New Science:
Advancing Understanding of the South Florida Ecosystem

The Comprehensive Everglades Restoration Plan (CERP) was approved by Congress in the Water Resources Development Act of 2000. CERP is a framework for the restoration, preservation, and protection of the Everglades ecosystem that also provides for other water-related needs of the region, including water supply and flood protection. CERP is the centerpiece of a broader restoration effort to "get the water right" in south Florida. A key premise of Everglades restoration is that the best available scientific information will guide our decisions.(CERP Programmatic Regulations, 33 CFR S.385) Since the inception of CERP in2000, considerable learning has taken place through applied research and monitoring, including the refinement of models and sampling methodology. Important new information now informs our understanding of how water flows through the system and how depths and durations of flooding influence Everglades ecology, fine-tuning our knowledge about the functional characteristics of the Everglades and the restoration needs of different parts of the landscape.

Understanding of the Natural System Evolves; Without Ecosystem-wide Restoration, Degradation Continues

Our fundamental understanding of the natural, pre-drainage Everglades ecosystem has evolved since the year 2000 when CERP was approved by Congress. There are now several lines of evidence that indicate that the historical some Everglades marshes were wetter and the southern estuaries were fresher in the past than was understood previously. when CERP was initially developed And, we now appreciate better howadditional focus on *water* flow and the rate of change of water levels has led to increased understanding of the role dynamic water movement plays in -shapinge landforms and ecology on virtually all scales, from the formation and maintenance of tree islands across the broad landscape to the seasonal survival and growth of apple snails in the Water Conservation Areasof fish in isolated pools in the Rocky Glades . The Everglades is not static and ecosystem-wide restoration is necessary to prevent further degradation. Ongoing monitoring, research, and recent opportunities to assess response to both drought and flood events have documented further declines in ecosystem health.

Fresher and Wetter: Recent paleo-ecological studies conducted in Florida Bay and Biscayne Bay show that estuarine animal communities that existed around the beginning of the 20th century were typical of a lower, more stable salinity pattern than is associated with the managed system today. , an tThe differences in salinity patterns are not fully explained by rising sea level (Wingard, (2007). Analysis of the relationship between water levels in the freshwater southern Everglades and salinity in the southern estuaries indicates that the volume of flow required to achieve the historical salinities is substantially larger than the pre-drainage hydrologic simulation models have predicted (Marshall et al 2009). were in the past adapted to greater freshwater flows and lower salinities than are present today Similar paleo-ecological studies in some marshes of the central/southern Everglades show evidence of ahistorical dominance of water lily, and a shift to a greater abundance of sawgrass over time (Saunders et al 2008). LWater lily is associated with of open water slough communities, which are typically characterized by greater water depths and longer periods of inundation than that found in the present-day sawgrass prairies.formed under greater water depths and longer flood durations than was previously understood (Fig. 1). Tree islands, even those existing in drier areas, are generally dominated by flood tolerant species. Improved pre-drainage hydrologic simulation models show greater volumes of water passed through the Everglades marshes than previously believed and indicate that more flow is required to achieve reduced salinity patterns in the southern estuaries. **(graphic: sawgrass/water lily map)**

Flow and Velocity: IIt is the flow of water that connects the upstream and downstream components of the ecosystem. In Everglades marshes, relatively high flowing water is velocities are required to transport fine sediment and organic matter and thereby shape the land into the linear ridge and slough systems and streamlined flow-sculpted tree islands that defined the pre-drainage system. Current Flow velocities in impounded areas of today's system are not sufficient to support these physical processes and maintain the characteristic flow-sculpted landforms of the historic Everglades (Sklar ?).

Rise and Fall of Water Critical: Extreme high and low water levels can damage aquatic vegetation and wildlife that depend upon it. The timing and rate of change of water levels (recession or ascension) are as critical to ecological functions in Lake Okeechobee and the Everglades marshes as are water depths and duration. Gradual changes in water depth are necessary to support foraging and reproduction of birds, alligators, and other species. For example, in marshes and lakes, reproduction of apple snails, the principal prey of the imperiled Everglade snail kite, is dependent on the timing and rate that water recedes. Rapid or extreme increases in water level can inundate and destroy snail egg masses. However, if water recedes too quickly during the dry season, young snails will hatch into conditions that are too dry, and they will perish or their growth will be impaired (Darby et al., 2008). The estimated population of the snail kite has decreased dramatically over the last decade (Figure 2), reduced by half and half again (Cattau et al. 2008). and factors Shifting water management regimes or natural patterns, such as drought, affect quality of critical marsh habitats or affecting apple snail abundance, and these factors may have contributed to the decline of the kite to the decline. In Lake Okeechobee, even short periods of extreme high and low water levels can damage aquatic vegetation and wildlife that depend upon it. **(graphic: image of snails or egg masses; image of birds; estimated kite population)**

In the Absence of Ecosystem-wide Restoration, Degradation Continues

The Everglades is not static and ecosystem-wide restoration is necessary to prevent further degradation. Ongoing monitoring, research, and recent opportunities to assess response to both drought and flood events have documented further declines.

