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# Detecting Hurricane History and Effect From Tree Rings

Recurrent hurricanes affect ecosystems along the coastal plain of the Gulf of Mexico. Hurricanes can be expected along the northern Gulf coast every 7 years. Hurricanes generate high winds and tidal surges that damage or destroy millions of dollars of forest resources and developed property. Studies of climate change indicate the likelihood that these storms will become more frequent in a warming global environment. We conducted a dendroecological study of southern pine growth and stand development along the Gulf coast from Louisiana to Florida to investigate the effect of hurricanes on coastal plant communities. We hypothesized that spatial and temporal imprints should be recorded in the growth rings of trees surviving the usual crown damage and windthrows associated with hurricanes. We also believed that the successional status of persisting stands was affected and that these imprints were likely to be coincident with the proximity and strength of individual storms. We explored several analytical approaches for using tree rings to detect the influence of past hurricanes on forest growth and succession.

## Forest Site and Tree Core Sampling

The study area encompassed the coastal areas of Mississippi, Alabama, eastern Louisiana, and northwestern Florida. Site selection focused on forested stands likely to be susceptible to hurricane damage. Each site consisted of forest inventory plots wherein the number, species, size, and crown class of trees was recorded along with the azimuth of leaning or downed logs. Individual trees of dominant and codominant crown position were randomly selected for core sampling and tree ring analysis. Increment borers were used to obtain two cores per tree, one each from the original north and south sides. Core samples were processed, dated, and measured according to standardized procedures. Only trees determined to be 50 years old or older were used for analysis to accommodate comparisons of mature trees and to reduce the effects of juvenile growth.

## Hurricane History and Simulation Model

This study area was chosen to include the storm-affected area of the "Hurricane of 1947" as well as hurricanes Camille (1969), Frederic (1979), Elena (1985), and Kate (1985). The distance between sites was sufficiently close to ensure growth responses across multiple sites and to define the spatial extent of storm damage. Because our study sites were located in remote forested areas, there was no available surface wind data to correlate with our growth ring data. Therefore, a simulation model of hurricane dynamics was developed to reconstruct chronologies of hurricane windforce and vectors for each plot location derived from historic tracking data of storms in the Gulf of Mexico. The model estimated maximum sustained windspeed and direction on a hourly basis according to hurricane forward speed, trajectory, and intensity. Simulated data were generated from recorded meteorological data for North Atlantic tropical storms to produce maximum predicted windspeed profiles for each site from 1895 to the present. These wind profiles were then used to determine whether critical wind speeds could be correlated with the pattern and degree of growth response in the tree ring record.

## Growth Analyses Verify Effects of Hurricane

Hurricane effect on the growth of individual trees was evident during the tree ring dating process. Suppressed growth patterns were noted in cores collected from all but two control sites. In particular, there were rings missing for years immediately following hurricane Camille. Several innovative approaches were used to determine whether the timing of a hurricane was coincident with changes in growth pattern. These detection methods included repeated measure analysis of growth rates before and after the hurricane, differences in within-tree stemwood distribution, and growth departures from expected biological growth. All site collections demonstrated some growth sensitivity to one or more hurricanes with one or more of the above analytical approaches.

Repeated measure analysis of prehurricane and posthurricane growth proved to be effective where the growth response among all trees within a site was consistently positive or negative. Some sites had tree cohorts that responded with growth suppression or release depending on the tree's age and stature that tended to average out the response of either group. Ratios of stemwood distribution that describe the pattern of growth allocation within a tree dramatically illustrated the effect of hurricanes in years immediately following major storms for all sites and collections. These results show that trees require 3–7 years to recover some balance in growth allocation after injury by a hurricane. Departures from expected growth trends were coincident with several hurricanes, most notably Hurricane Camille. Unlike the repeated measure analysis, this approach is sensitive to identifying suppressed and released ring series concomitant with the year of a hurricane.

## Hurricane Windspeed Critical to Spatial Effect

In all cases, the higher the windspeed, the more severe the effect was on tree growth and development. Based on wind profiles generated with the hurricane simulation model, minimum sustained windspeeds as low as 42 mps were sufficient to alter growth pattern and stand structure. As a rule, there was a direct correlation between the degree and evidence of storm effect with distance from the storm's eyewall. The susceptibility of a site to damage was dependent on forest conditions at the time of hurricane arrival and the relation of the site to the angle or side of a passing hurricane. In general, backside storm effects were always less than forward side effects of the same predicted windspeed, indicating the influence of wind sheltering by inland forests and landforms. Forest stands subject to intense crown competition demonstrated a greater propensity to windthrow and to growth response at critical windspeeds.

Trees blew over in accordance with the wind direction. Additional evidence from forest plot data demonstrates that windthrow azimuths of downed logs were nonrandom and that they correlated with hurricane wind vectors. Furthermore, age classes of trees within a site more often coincided with the dates of past hurricanes indicating seedling reestablishment following disturbance.

## Research and Management Implications

We offer a means to detect the historic pattern and effect of hurricanes on the growth and development of coastal forests. We developed new analytical approaches to use tree rings to build chronologies of past hurricanes beyond the existing meteorological records and to determine the spatial significance and intensity of such storms. The combination of forest inventory and growth data allows the construction of empirical equations describing the relation between hurricane abiotics and forest susceptibility and damage. The combination also offers the ability to construct statistical probabilities of hurricane frequency and intensity along stretches of the gulf coast. These empirical results are being used in computer simulation models to predict potential effects expected under global warming of increased hurricane activity on our coastal ecosystems.

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