).[11] Smaller populations can serve as a moderate disturbance agent infesting lightning struck trees or small groups of trees. Under certain conditions, southern pine beetle can outbreak, killing or damaging millions of cubic feet of standing timber and causing hundreds of millions of dollars in economic losses. In contrast to some anecdotal reports, an association between increased southern pine beetle-caused mortality and severe windstorms has not been officially documented.[12] Rather, stand-level characteristics, such as reduced radial growth prior to attack and high stand density have been implicated in southern pine beetle outbreaks.[13]

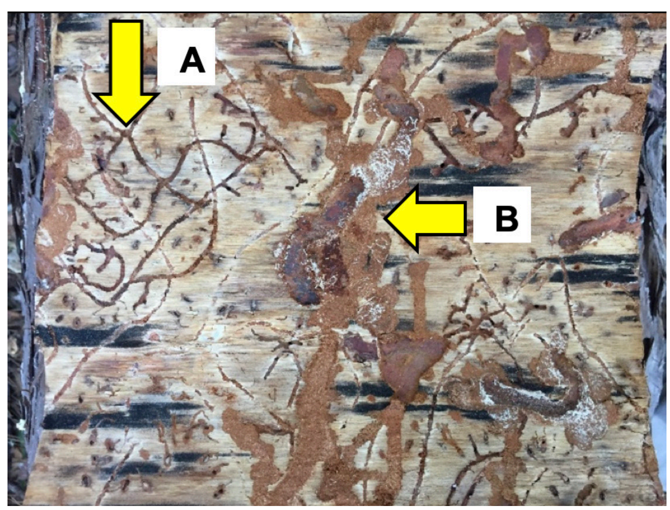

Fig. 2: ***A southern pine beetle (A) and woodborer beetle (B) galleries underneath the bark.***

Image credit: Elizabeth McCarty, University of Georgia

Numerous other beetle species are known to attack wind-damaged trees, including live, seemingly healthy trees. Black turpentine beetle [*Dendroctonus terebrans* (Olivier)], and three species of pine engravers [*Ips avulsus* (Eichhoff), *I. grandicollis* (Eichhoff), and *I. calligraphus* (Germar)] are not as economically damaging as southern pine beetle (Fig. 3A). However, they kill stressed trees and introduce the economically detrimental bluestain fungi as part of their attack process.[14,15] Woodboring beetles become important and may compete with developing beetle larvae later in the attack process or in more stressed trees.[16] The southern pine sawyers (*Monochamus* species) may be especially abundant and damaging to the wood of beetle-infested trees in the southeastern region (Figs. 2, 3B).

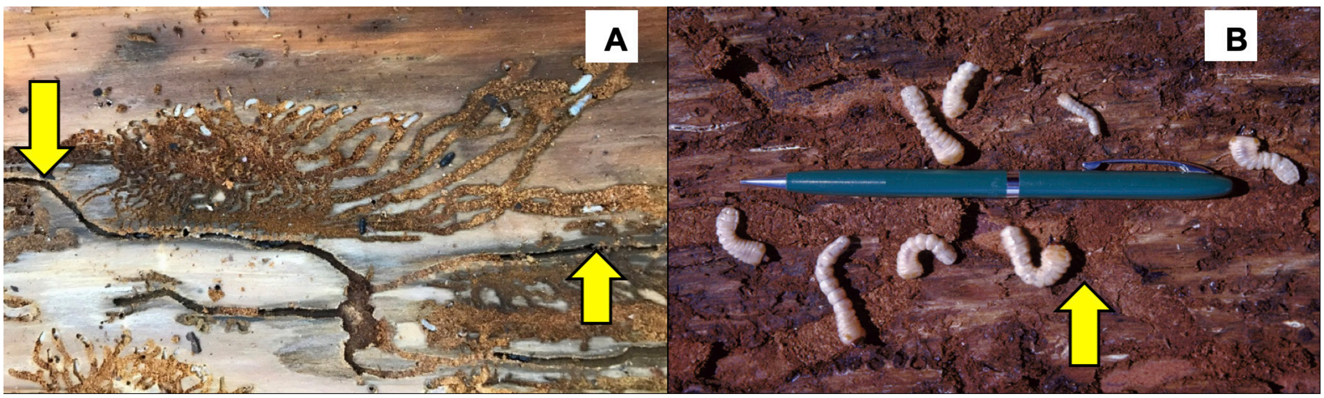

Fig. 3: ***An Ips beetle (A), and a Monochamus beetle larval galleries (B) on trees.***

Image credits: Elizabeth McCarty, University of Georgia (A), Lacy L. Hyche, Auburn University, Bugwood.org (B).

