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Hurricanes Winds, Tropical Storm Winds, and Tree Fragmentation

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Introduction

The purpose of this study was to collect information about the effects of high winds on different types of Floridian trees. The study was initiated in the summer of 2004 when four hurricanes made landfall in Florida. The objective was to derive information about damage to trees in severe winds that may be applied to planning for areas of human activity, with regard to landscape elements that may be more hazardous than others. Data and analyses here include part of the information from areas affected by hurricanes Charley, Frances, and Jeanne, with data from areas affected by hurricane Ivan not yet considered. This information is a report with limited analysis; estimates and conclusions discussed here are preliminary.

The hurricanes that affected Florida in 2004 were mid-season Atlantic hurricanes that affected nearly all parts of the state. The four hurricanes to make landfall in Florida during 2004 were (much of this information from Tuckwood et al. 2004):

- *Charley,* 13 August, estimated maximum winds: 145 mph (category four hurricane; see Table 1) at landfall. The storm made landfall at Captiva Island on the Gulf coast and moved north–northeast across the state.
- *Frances,* 5 September, estimated maximum winds: 105 mph (category two hurricane) at landfall. This storm made landfall at Hutchinson Island, moved slowly west–northwest across the peninsula, and produced much rain inland.
- *Ivan,* 16 September, estimated maximum winds: 130 mph (category three hurricane) at landfall. The center of the storm made landfall west of the Florida–Alabama border, and produced hurricane-force winds east into the Florida panhandle.
- *Jeanne,* 26 September, estimated maximum winds: 120 mph (category three hurricane) at landfall. This system made landfall at Hutchinson Island and entered the Gulf of Mexico north of Tampa Bay.

Changes associated with hurricanes

Major types of damage usually associated with hurricanes are changes caused by extreme winds. Winds cause much damage to biological communities by breaking or uprooting trees, but these changes are temporary as plants and their communities regrow and can recover from these disturbances in years or decades. Long-lasting disturbance may be caused by severe weather when floods are part of storms. Flooding may occur with extreme rainfall in inland areas and by extreme tides along the coast. In Florida, the land surface is mostly low with little topographic relief, so that serious flooding by rain and associated substrate movement by high-energy moving water is seldom significant. Coastal shorelines of Florida, however, are low with sandy substrates and are subject to change with

Wind speed (mph)	Storm strength
39–73	tropical storm
74–95	category one hurricane
96–110	category two hurricane
111–130	category three hurricane
131–155	category four hurricane
>155	category five hurricane

Table 1. The Saffir-Simpson Hurricane Scale. This scale identifies storm intensities with wind speed categories and descriptions of damage common for each category; damage descriptions are not included here. Tropical Storm designation includes lower strength storms (NOAA 2005).

extreme tides. Changes that involve movement of substrates and associated biological communities are more long-lasting and may affect the region's biological communities for very long periods.

- Hurricane Andrew (1992), category five hurricane, southern Florida. *Winds:* Extreme. *Rain flooding:* minor. This storm moved quickly across the southern part of the state and did not produce much rain. *Tidal flooding:* moderate. Tidal flooding occurred in low-lying areas, but significant changes in shorelines were not common (Loope et al. 1994). *Changes to trees:* high mortality of slash pines. Many of these trees succumbed to secondary infestations by insects or pathogens after hurricane-induced stress; many of these trees remained alive for 12–18 months after the hurricane. Most trees within or near to the eye of the storm were damaged.
- Hurricane Mitch (1998), category five hurricane, Central America. Winds: extreme offshore, but minor inland; this hurricane degraded to a tropical storm soon after moving over mainland Honduras. *Rain flooding:* Extreme. Rainfall of nearly 0.5 m in 24 hours was recorded (NOAA 2005). *Tidal flooding:* minor. *Changes to trees:* Wind damage to trees was in coastal areas; mangrove forests on the Bay Islands and northern shore of Honduras had high tree mortalities. Inland trees were commonly uprooted by flooding and associated substrate movement.
- Hurricane Charley (2004), category four hurricane, Gulf coast and central Florida. *Winds:* severe. *Rain flooding:* minor. This storm moved through the area quickly and produced hard rains, but little standing water resulted. *Tidal flooding:* minor. This storm made landfall on a falling tide so that tidal surges were minimized. *Changes to trees:* Much damage to trees occurred, mostly in areas with category two or greater winds.
- Hurricane Frances (2004), category two hurricane, and Hurricane Jeanne, category three hurricane, east coast and central Florida. Descriptions of these two storms are treated together, as the effects of each separately were not readily apparent after the second storm. *Winds:* moderate. For both storms, winds on the Atlantic shoreline were very strong, but attenuated fairly quickly as the storms moved on shore. *Rain flooding:* moderate. Large amounts of rain fell and accumulated inland during both storms, but little

