Assessment of Hurricane Andrew's Immediate Impacts on Natural and Archeological Resources of Big Cypress National Preserve, Biscayne National Park, and Everglades National Park

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How did Hurricane Andrew affect the resources of U.S. National Park Service units in south Florida? This report describes resource conditions immediately after the storm. A team of 27 scientists conducted this rapid appraisal (for a full list, see the Appendix). The team made field observations for one week and gathered information from colleagues who were also active in the field before and after the storm. The report also presents the team's recommendations for immediate and long-term actions to protect threatened resources and to understand better the relative effects of human and natural perturbations to the parks' resources.

Instantaneous ecological responses of South Florida park ecosystems appeared normal. The USNPS must now determine if the systems are still naturally resilient. Can they recover normally in time, extent, and degree before the next perturbation? Or have chronic habitat fragmentation, altered air and water resources, non-native species, and human disturbance fatally weakened the natural ecological recovery processes of the parks?

Hurricane Andrew was a small, intense hurricane. When it made landfall in southern Florida at 5:00 AM on August 24th 1992, it was a category four hurricane. It was one of the most intense storms ever recorded in Florida, with a minimum pressure of 922 millibars and maximum sustained winds of 242 km hr^{-1} (150 mph; National Weather Service). The eye of the storm passed through Biscayne and Everglades National Parks and southern Big Cypress National Preserve with a forward speed of 50 km hr^{-1} (32 mph).

The storm hit near the time of high tide. It produced a large, but localized, storm surge in the coastal portion of southeastern Dade County, 25 km (15 miles) south of Miami. Storm surge overtopped coastal water control structures and levees. The U.S. Geological Survey estimated Hurricane Andrew's maximum storm surge at 5.2 m (16.2 ft). A 34-m (105-ft) vessel was blown from its deep water anchorage and transported inland. It came to rest on the bank of the C-100 canal upstream of a water control structure.

Coastal flooding was minor, but high winds caused extensive damage throughout the 40 km-wide (25 miles) storm path across the State. Rainfall from the storm was low, presumably in response to the storm's rapid forward movement. Average rainfall for August 24th in Dade County was just over 5 cm (1.97 inches). The highest reported rainfall was 14.6 cm (5.75 inches) near the Atlantic Coast. Rainfall in central Dade County was generally less than 5 cm. Rainfall and water levels were above normal throughout most of southern Florida before Hurricane Andrew arrived. Inland flooding was a problem primarily in southeastern Dade County, where saltwater inundated a large portion of the farming areas.

The following sections provide detailed descriptions of resource conditions immediately after the storm and identify actions that need to be taken quickly to avert additional resource damage and to recover irreplaceable information. This report also presents recommendations for actions to protect park resources through long-term monitoring and research.

CURRENT RESOURCE CONDITIONS

Upland resources Hurricane Andrew drastically affected a swath of vegetation about 50 km wide from Old Rhodes to Sands Keys in Biscayne National Park, across Long Pine Key, the Shark River Slough and southern Big Cypress National Preserve, to the west coast of Everglades National Park. Portions of Big Cypress National Preserve north of the storm track also experienced significant storm effects. The northern edge of Cape Sable marked the southern boundary of the affected area.

Perhaps the most dramatic direct effect of the storm was major structural damage to trees. Most damage occurred in hardwood hammocks, coastal mangrove forests, and pine forests on Long Pine Key in Everglades National Park and the old-growth pine forest at Lostman's Pines in Big Cypress National Preserve. Within the storm's path, virtually all large hammock trees were defoliated, and 20-30% were windthrown or experienced broken trunks or loss of major branches. About a quarter of the royal palms were wind-thrown; many others were defoliated, but began resprouting within two weeks. Damage to upland woody vegetation was most severe in or near the eye of the storm, where winds were strongest. Severity of damage decreased rapidly away from the center of the storm track. Evidence of extreme cyclonic wind gusts also decreased with distance from the central storm track.

In all three parks, 25-40% of the pines were damaged by wind-throw or breakage. In Big Cypress National Preserve, pines were the most-impacted species, with 10% downed and 30% with broken trunks. Cypress trees fared much better than pines and hammock hardwoods. The cypress generally held their needles, but what appeared to be cyclonic winds leveled a few domes. Nearly 90% of the known red-cockcaded woodpecker nest trees were blown down and none of the active cavity trees remained standing in the storm's path.