Loss of Landscape Features: Tree islands are critical features in the Everglades landscape, producing biodiversity "hotspots" of native plants and animals, and serving as refuge for terrestrial species during periods of high water (NRC 2008). Within the impounded Water Conservation Areas (WCAs), upstream marshes tend to be over-drained, while downstream marshes experience prolonged flooding. Studies have documented a multi-decadal decrease in the number and areal extent of tree island habitat, due to the influence of both high and low water levels, and to increased fire frequency (Sklar 2007). - If restoration is further delayed and altered water management regimes continuelevels remain low, -tree islands will remain more vulnerable to fires in drier areas, and their resilience to natural hydrologic variability may decline, potentially leading to flooding stress when historic water depths are ultimately restored (NRC 2008).

Invasive Plants and Animals: Invasive exotic species are a serious and growing threat to the south Florida ecosystem. More than 30 invasive exotic plant and 150 invasive exotic animal species are known to occur in the region, and the numbers are increasing (NRC 2008). Several of these pests were recognized in 2000 and remain a persistent challenge, while new species, including Burmese pythons and Old World climbing fern (*Lygodium)*, have emerged as major threats to the achievement of restoration goals. The spread of many invasives, such as exotic fish, is clearly linked to canals and other human-altered landscape features. **(Graphic: python graph, fish/canal management graph)**

Water Quality: SWhile source control programs have been expanded and the combined best management practices and stormwater treatment areas (STAs) in the Everglades Agricultural Area have removed over 3,200 metric tons of total phosphorus. ., However, soil phosphorus levels still exceeded restoration targets in a greater proportion of the Everglades marsh in 2005 than in 1996 (49% versus 34%), indicating that degradation has spread (EPA/EMAP 2008). However, it should be noted that approximately 50% of the STA treatment capacity did not come on line until 2004. Mercury concentration in prey fish has dropped compared to the late 1990s, but still exceeds concentrations considered to be protective of birds and mammals in 67% of the Everglades marsh area. Sulfate, a factor exacerbating the biological effects of mercury, exceeded target levels in more than half of the Everglades marsh (EPA/EMAP 2008).
(Graphic: maps showing areas exceeding targets for soil phosphorus, sulfate, or mercury)

Water quality continues to decline in Lake Okeechobee, with total phosphorus concentrations in the waterlevels increasing. Phosphorus concentrations and loading rates to the Lake vary, but exceed restoration goals, particularly in wet years. Data suggest that there is sufficient legacy phosphorus that has accumulated in the bottom sediments of Lake Okeechobee in the past can be released to the water at levels sufficient to maintain elevated total phosphorus levels for many years. **(Graphic: Lake Okeechobee phosphate graph)**

Estuaries: Estuaries, the highly productive coastal margins of the system, serve as aquatic nurseries for many fish and invertebrate species and yield large economic benefits. Stressed by unnatural water deliveries and nutrient releases, they suffer from both too much and too little freshwater, impairing the resilience of these important areas. Damaging freshwater releases and extreme salinity variation in the northern estuaries, Indian River Lagoon and Caloosahatchee, have caused fisheries impacts and loss of aquatic vegetation. Oyster populations in the St. Lucie estuary have fluctuated widely and recovery is hindered by recurring incidents of excessive discharge and extreme low salinity.

In Florida Bay and the lower Biscayne Bay systems, low freshwater flow, salt intrusion, and rising sea level contribute to high salinity and a loss of diverse estuarine habitats that support wading birds and fisheries resources. The normally low-nutrient southern estuaries are highly sensitive to phosphorus and nitrogen releases, even from sources within the basin. Nutrients released from natural and human-related events have recently contributed to algal blooms of previously unknown scale and duration, and associated loss of seagrass and invertebrates were factors in sustaining the bloom and nutrient levels. **(Graphic: Maps and or graph of bloom patterns in NE Florida Bay and south Biscayne Bay)**

Climate Change: Knowledge of how the Earth's climate is changing has advanced rapidly since 2000 and understanding the implications of climate change for south Florida is critical to restoration efforts. Changing precipitation and temperature patterns, sea level rise, and the likelihood of storms of greater frequency and intensity will potentially have effects on all aspects of the system, including the coastal transition zone, invasive species, plant and animal physiology, and drought/flood/fire cycles. Future restoration science must proceed with the climate change reality acknowledged as an explicit aspect of our studies and management decision-making (see the report to the South Florida Ecosystem Restoration Task Force, *Climate Change in South Florida* for more information).