movement of substrate occurred. *Tidal flooding:* moderate. Some dune overwash and landward migration of dunes occurred; some mangrove communities received up to 50 cm of sand deposition. Hurricane Frances made landfall at about high tide, so that onshore winds (north of the eye) coincided with the rising tide as the storm approached. Hurricane Jeanne made landfall near low tide, so that onshore winds coincided with a falling tide. *Changes to trees:* The most severe damage to trees occurred within 1 km of the coast, but broken trees are common farther inland. Some coastal communities were inundated with substrate (above), so these tree communities will likely change. Perhaps the most consistent perturbation to trees was wind-pruning of leaves by long periods of strong winds in successive storms.

- Hurricane Ivan (2004), category three hurricane, Florida panhandle and adjacent areas. *Winds*: severe. *Rain flooding:* moderate. *Tidal flooding:* severe. This storm made landfall shortly after a weak high tide. Tidal amplitudes were low; tides were mixed with weak activity, and may have had little effect on storm surges. *Changes to trees:* Broken trees were common on barrier islands and within 1 km of the mainland shoreline. On barrier islands, substrate movement produced sand inundation in much of the leeward area dominated by trees. This change in substrate and topography will likely change these forest communities.

Methods

Surveys were done along highways in areas within 100 miles of landfall for hurricanes Charley, Frances, and Jeanne. Survey areas were located at 1-mile intervals. At each location the tree species were noted, and either the type of alteration by high winds (broken branches, broken trunks, uprooted trees, or no apparent damage) was noted, or the size of broken branches, broken trunks, or dbh (diameter at breast height) of uprooted trees was estimated. Estimates of sustained wind speeds were obtained from the National Oceanic and Atmospheric Administration (NOAA) and wind field contours for hurricanes were mapped with ArcView 3.2 contouring software to estimate winds at each survey location. These values were used as an independent variable to compare reactions of trees to winds.

Results

Surveys for hurricanes Charley, Frances, and Jeanne are considered here. On the southern Gulf coast, near the site of landfall of hurricane Charley, 448 sites were surveyed. On the Atlantic coast near the landfall sites of hurricanes Frances and Jeanne, 349 sites were surveyed. Records for 12,118 trees were compiled to compare types of damage, and 439 sites were recorded at which tree structure sizes were estimated.

Slash pine trees. Slash pine *(Pinus elliottii)* trees were the most commonly encountered trees in the surveys. They were selected as an indicator of tree reactions in high winds. Some slash pines lost branches in winds as low as 40 mph, and the proportion of these trees losing branches increased steadily until nearly 100% had branch loss at winds over 110 mph. In tropical storm winds (<74 mph) a few slash pine trees had snapped trunks or were uprooted, but this type of damage was not common until winds were well into the category one hurricane force range (74–95 mph). Proportions of trunk breakage increased to about 40% at

120-mph winds, and proportions of uprooted trees increased to about 10% at 120-mph winds.

Branches broken out of slash pine trees had a mean diameter of about 2 inches regardless of wind speed, suggesting that branches commonly break at about this size then do not break further, as most of the wind-resisting leaf surface area is lost. Tree trunks of about 8 inches dbh occasionally snapped in category one hurricane force winds. This mean diameter at which breakage occurred increased with wind speed to about 10.5 inches dbh at 105 mph and was reduced to about 8 inches dbh at 120 mph. Similarly, occasional uprooting occurred with trees of about 12–14 inches dbh during tropical storm winds with mean trunk size increasing to about 18.5 inches in 100 mph winds, and becoming reduced to about 12 inches at 120 mph winds. In these situations it appears that larger trees are snapped or uprooted by stronger winds, but smaller trees are limber and bend with winds up to about 100 mph. In winds greater than about 100 mph, smaller trees also snap or become uprooted, so that mean dbh estimates decrease with higher winds.

Native and exotic trees. A major consideration was comparing reactions of native trees in high winds with those of nonnative trees in similar situations. Casuarina *(Casuarina equisetifolia)* tree, an invasive tree native to Australia, was a common tree on Sanibel Island. The northwestern part of the island is close to the eye-wall track of hurricane Charley, and many Casuarina trees here were damaged by this storm. These trees are salt tolerant and common in coastal communities; they are gregarious and commonly form nearly monocultural stands on disturbed coasts (Ferriter et al. 2004). Casuarinas are generally much taller than native coastal hardwoods, and provide greater surface area in winds. Their root systems are commonly shallow and they uproot quickly in high winds, especially on shorelines where they may be solitary or in small colonies. In areas farther inland that are occupied by dense Casuarina populations, the trees appear more likely to have experienced snapped trunks, with fewer uprooted individuals. At the five sites surveyed on western Sanibel Island, 58.6% of Casuarina trees snapped or uprooted.