The storm knocked down a total of about 28,000 ha (70,000 acres) of mangrove forests in the parks. In contrast to the gradation of effects on upland trees, the boundary of effects in mangrove forests was sharply defined. At Highland Beach, at the center of the storm track on the west coast, 85-90% of the mature mangroves were downed. Mortality in mangrove forests will probably continue for a year or more. Many of the surviving trees have seriously cracked trunks. Experience from other hurricanes suggests that many of these trees will eventually die as a result of the storm.

It is too soon to determine the fate of other damaged communities. Only 16% of the wind-thrown trees and 29% of the broken trees died within two years after Hurricane Gilbert, which struck vegetation similar to south Florida hammocks with 300 km hr^{-1} (188 mph) winds on the Yucatan Peninsula. Most of the defoliated trees in the south Florida parks were releafing within a few days of the storm, especially the tropical hardwoods. Many seriously injured trees will probably survive.

Understory plant communities were only moderately affected by the storm, other than damage from falling limbs and trunks. Many understory plants retained their leaves and even fruits formed before the storm.

Most rare and endemic plants in south Florida are found in forest understory. Although immediate storm effects on rare and endemic plants appeared minimal, long-term effects may be more substantial. Effects of reduced canopy and increased light penetration to the forest floor will change the competitive interactions between herbaceous endemics and hardwoods with unknown consequences.

Non-native plants have spread extensively in south Florida following hurricanes in the past. Hurricane Donna spread Australian pine, *Casuarina* spp., up the west coast of Everglades National Park in 1960, requiring an expensive eradication program in the 1970s. Brazilian pepper, *Schinus terebinthifolius*, introduced to South Florida in 1898, was not perceived as a problem until after the 1960 and 1965 hurricanes. Invasive non-native plant species, such as *Melaleuca quinquenervia*, may have been spread by wind and water during Hurricane Andrew, but it was difficult to determine the extent immediately after the storm. Seed pods were found scattered up to 20 meters from potential parental stocks. Until seedlings appear, it will not be possible to determine the actual extent of spread.

The status of non-native plants in Biscayne National Park is poorly known and needs to be evaluated before management actions can be recommended. Local control measures for *Schinus* and *Colubrina asiatica* may be effective in Biscayne National Park, if the non-natives are not yet widespread. In Everglades National Park and Big Cypress National Preserve, the spread of some non-natives had nearly ceased before the storm. Their status may change if ecological conditions were altered by the storm.

Wildlife Storm surge, extreme rainfall, and flooding are generally the major causes of wildlife mortality in hurricanes. The major impacts of this storm were caused by high winds; consequently, wildlife fared relatively well. In spite of extensive surveys of the parks and contacts with field observers throughout South Florida, we found very little evidence of direct storm-caused mortality. Nevertheless, recruitment in several species may be low for the next year or more. In the single largest wildlife incident discovered, about 200 wading birds, mostly white ibis and egrets, were found dead near the Chicken Key roost in Biscayne Bay. Only one dead deer was found. It was in the stair-steps area between Everglades National Park and Big Cypress National Preserve, but this deer mortality cannot be positively related to the hurricane. In general, wildlife appeared unaffected by the storm. All radio-marked Florida panthers survived the storm. Radio-tagged black bears and snail kites survived the storm and appeared relatively normal, although some of the kites moved from storm-damaged roosts and feeding areas.

Deer seemed to be unaffected by the storm after three weeks. Hammock vegetation was re-leafing to provide both food and cover. All 32 radio-collared deer survived, but about one-third shifted their home ranges. We saw no evidence of deer over-browsing, and the current water levels of less than 0.5 m (20 inches) has not forced them onto limited high ground.

Adult alligators appeared unaffected by the storm, but nests and young of the year may have been impacted. The 1992 season was already a poor year for alligators before the storm arrived. In a normal year, egg mortality is 25%. In 1992, 43% died before the storm. The storm destroyed nests containing 27% of the year's egg production. The fate of those eggs is unknown because they were hatching as the storm struck. Some may have hatched and survived. This was already a poor year for alligator recruitment and the storm made it worse.