Advances in Scientific Tools & Methods

There have been numerous advances in scientific tools and methods since 2000. Through collaboration and scientific peer review, conceptual ecological models have been refined and system-wide ecological indicators have been developed. Both provide a framework for reducing uncertainty and developing restoration targets.

Improved models have enhanced our understanding of the linkages between hydrology and ecology, as well as our ability to predict responses to system changes. Since 2000, the Natural Systems Model (NSM) has been improved by incorporating additional historical topographic, hydrologic, and ecological information. New hydrologic and mathematic models couple upland landscape to southern estuaries, better defining how flow volumes determine salinity patterns. Other models link surface and groundwater flow and help address smaller scale management issues such as aquifer recharge, salt water intrusion, and seepage.

Broad scale, robust monitoring programs have been in place since 2000 (e.g., EMAP and the CERP Monitoring and Assessment Plan) and are providing vital feedback on ecosystem health and management strategies. Integration of new geostatistics, water level recorders, and Google Earth capabilities now produces accurate spatial renderings of Everglades performance and restoration. Monitoring of stormwater treatment areas (STAs), in combination with the use of near-real-time data, has allowed for improved decision-making for the optimization of STA operations to balance water flows and phosphorus load reduction. As CERP restoration efforts progress, monitoring and assessment will continue to document environmental conditions and the effectiveness of restoration efforts into the twenty-first century.

Conclusions

Because the greater Everglades systemecosystem and species that depend upon it continues to decline, implementation of timely ecosystem restoration is important.

While the success of our south Florida restoration efforts will ultimately be judged by the ecological responses they produce, our initial focus must remain on reestablishing the hydrological characteristics of the pre-drainage Everglades as we now understand them the independent review panel on Everglades restoration progress emphasized that "Natural system restoration will best be served by moving the system as quickly as possible toward physical, chemical, and biological conditions that molded and maintained the historical Everglades (NRC 20076). The pre-drainage system was wetter than previously known and so greater volumes of continuously flowing water are needed for restoration, beyond those contemplated in the CERP. Sheetflow must be reestablished through the impounded portions of the Everglades to recreate the flow conditions required to restore the linear ridge and slough systems and the streamlined tree islands that were so characteristic of the once natural system. In addition to the need for larger volumes of water in the southern estuaries and marshes, the critical role of sheetflow and flow velocity in the evolution and maintenance of the ridge and slough landscape is understood far better than when the CERP was formulated. Yet, increased flows must be achieved without harmful water levels or declines in water quality.

Avian species in the Everglades are highly dependent on natural water level transitions. The Cape Sable seaside sparrow and Everglade snail kite remain highly imperiled, making ecosystem restoration both more urgent and more challenging. Independent expert review has concluded that although careful management will be needed through the transition to a restored system, there are no true conflicts between the needs of these species in the Everglades and that completion of ecosystem-wide restoration will benefit both sparrows and kites (Sustainable Ecosystems Institute, 2007).

While Monitoring has demonstrated that the State's water quality program has made progress, particularly in regard to reducing phosphorus concentrations and load and discharges to the Everglades Protection Area in removing phosphorus, particularly as additional STA's have come on line in recent years; however,, further implementation of additional water quality improvements is needed for water entering Lake Okeechobee and the Everglades Protection Area. The issue of legacy phosphorus in the watershed of Lake Okeechobee will require additional load reduction strategies to reduce the mobility of theeis legacy phosphorus in sediments (SFER 2009).

Proactive management of invasive species is crucial, with an emphasis on prevention of new introductions. We must put national-level policies and regulations in place, based on strong risk analysis and screening tools that can scientifically evaluate the threat a species poses for invasion (see the report to the South Florida Ecosystem Restoration Task Force, *Invasive Exotic Animals: Managing a Threat to Everglades Restoration* for more information).

Sea level rise, and other consequences of climate change, must be considered in Everglades restoration planning and implementation. It is important to note that climate change only heightens the need to increase the flow of water through the Everglades and into the southern estuarine system in order to maintain the freshwater differential needed to offset sea level rise and salt water intrusion. Preparing now for a future with climate change will permit adaptation efforts that can reduce risks and increase sustainability for and resilience of both the natural ecosystem and the built environment of south Florida (see the report to the South Florida Ecosystem Restoration Task Force, *Climate Change in South Florida* for more information).

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