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Tree Damage and Restoration following Hurricanes Katrina and Wilma at Miami Metrozoo

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The Miami Metrozoo ground maintenance personnel assessed tree and palm damage after Hurricanes Katrina and Wilma during Aug. and Oct. 2005, respectively. They also estimated the costs associated with the removals, resetting, and cleanup of the debris. After Katrina, 546 trees and seven palms were reset and 142 trees and seven palms were removed. Following Wilma, 345 trees and 26 palms were reset and 380 trees and 53 palms were removed. The total damage and cleanup costs after Katrina and Wilma were $69,660 and $181,860. The five species that suffered the most damage after Katrina were: *Tabebuia caraiba,* yellow tab (134 trees); *Peltophorum pterocarpum,* copperpod (96); *Bucida buceras,* black olive (45 trees); *Bauhinia variegata,* orchid tree (35 trees); and *Syagrus romanzoffiana*, Queen palm (5). The top six species that suffered the most damage after Hurricane Wilma were: *Peltophorum pterocarpum,* copperpod (111 trees); *Bucida buceras,* black olive (77 trees); *Tabebuia caraiba,* yellow tab (63 trees); *Tabebuia heterophylla,* pink tab (31 trees); *Washingtonia robusta,* Washington palm (26 palms); and *Syagrus romanzoffiana,* Queen palm (17 palms). These findings confirm recent research that indicates that the species most damaged after these two hurricanes correspond to species with a low to medium-low wind resistance rating. In Aug. 2006 the list of existing plants in the Metrozoo was updated to include a total of: 207 tree species, 175 shrubs, 200 groundcovers and wild flowers, 15 vines, and 172 palms.

The National Oceanic Atmospheric and Administration considers southern Florida as "hurricane country" since it is one of the most vulnerable regions in North America for intense hurricanes and tropical windstorms. Partly as a consequence of hurricanes and tropical wind storms, the region is losing tree canopy. An urban ecological analysis estimated that the overall tree canopy in unincorporated Miami–Dade County was as low as 10% (American Forests, 1996). To improve the tree canopy cover, the county and Miami Metrozoo have embraced an aggressive tree planting program.

The mission statement of the zoo is to encourage an appreciation for the world's wildlife and to help conserve it for future generations. Miami Metrozoo is in a pine rockland habitat characterized by a very shallow organic layer of soil underlain by "Miami oolite" limestone. Excavations for tree planting are difficult in the limestone rock and are generally done with equipment such as backhoes or augers. Root penetration into the rock necessary for sufficient tree anchorage is an issue for some species.

Unfortunately, the 2005 hurricane season was exceptionally strong, as characterized by a record 28 storms, including 15 hurricanes, exceeding the 1969 record of 12 hurricanes, seven of which were major hurricanes. The season was also remarkable for its early beginning and number of storms as well as the intensity of the hurricanes, including the most intense hurricane on record for the Atlantic (personal communication with Robert Molleda, Warning Coordination Meteorologist, US National Weather Service). Two of these hurricanes, Katrina and Wilma, caused extensive damage to southern Florida and to Miami Metrozoo's trees. The center of Hurricane Katrina made landfall between Hallandale Beach and Aventura on the evening of 25 Aug. with wind gusts as high as 90 mph and was accompanied by rainfall amounts between 10 and 16 inches, with estimates in excess of 17 inches in South Miami–Dade County. After devastating southern Florida, the hurricane went on to affect the Gulf Coast. Two months later Hurricane Wilma made landfall on the southwestern Florida coast near Cape Romano in Collier County with 120 mph winds, then affected southeastern Florida with wind gusts to 120 mph.

Hurricane force winds can be extremely damaging to communities and urban forests. Improperly selected, planted, and located trees can pose risks to human safety and property as well as producing substantial amounts of post-hurricane tree debris. However, there are opportunities to be better prepared and respond to the next hurricane; after the hurricane there are opportunities to rebuild a healthy urban forest. Valuable lessons can be learned from knowing more about how, when, and why trees fail during storms. Recent research from the University of Florida has indicated that urban forest loss is related to wind speed and that certain tree species are more resistant (e.g., remain standing after hurricanes) to strong winds than others (Duryea et al., 2007). The resistance to hurricanes by trees growing in

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groups vs. individually, crown and wood density, and tree size were also studied by these authors.