About 10% of the 160 wading bird rookeries in South Florida were in the storm path. Many interior rookeries were in willow heads and therefore relatively unaffected, but coastal rookeries in mangroves were severely altered. Except for the losses already described in Biscayne Bay, resident white ibis and egret populations seemed unaffected. Within the storm's path south of the Tamiami Trail, nearly all active red-cockaded woodpecker cavity trees were knocked down, but the impact on the population will not be known until nesting surveys can be conducted. Most bald eagle nests in the parks were outside the zone of major disturbance, but several nests were lost or damaged, and impacts on the population will not be known until nesting surveys are conducted.

A monkey was observed at the East Cape Dock on Cape Sable. The extent and nature of other non-native animal introductions into the parks remain unknown. Several facilities adjacent to the parks housed such animals and were destroyed by the storm, so it is not surprising that non-native animals are now in the parks.

Documented wildlife effects appeared minimal, given the severity of the storm. Alligators will experience low recruitment in 1992, but that is probably not attributable to Hurricane Andrew. Bald eagle nests within the storm area were damaged, but the eagles themselves were probably not harmed. It remains to be determined if the eagles will rebuild their nests in the original areas. Though some dramatic mortality of wading birds was observed, it is not clear that this greatly altered their local abundance. The upcoming nesting season will provide the first opportunity to determine the effect of roosting habitat loss on nesting success. Finally, there is currently little evidence that white-tailed deer populations have been harmed by the hurricane. However, Hurricane Andrew apparently caused individual deer to migrate to new areas and some feeding areas were damaged. Further monitoring is needed to determine if food shortages arise because of population movements and loss of vegetation.

Freshwater resources Freshwater fish and macroinvertebrate populations seemed relatively unaffected by the storm, but historical data allow detection of only tenfold changes in populations. Strong seasonal and annual cycles in fish populations make short-term changes difficult to assess, even with optimal sampling schemes. The dynamics of these aquatic populations also vary with hydro-period. In some areas, fish abundance declined, apparently related to the loss of periphyton cover. At two central Shark River Slough sites, fish abundance dropped an order of magnitude after the storm and relative to normal seasonal levels (from 20 fish per meter^2 to 2 fish per meter^2, and from 54 fish per meter^2 to 5 fish per meter^2). High variability in the spotty historical record makes it difficult to be certain the observed declines were statistically significant and caused by the storm.

Storm effects on hydrology and interior water quality were not remarkable within the time-frame of this investigation, i.e., days to weeks. It was a relatively dry storm. The maximum precipitation recorded in the parks was 11.4 cm (4.5 inches), and most areas received less than 4 cm (1.5 inches) of rainfall. Pre-storm overland discharges of freshwater were normal for the summer wet season, and water levels were slightly higher than normal. Storm winds affected water levels, especially in Taylor Slough, where it rose over 30 cm (1 ft) briefly during the passage of the storm. The gradual rise observed in northwestern Shark River Slough at station P-34 over the weeks following the storm reflected high discharges through water control structures (S-12) following abnormally high rainfall in water management zones to the north. Suspension of flows into the northeast Shark Slough and loss of the two pump stations that deliver water to Taylor Slough combined to reduce wetland water levels, hasten drying of marshes, and reduce freshwater flow into northeastern Florida Bay. If the south Dade water delivery system is not restored quickly, marshes in eastern Everglades National Park will dry, persistent dry season flows will cease, and critically high Florida Bay salinities will increase even more. Paradoxically, Hurricane Andrew has thus far exacerbated the drought-like conditions in northeastern Florida Bay, rather than relieving it by flushing the bay with freshwater.

Within the constraints of limited grab-sample data, the storm appeared to have minimal effect on water quality in Everglades National Park. Nearly all post-storm water quality parameters were within the range of values recorded from 1986 to July 1992. The exceptions were temperatures at two central Shark River Slough stations that briefly increased four days after the storm, perhaps related to loss of periphyton cover. It is possible that we missed short-term water quality effects in samples taken 4 days and 24 days after the storm.

The most significant impact regarding freshwater resources was destruction of the hydrologic and meteorologic monitoring networks. Within the storm track, 80% of the monitoring stations sustained significant damage. Virtually all of the staff gauges will have to be re-surveyed to assure accurate reference to sea level.