Casuarina and native Virginia live oak. These trees are both large hardwoods that often occupy mesic, sandy soils. In areas that sustained tropical storm winds, live oak trees had damage to branches in about half of the trees observed; this branch damage increased to over 90% of trees in areas that had winds of category two hurricane force or greater. Live oaks occasionally snapped or became uprooted in nearly all wind situations, increasing to about 10% with snapped trunks and about 7% uprooted in areas with category two hurricane winds.

Casuarina trees had similar branch loss, but were about twice as likely to have trunks snapped or to have been uprooted, especially in tropical storm winds. Mean diameters of Casuarina branches lost increased from about two inches in tropical storm winds to about five inches in category two hurricane winds. The dbh measurements of trees snapped or uprooted were both about 8 inches in areas with category one hurricane winds (none was recorded in areas with stronger winds). In areas with tropical storm winds, the dbh measurements of trunks snapped were 8–10 inches and those of trees uprooted were 10–14 inches, indicating that these trees may be likely to be snapped or uprooted in relatively low winds.

Branch loss of exotic trees and native trees. Mean diameters of branches lost from four coastal hardwood tree species were compared with those of branches lost from three exotic hardwood tree species. These trees were selected from at least 18 locations, where each species was measured. Mean diameters of broken branches on native trees were lowest in areas that experienced category one hurricane winds and highest in areas that had tropical storm force winds; simple linear regression produced a negative slope when mean branch size was compared against wind speed. Mean diameters of broken branches on exotic trees were lowest in areas that experienced category one hurricane winds and highest in areas that had category two hurricane winds; simple linear regression produced a positive slope when mean branch size was compared against wind speed. This suggests that native coastal hardwoods may be more likely to lose branches in lower-energy winds than exotic trees (Ferriter et al. 2004; Bodle 2004). This supports the hypothesis that Caribbean trees tend to possess brittle branches that are more often lost quickly. This reduces the tree's crown surface area to decrease the likelihood that the entire tree may be uprooted or snapped near its base. Presumably this enhances these trees' opportunities for survival after severe storms.

Natives and exotics: gross tree alteration. Native Floridian trees showed slightly greater branch loss than exotic trees in areas with tropical storm winds; this early branch loss may contribute to survival of these trees, as just discussed. Overall, exotic trees experienced more damage than natives. Nearly all trees were significantly altered by winds of category three hurricane force or greater. Palm trees generally survived well, but native palm trees were less likely to be compromised. See Table 2 for general comparisons of tree alteration.

Table 2. Damage to native and exotic trees in Hurricanes Charley, Frances, and Jeanne (2004): Percents of all trees, preliminary data. 'Category two+' storm percents contain the few estimates from areas with winds greater than category two-force winds. Changes to palm trees ('Palms') are estimated for tropical storm force winds and hurricanes, including all hurricane-strength categories.

	Tropical storm	Category one	Category two+
All species studied, except palms			
Branches broken			
Natives	51.1	73.8	95.3
Exotics	48.7	81.4	97.6
Trunks snapped			
Natives	3.6	7.4	20.3
Exotics	9.8	11.8	26.2
Uprooted			
Natives	3.1	2.2	5.6
Exotics	6.7	5.3	9.5
No apparent damage			
Natives	48.9	26.2	4.7
Exotics	51.3	18.6	2.4

	Tropical storm	All hurricane-force winds
Palms only		
Trunks snapped		
Natives	0.0	0.0
Exotics	0.0	0.9
Uprooted		
Natives	2.2	3.4
Exotics	7.4	9.5
No apparent damage		
Natives	97.8	96.6
Exotics	92.6	92.4

Preliminary conclusions

An analysis of some data collected after four Floridian hurricanes in 2004 allows for some preliminary conclusions. Some of these conclusions are: (1) winds of category two hurricane force or greater cause damage to almost all trees; (2) exotic trees are more likely than native trees to have broken trunks or become uprooted;

(3) native coastal hardwoods are more likely than exotic trees to lose branches in storms; and (4) palm trees, especially natives, are more likely than dicotyledonous trees or conifers to survive storms.

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