Methods

The objective of this paper is to present the results of an assessment of tree and palm damage and restoration in the Miami Metrozoo after Hurricanes Katrina and Wilma during Aug. and Oct. 2005, respectively. Costs associated with the removal and resetting of trees and palms as well as cleanup of hurricane debris were also estimated. The Metrozoo is a county facility with 300 acres of developed land and 440 acres of pineland. The assessment area has approximately 3000 trees, consisting of 207 tree and 172 palm species.

Immediately after these two hurricanes, personnel at the Miami Metrozoo conducted a complete assessment of hurricane-affected trees and palms. Trees and palms were categorized into three categories: leave, damage, and removal. Leave trees were standing and had greater than 50% of their canopy intact. Damaged trees had been blown over, but were determined to still be alive and restorable due to the amount of canopy and root ball remaining and minimal stem damage. Removal trees had less than 50% of their canopy intact, were blown over, had the major limbs snapped and the majority of their roots severed and visual stem damage (e.g., cracking, splintering). Damage costs, or the financial costs of resetting trees and repairing infrastructure damage to facilities as defined by labor and equipment hours, as well as materials and infrastructure replacement costs, were recorded. Cleanup costs consisted of the financial costs in labor person hours and operation equipment hours required to remove debris, including "removal" trees.

Results

After Hurricane Katrina, 142 trees were removed as a result of hurricane damage and 546 trees were reset. After Wilma, 380 trees were removed and 345 trees were reset. Figure 1 shows an example of a damaged *Bauhinia variegata* and Figure 2 is an example of a reset *Bucidas buceras*. The total damage and cleanup costs after Katrina and Wilma were $69,660 and $181,860, respectively. The top six tree and palm species that were most damaged after both hurricanes are presented in Table 1.

Wind speed damage to trees at the Metrozoo is similar to a tree species wind resistance list created by the University of Florida (Duryea et al., 2007). This list indicates that the most commonly damaged trees at the Metrozoo have a low to medium-low wind resistance rating (Table 1). The results from the assessments after both of these hurricanes seem to verify the University of Florida's tree and palm wind resistance rating list.

Discussion and Conclusion

It is important to point out that in addition to wind intensity and speed, other factors can influence urban forest damage during hurricanes. Some of these factors include tree characteristics such as planting stock quality, proper pruning, age, size, health,

Fig. 1. Wind-damaged *Bauhinia variegata*.

Fig. 2. A *Bucidas buceras* that was reset.

Table 1. Tree and palm species that suffered the most damage after Hurricanes Katrina and Wilma.

Scientific name	Common name	Damaged trees and palms (no.)	Wind resistance[z]
Peltophorum pterocarpum	copperpod	207	Lowest
Tabebuia caraiba	yellow tab	197	Lowest
Bucida buceras	black olive	122	Medium–low
Bauhinia variegata	orchid tree	35	Medium–low[y]
Tabebuia heterophylla	pink tab	31	Medium–low
Washingtonia robusta	washington palm	26	Lowest
Syagrus romanzoffiana	queen palm	22	Lowest

[z]According to Duryea et al. (2007) relative wind resistance ratings.
[y]*Bauhinia variegata* was not rated, thus rating represents that for *Bauhinia blakeana*.

condition, and pre-existing canopy and root damage. Other factors are associated with soil characteristics such as depth, volume, and moisture as well as conditions during the hurricane, such as rainfall intensity and pre-hurricane soil saturation. Overall tree canopy and density can also play a role. For example, soil conditions present at the Metrozoo, which has a very shallow, non-rock-plowed pineland soil, can affect tree rooting depth, tree condition, and severely affect a mature tree's ability to withstand high wind speeds. In addition, after Hurricane Katrina the soils were saturated, which might have predisposed certain trees to windthrow after Wilma hit 2 months later.

Valuable lessons can be learned from knowing more about how, when, and why trees fail during wind storms. Results from this assessment can help managers effectively plan for and respond to a hurricane's effects on urban trees. There are also opportunities to rebuild a healthy urban forest after a hurricane. Proper maintenance, tree and species selection, and planting the right tree in the right place can serve to increase the wind resistance and health of urban forests.

Literature Cited

Duryea M.L., E. Kampf, R.C. Littell, and C.D. Rodríguez-Pedraza. 2007. Hurricanes and the urban forest: II. Effects on tropical and subtropical tree species. Arboriculture Urban For. 33(2):98–112.

US Department of Agriculture, Natural Conservation Service. 1958. Soil survey of Dade County area, Florida.