Marine resources The major storm effects in the marine environment were changes in nearshore water quality, patches of intense bottom scouring, and beach overwash. Dramatically increased turbidity persisted in some areas at least 30 days after the storm, particularly in western Biscayne Bay where mangrove peat soils continued to break down and enter the water column. In northeastern Florida Bay, at the southern edge of the affected area, dissolved phosphate, ammonium, and dissolved organic carbon all increased dramatically. Plankton blooms added to increased turbidity, and combined with observed low oxygen levels will probably have severe, long-term effects on fish and invertebrate populations. Fuel from hundreds of damaged boats in Biscayne Bay and adjacent marinas continued to discharge into the water at least 27 days after the storm.

Hard-bottom communities in central Biscayne Bay were scoured heavily in some areas. Those areas gave the appearance of having been repeatedly trawled. Sponges, octocorals, and corals were sheared from the substrate, and found lying amongst expansive wracks of debris consisting of seagrass, algae, and mangrove leaves. Half of the sponges were missing from fixed plots sampled before and after the storm, and some remaining individuals were killed by sedimentation. In other areas it appeared that more than 90% of the larger sea whips and sponges were missing, though smaller individuals survived. Most of the juvenile spiny lobsters that resided under the sponges and corals in central Biscayne Bay were not present after the storm. Their fate may not be known for several years, until that cohort is recruited into the offshore fishery. In eastern Biscayne Bay, within a kilometer of Elliott Key, and in southeastern Florida Bay, benthic communities appeared relatively unaffected: lobster, sponge, and coral abundance were virtually the same before and after the storm.

Cape Sable and other west coast beaches experienced overwashes of 3-13 m, with as much as 100 cm deposition in a new beach ridge. Beach modifications associated with this storm are minor when compared to slower-moving historical Florida storms.

Disturbance to coral reefs was patchy, but locally severe. A few reef tops were scoured, 200-year-old corals were rolled over, and branching corals were broken. Loose sponges of unknown origin accumulated at the bases of deep reefs. The levels of disturbance observed, however, are consistent with normal reef diagenesis.

The most severe reef damage was associated with anthropogenic debris. Lobster and crab traps smashed into corals and sponges. A ship sunk as an artificial reef at a depth of 23 m broke up and moved into Biscayne National Park, where it was impaled on natural reefs.

Seagrass beds in the storm track survived remarkably intact. Propeller cuts in grass beds did not widen. Only a few areas south of Key Biscayne showed evidence of storm surge or wave action, with elongate scour patterns cut 50-100 cm into the seagrass-bed surface. These effects are in marked contrast with those of Hurricane Betsy in 1965 and other storms that have caused extensive destruction to seagrass beds. Fishes in the mangrove zone also appeared relatively unaffected, as evidenced by the presence of tagged fish in virtually the same places they were before the storm.

Direct effects on marine wildlife by the storm were not remarkable. A standard aerial census of manatees in Everglades National Park revealed 209 manatees in 9.5 hours, the most counted since monitoring began several years ago. Sea turtle nesting beaches were probably improved by the overwash and deposition of more sand. A successful hatching was seen after the storm, so surge and runoff did not inundate all existing nests. Known crocodile nesting beaches were south of the major storm influence and appeared unaffected. The status of adult and young-of-the-year crocodiles is unknown, but no evidence of storm-related mortality was found.

Special resource issues Disposal of hurricane-generated debris in metropolitan areas created two kinds of issues related to air and water resources in the parks. The assessment team defined the debris problems: how much debris, what kind of debris, where will it go, how will it get there (burn, bury, or carry away), and what are the likely effects on resources, and determined the points of control: what can be done to mitigate impacts and what are the management options?

The storm generated some 20 million cubic yards of debris (six times the volume of Cheops great pyramid at Giza, Egypt). Most of it was trees and shrubs (73%) and building materials (24%), but some was hazardous waste such as paint, solvents, insecticides, and batteries. In spite of the urgency to dispose of this material, the Florida Department of Environmental Regulation recognizes in its Emergency Final Order of August 26, 1992, that "The hurricane has . . . created a risk of further substantial impact on the environment" in addition to devastating direct storm impacts. As of September 21, 1992, Dade County Environmental Resources Management (DERM) had authorized 81 dump sites, and estimated that 100 will eventually be authorized. The Army Corps of Engineers manages most of the dump sites near USNPS interests and has prepared an Environmental Assessment describing their plans that has been reviewed by the assessment team and Everglades National Park staff. If this material is burned, some will enter the parks, and if it is stored in or on the ground some will leach into ground water that will enter Everglades National Park or Biscayne National Park. As burning began, no one was monitoring air quality in Dade County, including the USNPS, because the storm destroyed all monitoring equipment.