Management Strategies

Pre-wind-damage Management: A rapid Hurricane Michael damage assessment by the Georgia Forestry Commission found that young, well stocked and healthy pine stands weathered the storm the best.[4] Evidence suggests that the most severe timber damage was found in recently thinned pine stands. This is because stands had trees with lower basal area that had lower wind resistance and fewer neighboring trees to provide support to tree tops. In addition, root systems of affected trees were inadequate anchors, and the stems were not strong enough to withstand heavy winds.

Despite susceptibility of recently thinned stands to wind damage, thinning and other stand management activities are recommended at the appropriate stand age and tree condition. For example, well established, uneven age, longleaf pine forests did not suffer for having lower basal areas, and were only moderately damaged during Hurricane Michael. Damage was also less likely in mature longleaf pines than loblolly pines, due to their larger stems and well-developed root systems, as also documented during Hurricane Katrina.[17] In areas with wind speeds greater than 110 mph (Category 3 and greater hurricane speeds), however, stand attributes does not seem to matter and generally results in severe and catastrophic damage, no matter the basal area or pine species.

Post-wind-damage Management: Post-windstorm management options will depend on the severity of wind damage (Table 1) and overall goals for the property. Landowners facing a complete harvest may consider reforestation with the most appropriate pine species for the site. If the management goal of the stand is beyond economic returns, issues such as native plant restoration, wildlife habitat, and encouragement of natural regeneration (facilitated by proper management of stands with heavy cone crops) may take precedence. The increased structural diversity resulting from downed and damaged trees can benefit soil-dwelling organisms and detritivores, enhancing biodiversity, while salvage operations can compound the initial disturbance by moving soil and damaging remaining trees. Activities of salvage crews, such as bringing equipment from other stands, increases the risk of introducing invasive species. Land managers may further consider impacts on fire risk as leaving behind large logs, stumps and tree tops may create fire and smoke hazards.

Future Monitoring and Research

Wind-storm damaged stands should be monitored for 2-3 years for bark and woodboring beetle activity, with frequent (every 2-3 weeks) inspections during the first year. Tree stress from strong winds, and the prevalence of dead, downed material are risks for increased beetle abundance and activity. Long-term monitoring efforts are underway, which will be useful to land managers. Monitoring efforts include the south-wide southern pine beetle survey by the USDA Forest Service, as well as monitoring by state forestry agencies. Multiple post-Hurricane Michael studies involving state forestry agencies, the Jones Center at Ichauway, the University of Georgia, and the USDA Forest Service are examining the responses of bark and woodboring beetles, root colonizing insects, blue stain fungi, and other pathogens to wind damage. Further research is answering questions about impacts of post-windstorm salvage and prescribed burning on these beetles.

Acknowledgements

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Table 1. Categories of Post-Wind Damage and Management Recommendations[a]

Damage Category	Stem Damage	Damage Observations	Management Recommendation
Minimal	Little to none	Few trees are bent (< 45˚). Scattered branches broken; little to no damage to stand, in particular to tree stems.	No salvage operation necessary; stand should recover with time.
Light	Average: 10% Range: 0 - 20%	Trees are bent < 45˚. Only branches broken from trees; minor damage to tree stems.	No salvage operation necessary; stand should recover with time.
Moderate	Average: 25% Range: 20 - 50%	Some trees are noticeably uprooted with severe lean > 45˚. Branches broken from the trees with visible damage to tree stems in the overall stand.	Salvage thinning is recommended after major clear-cut salvage operations are completed..
Severe	Average: 65% Range: 50 - 80%	Trees are bent over > 45˚. Many stems broken, tops broken out across the stand, limbs stripped.	Salvage operation should be considered, and a clearcut will be prudent in most cases.
Catastrophic	Average: 90% Range: 80 - 100%	Trees are bent over > 45˚. 90 - 100% of stems broken across the stand, tops broken out across the stand limbs stripped, and trees bent.	Salvage is unlikely, but a case by case evaluation is required by the landowner, forester, and logger. Clearcut and replanting is recommended.

[a]*Based on Dickens et al. (2018).*[18]

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