Archeological resources Marine archeologists resurveyed 14 of the 40 known wrecks in the parks and searched for newly uncovered sites. Storm-scour moved sediment off some vessels, thus revealing new artifacts, including a cannon and a wooden cannon truck from an early 18th-century man-of-war. The degree to which hurricanes rework sediments and compromise the stratigraphic integrity of submerged archeological material has been a difficult question to answer with the lack of storms on well-known sites. This storm revealed that hurricanes do not necessarily jumble wrecks, as has been suggested by some people. We found evidence of recent looting of shipwrecks in Biscayne National Park, with significant losses from at least one 1733-vintage site.

Archeologists assessed a representative sample of 22 of more than 500 known upland sites in the three parks. The sample was stratified by proximity to the storm tract and site type (i.e., hammock, shell mound) so a predictive model could be constructed to estimate total site disturbance.

Disturbance to upland archeological sites was generally minor. About 75% of the interior hammocks assessed contained wind-thrown trees that exposed about 5% of each site. Sites along the Gulf Coast were similarly affected, with about 80% of the sites containing wind-thrown trees that disturbed 10% of each site. Storm surge deposited about 30 cm of shell and sand on about a third of the Gulf coast sites sampled, effectively covering any disturbance caused prior to the deposition.

CONCLUSIONS

While storm effects on natural resources were dramatic, initial ecosystem responses appeared normal. Trees sustained severe damage, especially mangroves and tropical hardwoods. Many defoliated trees resprouted within weeks of the storm, and rare plants in hammock and forest understories were relatively unaffected. Coastal wading bird rookeries, eagle nests, and red-cockaded woodpecker cavity trees were damaged, but no major mass mortality of wildlife occurred. Hurricane winds and water spread non-native plants. Exotic animals escaped from storm-damaged facilities and entered the parks. Some freshwater fish populations declined dramatically after the storm. Storm damage to the South Dade water delivery system interrupted normal freshwater flow into Florida Bay. The storm scoured shallow marine communities and altered marine water quality. An artificial reef broke up and moved into Biscayne National Park. Sea turtle nesting beaches may have been enhanced by storm overwash, and seagrass beds survived remarkably intact. Wind-thrown trees and storm-scour exposed previously unknown archeological artifacts on ship wrecks and upland sites. Disposal of urban debris from the hurricane threatens air and water quality in the parks.

Chronic anthropogenic stresses, such as habitat fragmentation, non-native species, altered water resources, and air pollution have affected ecosystem stability in south Florida. Can such stressed ecosystems recover to pre-storm conditions before the next major perturbation? Do storm clean-up activities threaten resources and human health and safety in the parks? These questions need to be addressed to protect park resources immediately, and to develop long-term strategies that assure their perpetuation. The following recommendations describe actions needed to provide the necessary information.

Recommendations for immediate action The highest priority items for immediate action are to:

- Restore park environmental monitoring capability;
- Protect exposed archeological material on shipwrecks;
- Remove non-native animals introduced by the storm;
- Determine short-term ecological storm effects; and
- Replace boat warning signs that protect manatees.

Next in urgency are actions to:

- Determine non-native and native plant population status;
- Determine wildlife population status;
- Improve environmental monitoring networks; and
- Limit urban debris disposal impacts.

Finally, resource impacts will accelerate or the window of opportunity will close if actions are not taken soon to:

- Survey disturbed archeological resources;
- Remove artificial reef remains from Biscayne National Park;
- Restore integrity of Cape Sable coastal marshes;
- Protect resources threatened by clean-up activities;

- Evaluate storm-altered management practices; and
- Determine urban debris disposal impacts on parks.

The storm destroyed most of the USNPS hydrologic, marine water quality, meteorologic, and air quality monitoring networks in the parks. The networks need to be replaced and activated to measure the potential effects of post-hurricane clean-up on air and water quality and to evaluate short-term ecological responses. Historic shipwrecks exposed by the storm need to be surveyed, stabilized, and monitoring to enhance site protection. Backcountry patrols need to be increased over normal levels to detect and remove non-native animals before they become established in the parks. Removal techniques for exotic animals may need to be developed and tested in conjunction with other agencies.

Studies to determine the short-term ecological effects of Hurricane Andrew need to be initiated while the first, most dramatic changes, are taking place. Historical data need to be compiled and analyzed to provide a basis for designing studies and establishing monitoring plots stratified by hurricane influence. Opportunities to determine spatial variability of storm effects, examine the roles of storm-altered detritus distribution and nutrient cycling, and to evaluate storm effects on fishery recruitment, subtidal sediments, and heavy metals in hardwood hammocks will be lost soon.

Surveys of seedling non-native plants need to be conducted to assess the extent and magnitude of storm-caused spread, and to determine if new control methods need to be developed. The status of mangrove forests and rare plant populations will not be apparent until a year after the storm. The environmental monitoring networks need to be hardened to survive future storms, in addition to restoring the pre-storm capability. Additional monitoring sites are needed to evaluate storm effects on park resources and link upland effects to estuarine and marine systems. Detection of storm impacts on fish and wildlife will require intensified surveys during reproductive seasons to document reproductive efforts, success, and recruitment.

Significant park staff time will be required to coordinate debris disposal regulated by other agencies to assure protection of park interests. The USNPS needs to characterize emissions from debris burning, model air quality and visibility, and monitor air quality, visibility and meteorology to establish actual impacts on park resources.

The hurricane exposed significant amounts of archeological material on upland sites that need to be surveyed, monitored, and protected from vandalism. Removal of artificial reef debris from natural reefs needs to be initiated before it is incorporated into the sediment and overgrown. Its damage to the reef needs to be documented to help develop guidelines for future artificial reef placement. Storm-breached plugs in canals on Cape Sable permit accelerated salt water intrusion into coastal marshes, and the plugs will continue to widen with tidal flushing if not repaired soon. More permanent solutions to restoring the integrity of these marshes need to be found, such as filling in longer sections near the coast, to prevent this kind of damage and repair costs with each hurricane. Fire management practices need to be verified following storm-altered fuel loads. Impacts of storm clean-up activities on rare plants and opportunities for interpreting hurricane influences on native communities need to be evaluated. The effects of storm-altered shelter for manatee and crocodile populations on protection activities need to be considered, before public facilities and access are fully restored.

Recommendations for long-term actions There are long-term actions that need to be taken to protect park resources. Together these actions will provide a basis for understanding resource dynamics and the relative effects of human activities on park resources in South Florida and those of natural extreme events such as hurricanes. The actions are to establish ecological monitoring programs, and conduct long-term research on major resource issues.

Long-term data sets are needed to differentiate natural dynamics, driven by hurricanes, fires, and freezes, from changes caused by chronic environmental stresses such as habitat fragmentation, non-native species, and altered air and water quality. Correlations among system components will yield the best indications of ecological cause-and-effect relationships, until large-scale, long-term controlled experiments can be conducted. Such experiments may never be possible in South Florida, so we must continue to monitor system components in a systematic way to learn what drives the systems and thus place human impacts in proper perspective. For example, vegetation plots established to monitor effects on Hurricane Donna in 1960 were lost because the park had no monitoring program to maintain them. As a result, today we can not precisely project the effects of Hurricane Andrew and compare them with previous storms or human activities. Doubt about our understanding of park ecosystems will delay necessary actions to protect park resources. Better knowledge of system dynamics will speed and improve their protection.

The monitoring program will be designed to (1) determine current and future health of ecosystems, (2) establish empirical limits of variability, (3) diagnose abnormal conditions early enough to implement effective remedial actions, and (4) identify potential agents of ecological change.

Experimental research is also needed to assess the potential of Hurricane Andrew to alter flows of energy and nutrients in South Florida ecosystems. Potential nutrient release from storm-related detritus and the effect of changes in landscape heterogeneity on large animals need to be measured over time. Because the Everglades landscape may be described as a mosaic of terrains or drainage basins that traverse several physiographic subregions in southern Florida, a variety of approaches will be necessary to address these questions. Past research and restoration efforts have focused on individual species or habitats, usually within limited spatial or temporal scales. An integrated understanding of the system's response to anthropogenic and natural perturbations, such as Hurricane Andrew, would greatly refine ongoing restoration and management activities. Several critical hypotheses concerning the ecosystem's productivity and resilience must be resolved to produce a scientific basis for restoration and management.

Appendix: USNPS Resource Assessment Team and Active Collaborators

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